

**Missouri
Soil Fertility and Fertilizers
Research Update
2007**

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

Thank You
Missouri Fertilizer and Ag Lime Distributors

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

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Sanborn Field Update

Historic Sanborn Field: 2007 Growing Season

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Introduction

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

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

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

Soil Sampling, Fertility Recommendation, and Fertility Applications

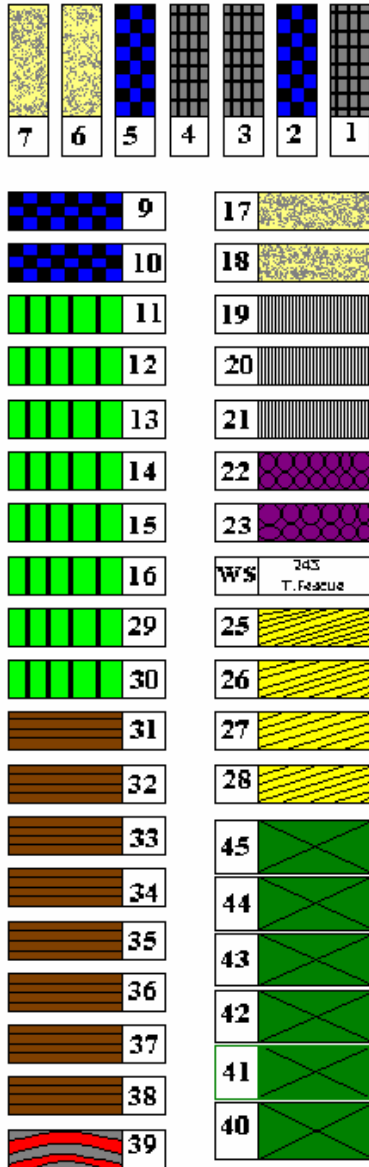
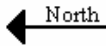
Soil sampling procedures set forth by the Second Century Plan call for the collection of soil testing samples every 5 years with the most recent set of samples being pulled in the fall of 2003. Every 25 years (1938, 1962, 1988), deep core samples have been taken from each plot. In 1962 and 1988, these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

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





Sanborn Field

2nd Century Plot Plan







Initiated 1990-1991



Historical Cropping Systems

-  Continuous Corn
plot 6 Full Fertility Conventional Tillage
7 Full Fertility No-tillage
17 No Fertility
18 6 Tons Manure/acre per year
-  Continuous Timothy
plot 22 6 Tons Manure/acre per year
23 No Fertility
-  Continuous Wheat
plot 2 Full Fertility
5 6 Tons Manure/acre per year + Nitrogen
9 No Fertility
10 6 Tons Manure/acre per year
-  C-W-RC
plot 25 6 Tons Manure/acre per year
26 Full Fertility
27 No Fertility
28 Full Fertility minus Nitrogen

Cropping Systems Initiated in 1990

-  Continuous Soybeans
plot 39 Full Fertility
-  C-W-RC (since 1950)
plots 1, 3, & 4
-  GS-SB-W(rc green manure)
plots 19, 20, & 21-Full Fertility
-  C-SB-W-RC
plots 11, 13, 16, & 29-Full Fertility
plots 12, 14, 15, & 30-Full Fertility minus Nitrogen
-  C-SB-W(rc green manure)
plot 31 Full Fertility
32 Full Fertility minus Potassium
33 Full Fertility minus Phosphorus
34 6 Tons Manure/acre per year
35 No Fertility
36 Full Fertility (clover omitted)
37 Full Fertility
38 Full Fertility
-  Research, Teaching, and Demonstration
plots 24S (tall fescue), 40, 41, 42, 43, & 44 -
Full Fertility
45 (warm season grass)-Burn Only

WS-Weather Station

Weather

The effects of weather conditions on growth and development of non-irrigated agriculture crops in Missouri plays a major roll on crop yields. The weather data that is presented in Table 1 was collected from a weather station located on Plot 24 on Sanborn Field. In 1994, an automatic weather station was placed on the north half of plot 24. In 2003 the weather station was updated to allow for real time weather information to be obtained. This information is fed back to computer on campus and is available for viewing on the web at aes.missouri.edu/sanborn/weather/sanreal.stm. The lower than average precipitation as well as slightly greater maximum and minimum temperatures for 2007 as well as the precipitation deficit for the later part of 2006 explains the smaller than the 30 year average yields delineated later in this report.

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

| Month | Maximum Temp. Avg. | | Minimum Temp. Avg. | | Precipitation Totals | |
|---------------|--------------------|---------|--------------------|---------|----------------------|---------|
| | 2006/07 | 30 year | 2006/07 | 30 year | 2006/07 | 30 year |
| 2006 | | | | | | |
| September | 77.3 | 78.7 | 56 | 56.2 | 0.57 | 3.21 |
| October | 64.3 | 67.2 | 43.8 | 45.3 | 3.22 | 3.08 |
| November | 56.9 | 53.6 | 38.7 | 35.1 | 2.31 | 3.42 |
| December | 47.9 | 41.6 | 31.5 | 24.5 | 1.42 | 2.22 |
| 2007 | | | | | | |
| January | 39.3 | 37.9 | 23.5 | 20.7 | 1.89 | 1.79 |
| February | 37.8 | 42.8 | 20.4 | 24.0 | 1.78 | 2.19 |
| March | 63.1 | 54.6 | 43.8 | 33.9 | 3.14 | 2.71 |
| April | 63.6 | 65.8 | 42.2 | 44.2 | 3.53 | 4.29 |
| May | 78.9 | 74.5 | 60.6 | 53.9 | 3.2 | 5.15 |
| June | 83.8 | 82.8 | 65.9 | 62.7 | 4.23 | 4.32 |
| July | 86.7 | 88.6 | 67.8 | 67.6 | 2.12 | 3.90 |
| August | 93.7 | 87.4 | 72.2 | 65.6 | 2.49 | 4.42 |
| September | 84.1 | 78.8 | 61.3 | 56.1 | 1.62 | 5.03 |
| October | 71.7 | 67.4 | 51.3 | 45.5 | 2.96 | 3.04 |
| November | 56.9 | 53.7 | 36.1 | 35.1 | 1.99 | 3.42 |
| December | | | | | | |
| Total or avg. | 63.3 | 61.2 | 45.4 | 42.4 | 29.0 | 40.3 |

Cropping Systems

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

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

Table 2-Harvest data of winter wheat from plots 2, 5, 9, and 10 on Sanborn Field in 2007.

| | | 2007 Yield | 2007 Yield | Average Yields | Average Yields |
|------|----------------|------------|------------|----------------|----------------|
| | | Bushels/ | Kilograms/ | 1977-2007 | 1977-2007 |
| Plot | Treatments | Acre | Hectare | Bushels/Acre | Kg/Ha |
| 2 | Full Fertility | 33.6 | 2258 | 26.9 | 1807 |
| 5 | Manure + N | 26.8 | 1801 | 26.7 | 1794 |
| 9 | None | 5.3 | 356 | 9.1 | 611 |
| 10 | Manure | 24 | 1613 | 30.1 | 2022 |

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

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

Table 3-Harvest data of corn from plots 6, 7, 17, and 18 on Sanborn Field in 2007.

| | | 2007 Yield | 2007 Yield | Average Yields | Average Yields |
|------|----------------|------------|------------|----------------|----------------|
| | | Bushels/ | Kilograms/ | 1977-2007 | 1977-2007 |
| Plot | Treatments | Acre | Hectare | Bushels/Acre | Kg/Ha |
| 6 | Full Fertility | 117 | 7337 | 105.9 | 6641 |
| 7 | Full Fertility | 132.5 | 8309 | 95.2 | 5970 |
| 17 | None | 20.1 | 1260 | 12.4 | 778 |
| 18 | Manure | 50.8 | 3186 | 54.3 | 3405 |

Continuous Soybean: Plot 39

In 1990 the Second Century Plan outlined that plot 39 would be in continuous soybean production. The reasoning for looking at such a system is to assess the changes in weed, insect, and disease pressures compared to soybean production in a rotation. This plot does receive a full fertility treatment. This plot yielded 22.6 bushels per acre (1518 kg/ha) in 2007.

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

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

Table 4. Harvest data from the continuous forage crops on Sanborn Field in 2007.

| Plot | Crop | Treatment | 2007 Forage Yields | 2007 Forage Yields | Average* Forage Yields | Average* Forage Yields |
|------|-------------|----------------|--------------------|--------------------|------------------------|------------------------|
| | | | Tons/Acre | Kg/Hectare | Tons/Acre | Kg/Hectare |
| 22 | Timothy | Manure | 2.81 | 6294.4 | 3.09 | 6921.6 |
| 23 | Timothy | None | 1.73 | 3875.2 | 1.51 | 3382.4 |
| 24 | Tall Fescue | Full Fertility | 4.82 | 10796.8 | 4.25 | 9520 |

*Averages for plots 22, 23, 24 are based data from 1991-2007.

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

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

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

| Plots | Treatment | 2007 Crop | Yield | | | | | | | |
|-------|-----------|------------|------------|------------|-------------|-------------|----------|-----------|--------|------|
| | | | 2007 Grain | 2007 Grain | 2007 Forage | 2007 Forage | Average* | | | |
| | | | Bu/acre | Kg/ha | Tons/acre | Kg/ha | Grain | | Forage | |
| | | | | | | Bu/acre | Kg/ha | Tons/acre | Kg/ha | |
| 1 | Full | Corn | 124.5 | 7807 | | | 151.0 | 9468 | | |
| 3 | Full | Wheat/RC | 48.2 | 3239 | 1.87 | 4189 | 58.9 | 3957 | 2.45 | 5482 |
| 4 | Full | Red Clover | | | 2.57 | 5757 | | | 4.46 | 9996 |
| 25 | Manure | Wheat/RC | 41.3 | 2775 | 2.99 | 6698 | 36.3 | 2442 | 2.67 | 5981 |
| 26 | Full | Wheat/RC | 57.9 | 3890 | 2.02 | 4525 | 65.7 | 4418 | 3.15 | 7056 |
| 27 | None | Wheat/RC | 21.2 | 1424 | 2.73 | 6115 | 28.4 | 1907 | 2.25 | 5029 |
| 28 | Full-N | Wheat/RC | 38.8 | 2607 | 2.78 | 6227 | 41.6 | 2792 | 3.07 | 6871 |

*Average is based on the past 4 times that particular plot was in the same crop as year 2007.

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

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

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

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

| Plots | Treatment | 2007 Crop | Yields | | | |
|--|----------------|--------------------|--------------------------|------------------------|-------------------|-------|
| | | | 2007 Grain Bu/Acre | 2007 Grain Kg/Ha | Average* Grain | |
| | | | | | Bu/Acre | Kg/Ha |
| 19 | Full Fertility | Soybeans | 47.1 | 3165 | 49.8 | 3346 |
| 20 | Full Fertility | Grain Sorghum | 115.4 | 7753 | 117.6 | 7902 |
| 21 | Full Fertility | Wheat/(red clover) | 37.6 | 2526 | 62.3 | 4186 |
| *Average is based on the past 4 times that the particular plot was in the same crop as it was in 2007. Bu/Acre=Bushels/Acre (red clover) is plowed down and no harvest yields are taken | | | | | | |

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

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

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

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

Table 7. Harvest data form the corn-soybean-wheat (rc) rotation on Sanborn Field in 2007.

| Plots | Treatment | 2007 Crop | Yields | | | |
|---|-----------|-----------------------|--------------------------|------------------------|------------------------------|----------------------------|
| | | | 2007 Grain Bu/Acre | 2007 Grain Kg/Ha | Average* Grain Bu/acre | Average* Grain Kg/Ha |
| 31 | Full | Soybean | 30.5 | 2052 | 38.0 | 2550 |
| 32 | Full-K | Soybean | 26.7 | 1792 | 37.1 | 2492 |
| 33 | Full-P | Soybean | 25.1 | 1686 | 39.8 | 2671 |
| 34 | Manure | Soybean | 30.0 | 2013 | 40.5 | 2723 |
| 35 | None | Soybean | 25.2 | 1690 | 37.4 | 2515 |
| 36 | Full-(rc) | Soybean | 31.1 | 2090 | 38.7 | 2599 |
| 37 | Full | Wheat/(red clover) | 25.3 | 1699 | 57.3 | 3848 |
| 38 | Full | Corn | 117.5 | 7368 | 142.3 | 8920 |
| <p>*Average is based on the past 4 times that particular plot was in the same crop as the year 2007.</p> <p>Bu/acre = Bushels/Acre</p> <p>(red clover) is plowed down and no harvest yields are taken</p> | | | | | | |

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

The main objective in this four-year rotation is to measure the impact of using no additional fertilizer nitrogen versus nitrogen application. Plots 11, 13, 26, and 29 all receive fertilizer nitrogen and plots 12, 14, 15, and 30 do not receive any additional nitrogen. All the plots in this series receive full fertility application of fertilizer except the nitrogen which was stated earlier. Harvest data for this set of plots can be seen in Table 8.

Table 8. Harvest data from the corn-soybeans-wheat/rc-red clover rotation on Sanborn Field in 2007.

| Plots | Treatment | 2007 Crop | 2007 Grain Bu/ acre | 2007 Grain Kg/ Ha | 2007 Forage tons/ acre | 2007 Forage Kg/ Ha | Average* | | | |
|-------|------------------|------------------|------------------------------|----------------------------|---------------------------------|-----------------------------|----------------------|--------------------|-------------------------|---------------------|
| | | | | | | | Grain Bu/ acre | Grain Kg/ Ha | Forage tons/ acre | Forage Kg/ Ha |
| 11 | Full Fertility | Corn | 151.5 | 9501 | | | 107.5 | 6741 | | |
| 12 | Full Fertility-N | Corn | 160.9 | 10090 | | | 104.4 | 6547 | | |
| 13 | Full Fertility | Soybeans | 38.2 | 2567 | | | 36.1 | 2426 | | |
| 14 | Full Fertility-N | Soybeans | 33.1 | 2224 | | | 34.8 | 2338 | | |
| 15 | Full Fertility-N | Wheat/Red Clover | 49.2 | 3306 | 2.59 | 5802 | 26.0 | 1747 | 1.82 | 0 |
| 16 | Full Fertility | Wheat/Red Clover | 42.8 | 2876 | 2.03 | 4547 | 53.0 | 3561 | 1.78 | 0 |
| 29 | Full Fertility | Red Clover | | | 3.16 | 7078 | | | 4.45 | 9968 |
| 30 | Full Fertility-N | Red Clover | | | 3.03 | 6787 | | | 4.96 | 11110 |

*Average is based on the past 3 times that particular plot was in the same crop as the year 2007.
 Bu/Acre = Bushels/Acre
 N/A=Not Applicable-no yields were taken

Agricultural Lime

Final Report

The Influence of Calcitic and Dolomitic Lime and Phosphorus on Species Composition in Tall Fescue Pastures

R.J. Miles and D. G. Blevins
E.J. Hamilton, W.E. McClain, and M. Remley, Graduate Students

INTRODUCTION

This project was initiated during the summer of 2005 with the selection of field plots at the Southwest Research Center (SWC) at Mt. Vernon. An established tall fescue stand with a diverse plant community was selected for this study. The objective of this project was to ascertain the effect of lime and phosphorus (P) on species composition in tall fescue pastures. A large percentage of the tall fescue acreage in Missouri is on acid soils with low to very low available P. The soil resource in the plot area is primarily the Gerald silt loam (fine, mixed, active, mesic Aeric Fragiqualf) with some inclusions of the Creldon silt loam (fine, mixed, mesic, Oxyaquic Fragiudalf). Soil test samples from the plot area had the following initial values:

| <u>Soil Parameter</u> | <u>Value</u> |
|----------------------------------|--------------|
| CEC (meq/100g) | 10.1 |
| Neutralizable Acidity (meq/100g) | 5.2 |
| pHs | 4.6 |
| Bray P-1 (lbs/A) | 6 |
| Potassium (lbs/A) | 1515 |
| Calcium (lbs/A) | 258 |
| Magnesium (lbs/A) | 203 |

Initial botanical composition was assessed in June 2005 for sectors of the plot area for species composition. Plots with 10 ft by 25 ft dimensions were delineated with 5 ft borders. Liming treatments used were calcitic and dolomitic aglime with each material having 0X, 0.5X, 1X, and 2X the amount recommended by the Missouri Soil Testing Laboratory Woodruff Buffer method. Additionally, P treatments for each aglime treatment were 0 and 50 lbs P/A. Maintenance K was added as called for by soil test value and 100 lbs N/A was also applied. Each treatment was replicated 6 times.

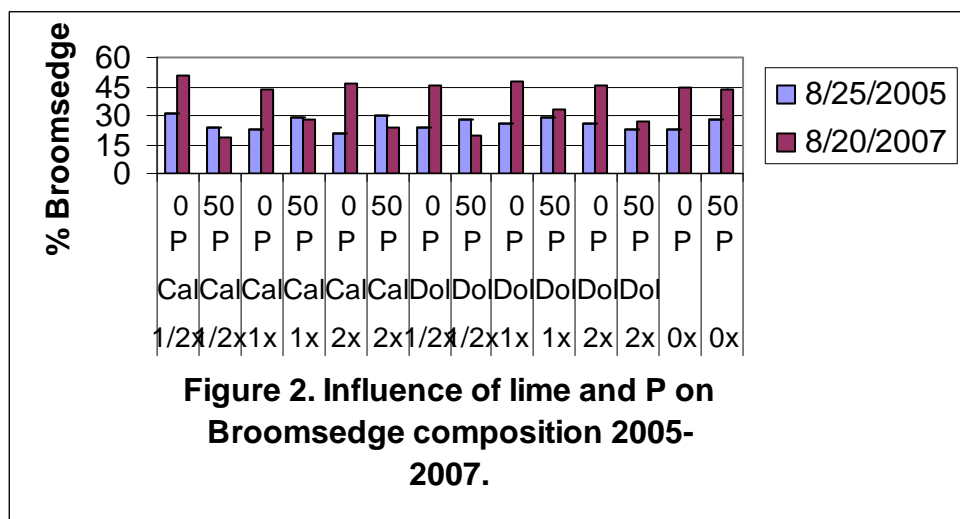
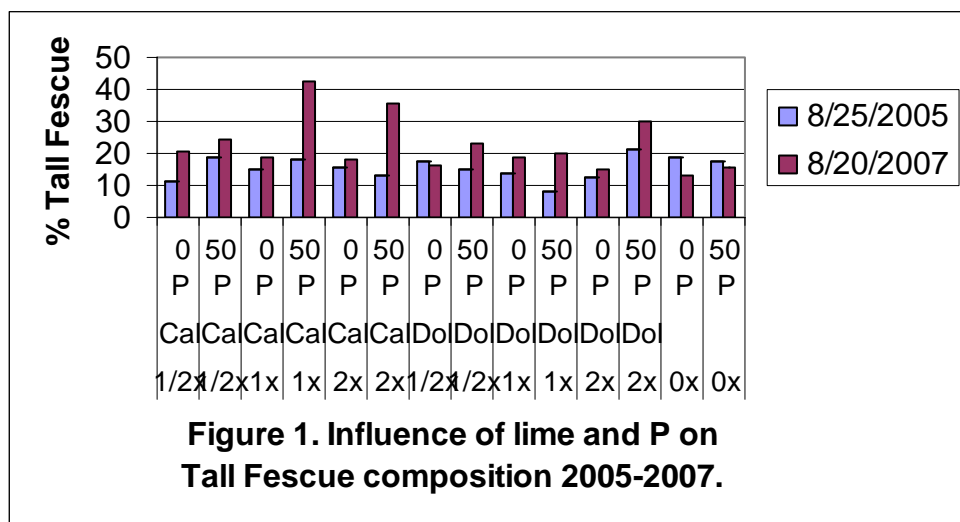
The calcitic limestone used possessed an ENM value of 396 and the dolomitic limestone exhibited an ENM of 452. The limestone recommendation (1X) for the limestone was 3.67 T/A and 3.22 T/A for the calcitic and dolomitic materials, respectively. Initial vegetative composition assessments were made in the summer of 2005. Vegetative composition assessments and forage yields after the application of lime and fertilizer inputs were taken in May 2006, August 2006, May 2007, and August 2007. Soil samples from each individual plots were taken in September 2007 for similar soil testing analysis as the initial samples.

ACCOMPLISHMENTS

The data was assessed from three viewpoints: species composition by lime and fertilizer inputs over the 2 years after initiation; yield by lime and fertilizer inputs; and ending soil test values by lime and fertilizer treatments.

Species composition by lime and fertilizer treatments

The plant species identified in the pasture at initiation were: annual lespedeza, Aster, Blackeyed susan, Broomsedge, Buckbrush, Buckhorn plantain, Bull thistle, Canada goldenrod, Carex, Cheat grass, Common ragweed, Common yarrow, Crabgrass, Crown Vetch, Daisy fleabane, Dalis grass, Deptford pink, Dewberry, Eastern Gammagrass, Eastern red cedar, Elm, Germander, Giant foxtail, Goatsbeard, Grape, Hairy Hawkweed, Hop clover, Horse nettle, Indian grass, Ironweed, Juncus, Kentucky bluegrass, Little bluestem, Milkwort, Mustard, Nightshafe, Orchardgrass, Persimon, Poison ivy, Prairie dogbane, Purple top, Quen Anne's lace, Res sorrel, Red top, Rough-fruited cinquefoil, Sassafras, Sececia lespedeza, Smoothbrome, Sourgrass, St. John's Wort, Suma, Tall fescue, Tall green milkweed, tall thistle, Three seeded mercury, Tick, trefoil, Virginia creeper, Western panicgrass, Wild Cherry, Wild lettuce, Wild Onion, Wild Rose, Wild senna, Witch grass, Yellow foxtail. The summary of major species occurrence is summarized in Figures 1 through 6.



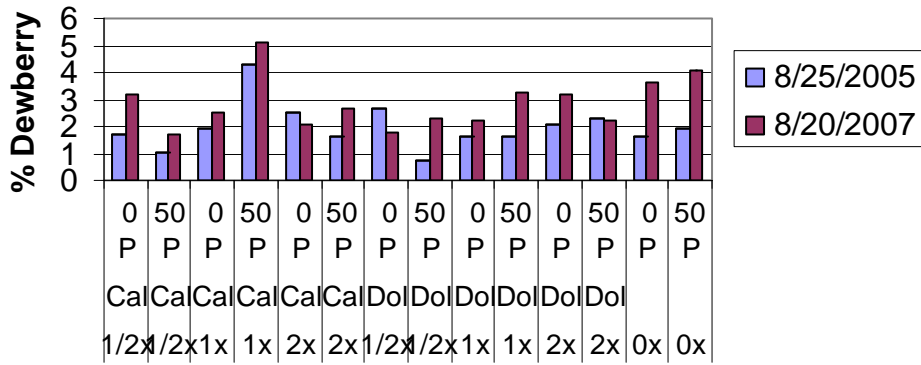


Figure 3. Influence of lime and P on Dewberry composition 2005-2007.

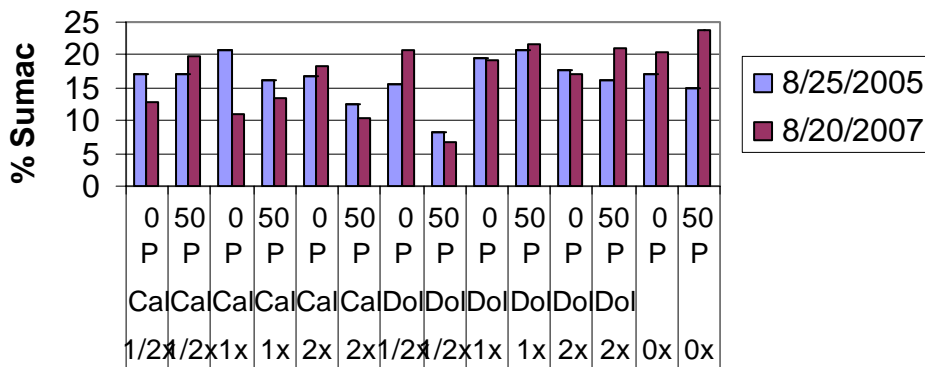


Figure 4. Influence of lime and P on Sumac composition: 2005-2007.

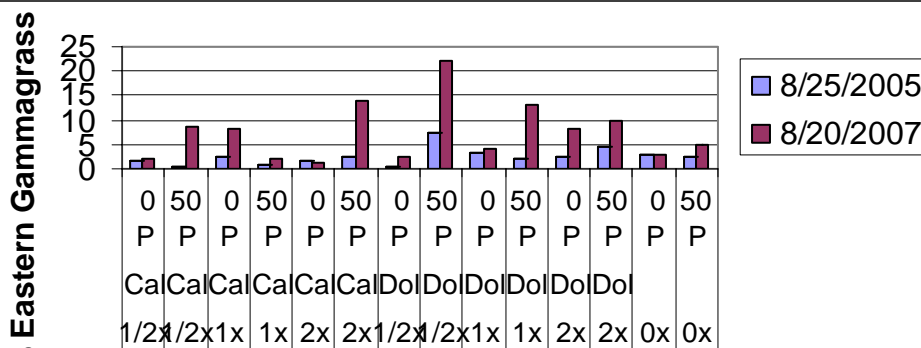
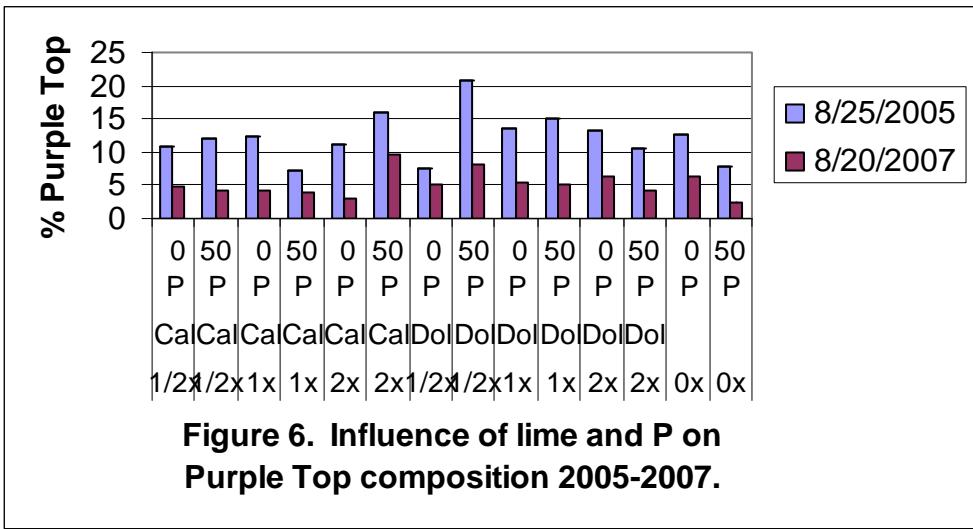


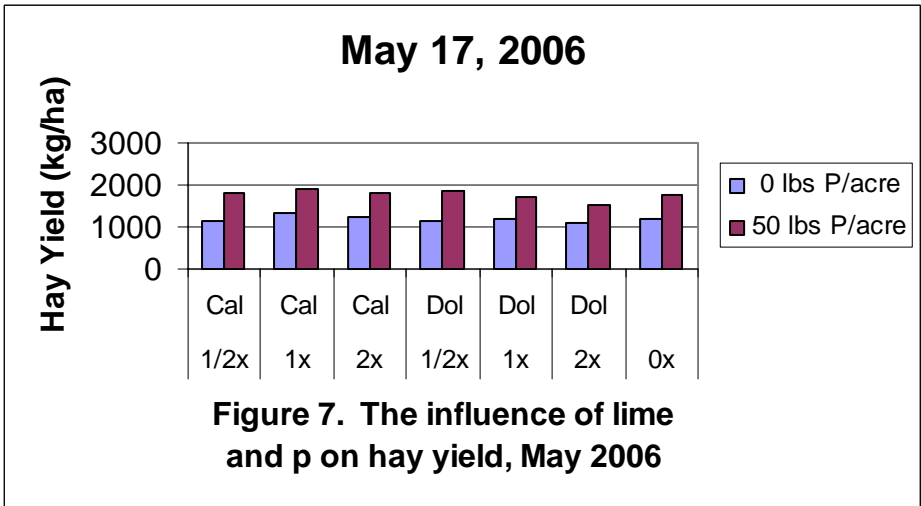
Figure 5. Influence of lime and P on Eastern Gammagrass composition 2005-2007.

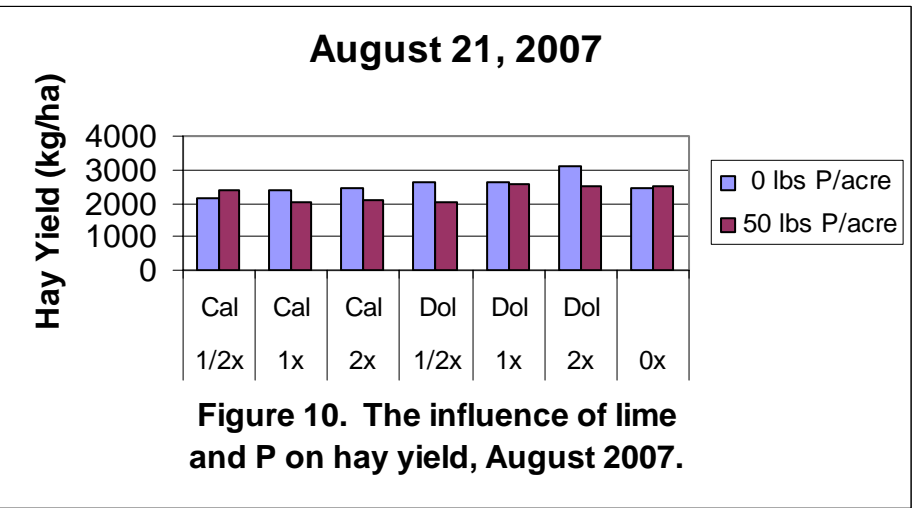
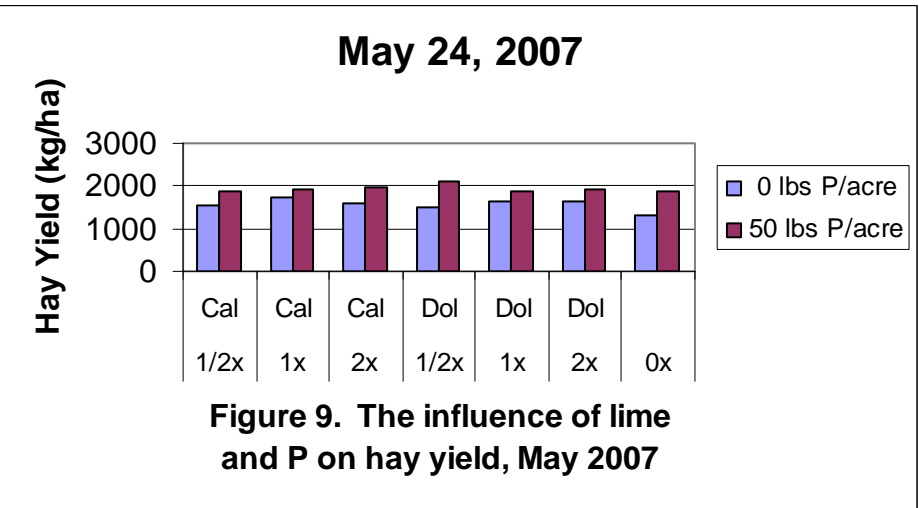
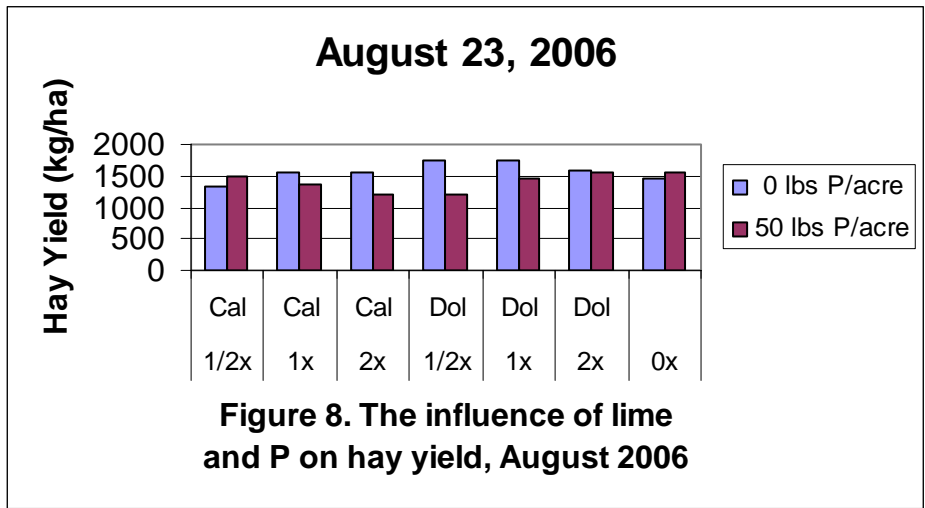


Over the two year period (2005-2007) after liming, it was observed that tall fescue increased in coverage with P treatments when limed (Figure 1). Broomsedge decreased with P applications and lime. The use of calcitic limestone tended to lessen broomsedge percentages more than dolomitic although plant occurrence numbers increased with time after treatment application (Figure 2). Dewberry coverage tended to decrease with calcitic and dolomitic limestone (Figure 3). However, P had little influence of Dewberry. Few consistent trends were observed with sumac relative to liming or P treatments (Figure 4). Calcitic limestone tended to decrease Eastern gamma grass occurrence more than dolomitic limestone (Figure 5). The occurrence of purple top is much less with both calcitic and dolomitic limestone over time regardless of P treatment (Figure 6).

Hay yield with limestone and P treatment

The influences of limestone and P treatments on hay yield over the years after application are presented in Figures 7 through 10.

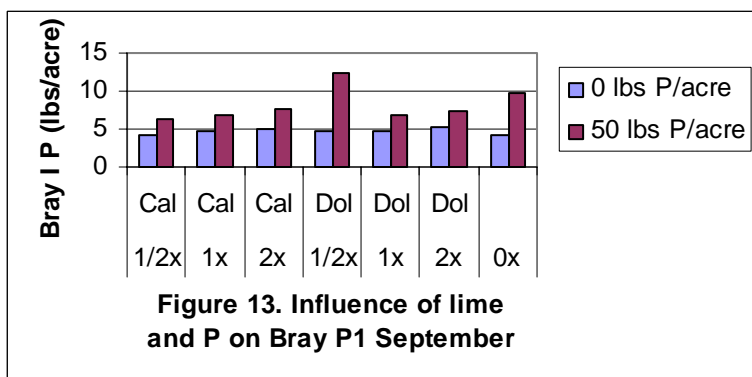
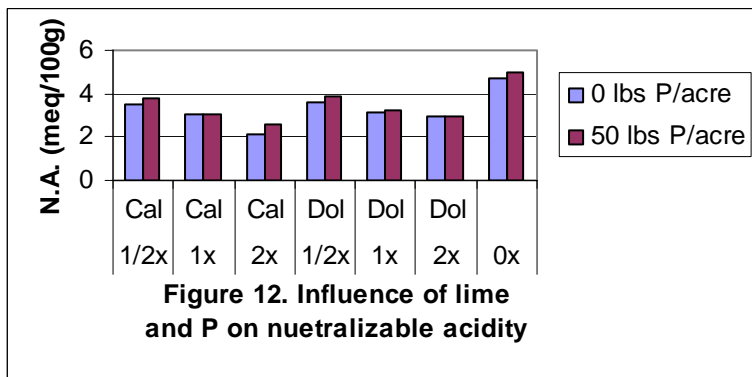
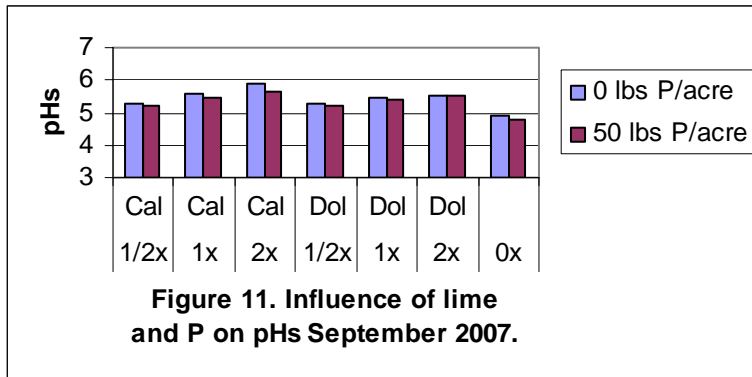


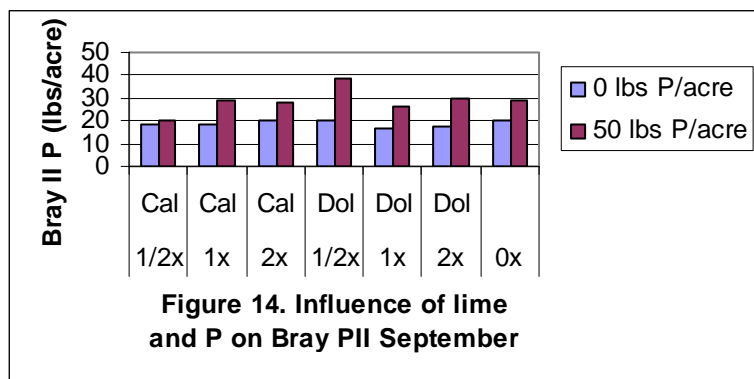


In both years the May yields were greater for P applications than the corresponding no P treatment at the comparable limestone quantity and type. This occurrence is best explained by the plant's need for a large portion of its annual P to be in the early part of the growth season. Whereas, both August yields were slightly greater for the no P than the P treatment and dolomitic limestone provided a slighter greater yield at comparable quantities than the calcitic limestone.

Soil test values with lime and P treatments

The 2 years influences of the lime and P treatments on specific soil test values are presented in Figures 11-14.





The various additions of limestone increased the salt pH from the initial 4.6 value to values in the 5 range. The 2X application of calcitic limestone provided the largest salt pH value (Figure 11). However, the values after liming were not near the desired salt pH value range one would target for top management tall fescue production. The salt pH values for tall fescue were much smaller than desired. Perhaps soil test values and liming recommendations for tall fescue production needs to be further researched to provide a greater long-term sustainable production level. All incremental increases of both limestones decreased neutralizable acidity with the calcitic material providing a lesser amount of acidity at the comparable dolomitic material (Figure 12). The addition of 50 lbs of P did increase Bray PI P levels within each liming material and within each incremental increase over the 0 P. However, Bray PI levels were greater for the dolomitic material than the calcitic material (Figure 13). These levels are still too low for consistent tall fescue production levels. Additionally, additions of P increased Bray PII levels with a slightly greater response for dolomitic limestone.

SUMMARY AND CONCLUSIONS

The addition of limestone and P to acid soils which are used for tall fescue production provided the following major observations over a 2 year period after application of the materials

1. With increased limestone and P treatments, the species composition changes gradually. Tall fescue tends to increase with P inputs when it was limed. Additional P drove broomsedge numbers down but only in the limed plots. Dewberry decreased with calcitic and dolomitic limestone. It is apparent that good liming and P management can be an effective weed control management tool. Control of woody species such as Sumac was limited at best. Perhaps grazing practices could assist with partial control of invader species. However, use of limestone and P may be a consistent but slow, evolutionary process in the control of invader species and management for desirable species.
2. Early season yields were greater than later season yields with P treatment. It is apparent that P is critical in the early part of the growing season. In the late-summer, P is not a factor with yield increases while dolomite has a greater positive influence on yield than calcitic limestone.
3. Target salt pH values are not being attained even with twice the Woodruff Buffer soil test recommendation for both calcitic and dolomitic limestone. This consistent finding along with previously funded Fertilizer/Ag Lime research we have preformed catalyzes the consideration that more research in the area of soil test calibration with limestone recommendations is needed to provide a greater long-term sustainability for tall fescue production.

4. Application of 50 lbs P does little to increase the Bray PI values for high yield forage production with very low initial P levels.

Pelletized Lime for Short-Term Treatment of Soil Acidity

Gene Stevens and David Dunn

University of Missouri-Delta Research Center

Correct soil pH is the cornerstone of a successful crop nutrient management program. Annual applications of nitrogen fertilizers on crops slowly produce acid conditions in fields. If low pH is not corrected by agricultural lime applications, soil acidity will reduce nutrient availability to plants (especially P), produce toxic levels of aluminum and manganese, and diminish the weed control activity of some herbicides.

In recent years, agricultural fertilizer dealers have reported 2 to 3 fold increases in sales of pelletized lime. Pelletized lime is finely ground limestone, which is made into small pellets for broadcasting with conventional fertilizer equipment. Because pelletized lime is relatively expensive per ton, it is applied at lower rates (<300 lbs/acre) as compared to recommended rates of agricultural lime. A “1:10 ratio” rule of thumb has been promoted for comparing the short-term neutralizing effectiveness of pelletized lime to agricultural lime. (Example: if a soil test recommends the ENM equivalent of 2000 lbs of agricultural lime per acre apply 200 lbs of pelletized lime/acre). Most farmers realize that pelletized lime is not a long-term “fix”, but expect it to reduce soil acidity to tolerable levels for one year. Typically, farmers apply this material on fields that a landlord is unwilling to share part of the cost of applying agricultural lime or will not provide a lease agreement for more than one year.

A study was conducted in 2005-2005 in Southeast Missouri to evaluate the general philosophy of using finely ground lime to provide a short-term, “quick fix” of soil acidity and compare soybean and corn yield response of pelletized lime and agricultural lime.

Materials and Methods

Soybeans. Elemental sulfur was uniformly broadcast at a rate of 2000 lb/acre to acidify a Reelfoot sandy loam soil at the Delta Research Center at Portageville in February 2005. Soil samples were collected before soybean planting in 2005 and analyzed at the MU Delta Center Soil Test Laboratory. Soil test reports showed that 1209 ENM/acre was recommended to neutralize the acidity. Ag lime (514 ENM/ton) and pelletized lime (720 ENM/ton) were applied to 10' X 40' plots in a randomized complete block design with four replications. Lime materials were incorporated with tillage. Soybeans were planted with 30-inch row spacings in early May in 2005-2007.

Treatments included agricultural and pelletized lime applied at $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, and 100% of the recommended ENM per acre. Also, pelletized lime treatments were included with very low rates (4, 8, 12, and 16 lb/acre) dribbled over the seed furrow behind the planter press wheel and applied directly in the seed furrow with soybean seeds. Soil samples from each plot were collected in March 2006. Results showed that the sulfur probably continued to react and acidify the field throughout the 2005 growing season. Additional agricultural and pelletized lime was applied to the same plots in April 2006 using the same pattern of rates relative to MU recommendations. Liming materials were applied in 2006 with 1842 ENM/acre for the 100% recommended rates and proportionally lower amounts for $\frac{1}{16}$, $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ of the recommended amount of lime from agricultural and pelletized materials. The center two rows of each four row plot were mechanically harvested with a plot combine and the grain weights adjusted to 13% moisture.

Corn A corn experiment was conducted in 2006 and 2007 using fields with silt loam soils in a corn/soybean rotation. Plots in this experiment were not artificially acidified with sulfur. Soil pH_{salt} values were 4.9 in 2006 and 4.6 in 2007. Four rates of ag lime (1000, 2000, 3000, and 4000 lb/acre) and four rates of pelletized lime (100, 200, 300, and 400 lb/acre) were applied and incorporated before corn planting. Each pelletized lime rate was 1/10 of a corresponding agricultural lime treatment. Corn was planted on 30-inch row spacing and mechanically harvested with a plot combine. Grain weights were adjusted to 15% moisture.

Results and Discussion

Applying less than 25% of recommended rates of lime on acid soil in soybean plots did not significantly increase yield compared to soybean in untreated plots. Agricultural lime and pelletized lime produced the same increase in soil pH and soybean yield response when equivalent ENMs per acre were applied of each material. Soybean yield increases in 2006 and 2007 showed a positive linear response to increasing lime for rates up to 100% of MU soil test recommendations (Figures 1 and 2). Dribble and in-furrow placement of pelletized lime at very low rates did not significantly increase soybean yield. Averaged across years, the untreated check soybean plots produced 30 bushels per acre compared to infurrow and dribble pelletized lime plots which both averaged 31 bushels per acre. Applying 1/10 the recommended rate of pelletized lime on corn was not as effective in neutralizing soil acidity as a full rate of agricultural lime. Averaged across years and rates, corn receiving 1000 to 4000 lb/acre of agricultural lime averaged 164 bu/acre compared to 100 to 400 lb/acre rates of pelletized lime which produced 143 bu/acre.

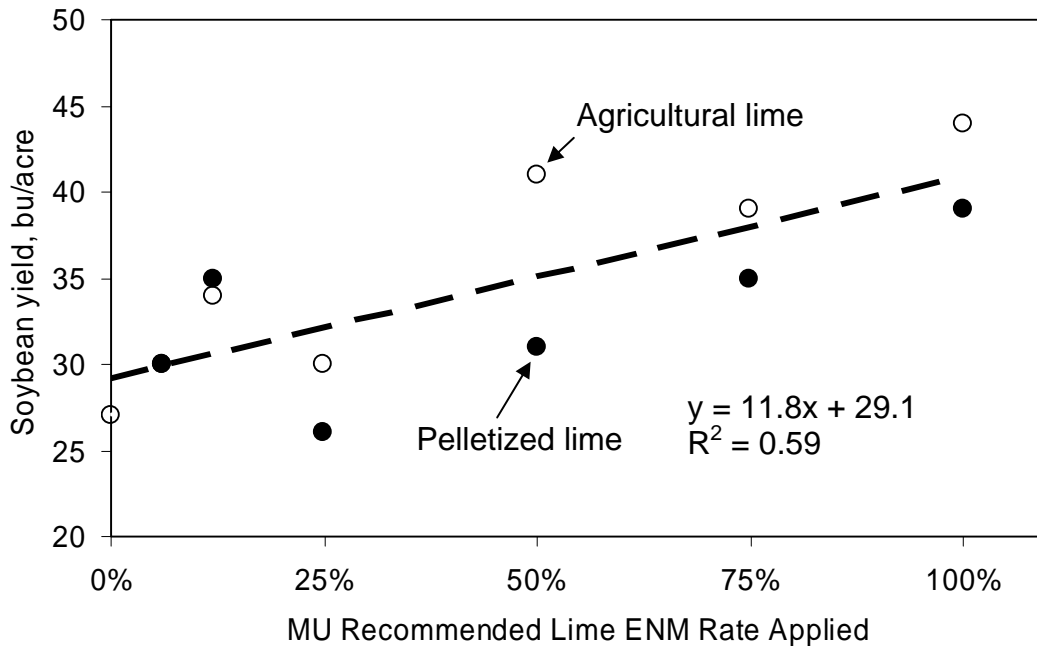


Figure 1. Soybean yields in 2006 as affected by agricultural lime (514 ENM/ton) and pelletized lime (720 ENM/ton) treatments with rates based MU recommendation of 1209 ENM/acre in 2005 and 1842 ENM/acre in 2006.

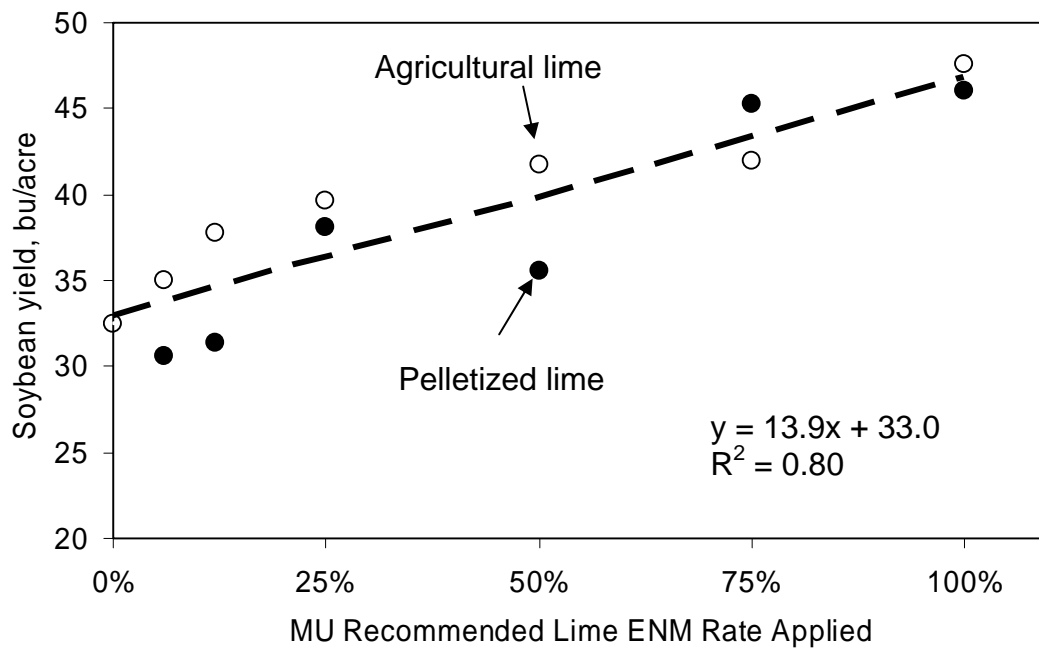


Figure 2. Soybean yields in 2007 as affected by agricultural lime (514 ENM/ton) and pelletized lime (720 ENM/ton) treatments with rates based a MU soil test recommendation of 1209 ENM/acre in 2005 and 1842 ENM/acre in 2006.

Table 1. Corn yield response to agricultural and pelletized lime on fields using the 10:1 rule of thumb for pelletized lime rates of application relative to agricultural lime.

| Lime | Material | 2006 | 2007 | Average |
|-----------|----------|-------------------|------|---------|
| | per acre | -----bu/acre----- | | |
| Check | 0 | 98 | 193 | 146 |
| Ag lime | 1000 lb | 126 | 192 | 159 |
| | 2000 lb | 123 | 210 | 167 |
| | 3000 lb | 145 | 195 | 170 |
| | 4000 lb | 121 | 201 | 161 |
| Pell lime | 100 lb | 100 | 190 | 145 |
| | 200 lb | 96 | 191 | 143 |
| | 300 lb | 98 | 191 | 144 |
| | 400 lb | 103 | 182 | 142 |

Progress Reports

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

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

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

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

Table 1. Initial soil test results for the tall fescue pasture used in the liming/P timing experiment at the University of Missouri SW Center near Mt. Vernon. Samples collected and analyzed in June, 2007.

| Sample # | pHs | N.A. meq/100g | O.M. % | Bray I P lbs/ac | Bray 2 P lbs/ac | Ca lbs/ac | Mg lbs/ac | K lbs/ac | CEC meq/100g | Mn ppm |
|----------|-----|------------------|-----------|--------------------|--------------------|--------------|--------------|-------------|-----------------|-----------|
| 1 | 5.6 | 1.5 | 2.8 | 10 | 16 | 2291 | 220 | 75 | 8.2 | 21.6 |
| 2 | 5.7 | 1.5 | 2.4 | 8 | 19 | 2190 | 184 | 72 | 7.8 | 26.7 |
| 3 | 5.7 | 1.5 | 3.0 | 7 | 18 | 2147 | 207 | 93 | 7.8 | 39.8 |

In mid-July, forage was cut and removed from the plot area. Plots were established with the following dimensions: 10' x 25' with 5' alleys (Fig. 1). On July 19, dolomitic limestone (ENM = 467 & EMG = 137) was applied to specific plots at a rate of 0 or 2000 lbs/acre (Fig. 2). During late August, forage was harvested and removed from the plot area and, on September 7, 100 lbs N/acre (as urea) was applied to all plots. In mid-September, a total of 25 lbs P/acre was applied to the September P treatment plots and all other P treated plots were treated with 12.5 lbs P/acre, as 0-46-0, Then in October, the October plots were treated with their remaining 12.5 lbs P/acre, and in November and December, those specific P-treated plots received their remaining 12.5 lbs P/acre, according to the attached timing chart (Table 2). January and February plots will be treated with their final 12.5 lbs/P acre in 2008. Starting in October 2007, 20 of the most recently collared leaves from each plot were harvested monthly. Leaf samples from the September through December harvests are currently dried and are in the process of being ground, digested in nitric acid in our microwave digestion system, diluted, filtered and analyzed for macro- and micronutrient concentrations by ICP.

Figure 1. Plot map of the liming/time of P application experiments begun at the University of Missouri SW Center near Mt. Vernon in summer 2007.

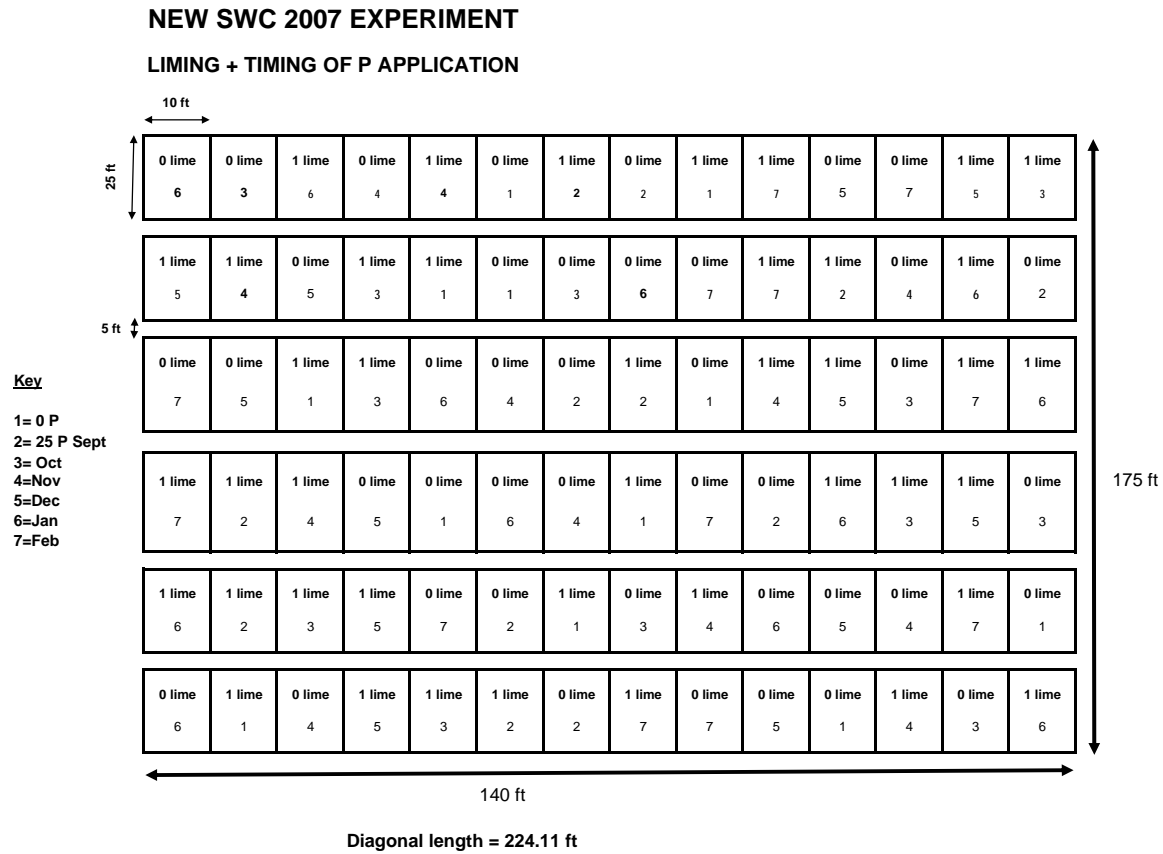


Table 2. P application schedule for phosphorus fertilization.

| Trtmt # | Sep | Oct | Nov | Dec | Jan | Feb |
|---------|----------|------|------|------|------|------|
| | lbs/acre | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 25 | 0 | 0 | 0 | 0 | 0 |
| 3 | 12.5 | 12.5 | 0 | 0 | 0 | 0 |
| 4 | 12.5 | 0 | 12.5 | 0 | 0 | 0 |
| 5 | 12.5 | 0 | 0 | 12.5 | 0 | 0 |
| 6 | 12.5 | 0 | 0 | 0 | 12.5 | 0 |
| 7 | 12.5 | 0 | 0 | 0 | 0 | 12.5 |



Figure 2. Plots at the SWC on July 19, 2007 when dolomitic limestone was applied.

Nitrogen Management

Final Reports

Rice Nitrogen Management- Rates and Timing of Urea Fertilizer

Gene Stevens and David Dunn
University of Missouri-Delta Research Center

Managing nitrogen fertilization can be a challenge due to potential N losses from urea volatilization before flooding and denitrification after flooding. Extension recommendations for pre-flood N (PFN) rates in rice are usually based on empirical N field tests and adjustments are made for specific varieties, crop rotation, and soil texture. To help reduce rice N deficiency stress from early season N losses and supply N needs during grain-filling growth stages, midseason N (MSN) by aerial topdressing on rice can be applied near panicle differentiation (R1) growth stage. Measurements such as leaf area index, biomass accumulation, Y-leaf (most recently fully expanded leaf) N concentration, and whole-plant N concentration have been used to estimate midseason plant N sufficiency for determining whether topdressing is likely to increase rice yields.

Plant area measurements with a rice gauge have also been used to predict midseason N need. The rice gauge has two main components: (1) a vertical wooden board (1.5 inch wide X 40 inch tall) with centimeter digits for measuring plant height and (2) a height adjustable inverted trapezoid (15 inch across the top) with centimeter digits along the top edge for measuring canopy spread. The vertical board is positioned in the center of a rice drill row, and the trapezoid is slid to the top of the canopy. Then a person visually estimates the rice plant height and width at the sample location. These numbers are used in a formula to calculate plant area. Scientists in Arkansas found that plant area values from a rice gauge were a good estimator of rice dry matter and a more reliable estimator of total N accumulation than Y-leaf N concentrations and SPAD readings. Although use of the rice gauge for predicting rice need for midseason N has been widely promoted by state extension services in the upper Mississippi Delta region, very few rice consultants or farmers use it because of the labor required. Much of the rice in the Delta region is scouted by a single person walking across a field checking for disease, insect, weed, and nutrient problems. For monitoring rice plant midseason N status with a rice gauge, one person must carry a clip board and pencil to record numbers, slide and lock the trapezoid in place, prevent the vertical shaft from falling over in the mud while backing away to estimate height and width, and then move to another sample location in a field.

The objective of this study was to develop thresholds using visual and digital image measurements for predicting rice yield response to MSN applications at R1 growth stage. In 2004-2007, we conducted experiments to determine if plant area estimates based on plant height or numbers visible on a yardstick floating on floodwater between rice rows were reliable predictors of rice need for MSN applications. In 2005-2007, percent green pixels in digital images from rice plots recorded with a digital camera were evaluated as a predictor of rice need for MSN.

MATERIALS AND METHODS

Rice field experiments were conducted at Glennonville, Missouri on a Dewitt silt loam soil, and at Portageville, Missouri on a Sharkey clay soil. Plots were shifted to a new location each year to maintain a soybean-rice rotation. Rice plots were drill seeded (7.5 inch row spacing) with 'Francis' and 'Cheniere' varieties in 2004-2006. Cocodrie was substitute for Cheniere in 2007 because of a ban on Cheniere planting due to Liberty Link genes being found in the seed supply. A split-plot design with four replications was used with rice varieties in main plots and N treatments in subplots. N treatments were urea N applied 0, 35, 70, 105 and 140 lb N acre⁻¹ before flooding at V4 to V5 growth stage with no additional N at midseason and the same PFN rates with MSN applied 30 lb N acre⁻¹ urea at R1 growth stage followed by 30 lb N acre⁻¹ urea again at R1 +7d. Each subplot was 12 feet wide by 25 feet long.

In this study, MSN rates of 30 lb N acre⁻¹ at R1 growth stage followed by 30 lb N acre⁻¹ one week later were used because this topdressing program has been the standard practice in the Delta region for many years. Recently, many rice farmers began making a single midseason application of 45 to 60 lb N acre⁻¹ to reduce aerial application costs. This system may change the magnitude of yield change from midseason N, but in-season diagnostic indicators predicting rice response to additional N will continue to be needed.

Clomazone herbicide (0.50 lb a.i. acre⁻¹) was applied preemergence for weed control at each site. Quinclorac (0.30 lb a.i. acre⁻¹) and propanil (2.5 lb a.i. acre⁻¹) were applied postemergence before flooding grass and broadleaf control. In 2005 on the Dewitt silt loam, an infestation of duck salad developed after flooding and bensulfuron (0.05 lb a.i. acre⁻¹) was applied for control.

Plots were mechanically harvested with a combine and adjusted to 13% moisture. Rice yields for each pre-flood N rate subplot without midseason N were subtracted from yields in pre-flood N rate subplots with midseason N.

Three methods of measuring midseason plant area per plot were evaluated 1-2 d before R1 growth stage. For the first method, a yardstick was floated on floodwater between two center drill rows and the numbers visible were counted. Inch digits on the yardstick were approximately 2.0 mm tall. Standing between adjacent rows and leaning over the sampling rows, we counted the inch numbers showing on the yardstick (not hidden by rice leaves) out of 36 numbers possible (Figure 1). When a rice leaf obstructed the view of one digit in a two-digit number to the point that the whole number was not recognized, we did not count that number. For the second method, plant height was measured at the same sample location in each plot. One location per plot was sampled.

For the third method, digital images were collected 1 to 3 days before midseason N applications with a camera mounted on 5-ft rod held above the plot in 2005-2007. This method was not used in 2004. The camera was positioned level with the soil surface and recorded a plot area of 32 inches X 45 inch (Figure 2). A computer macro program developed at University of Arkansas was used with Sigma ScanTM Pro 5.0 image software to determine the percentage of green pixels in each photo. We defined green color in Sigma Scan as 52 to 110° hue on the color wheel and a saturation of 35 to 100%.

The statistical analyses of plant height, yardstick numbers showing, percent green pixels, and rice yield were performed using Proc Mixed from Statistical Analysis System. This procedure provided Type III *F* values but did not provide mean square values for each source of variation within the analysis or the error terms. Mean separation was evaluated through a series of pair-wise contrasts among all treatments. Probability levels greater than 0.05 were categorized as non-significant. ExcelTM 2000 spreadsheet software was used to graph and develop regression equations for yardstick number showing and percent green pixels relative to rice yield changes from midseason N.

In 2007, we also evaluated additive to urea and soil release N sources on rice at the Missouri Rice Research Farm and Delta Center Lee Farm. Treatments included four pre-flood rates of urea applied with and without Agrotain, applications of ESN, ammonium nitrate, Scotts slow release N, calcium thiosulfate, and NutriSphere-N. Soil conditions were managed to promote volatilization by scheduling applications after a rain and 1 week before establishing a permanent flood.

RESULTS AND DISCUSSION

Although Francis variety rice plants grew taller and matured 3 to 5 days later than Cheniere, we found no consistent rice yield pattern indicating that one variety should be fertilized with more or less N than the other variety on a specific soil (Tables 1 and 2). However, rice varieties did not always respond the same to N treatments in different weather and soil environments. Only in 2 out of 12 cases (Francis, Sharkey clay, 2004; and Francis, Dewitt silt loam in 2006), did a variety with 105 lb N acre⁻¹ PFN produce statistically lower yields than the same rice variety with 140 lb N acre⁻¹ PFN. A significant yield response to N was not found on either soil in 2007 (Figure 3).

The wind conditions from the aftermath of Hurricane Katrina on August 30, 2005 at Portageville provided a unique opportunity to study the effect of MSN fertilization on rice lodging. Although applying MSN is an important management tool for relieving N-deficiency stress in rice, plants may be more likely to lodge. By chance, the rice drill rows in plots were planted east to west because of the field grade. Weather records indicate the wind gusts were strongest from 3 to 6 am CDT when wind was blowing straight from the east in the row direction. Rice plants prone to lodge fell towards the alleys rather than an adjoining plot on the right or left. We observed plots without midseason N that were completely standing from border to border. Often these plots were immediately adjoining plots with high PFN rates and MSN that sustained 60

to 80% lodging. One explanation for the high lodging in MSN plots is that midseason N fertilization may have produced plants with heavier panicles which is desirable for increasing grain yields but makes the plant top heavy and more likely to lodge in high winds.

Preflood Nitrogen

An important factor to consider before applying MSN is the amount of N that was applied pre-flood. The small plots in this study were managed with ideal cultural practices for minimizing N losses from urea volatilization. We were able to completely flood plots within 4 hr of applying pre-flood urea and maintained the flood for the rest of the season. Unfortunately, farmers may need several days to flood a field and they may be uncertain of how much PFN was lost due to N volatilization. Nevertheless, pre-flood N remains one of the best predictors of whether yield increases are likely to occur from MSN.

Regression analyses were performed after removing Sharkey clay 2005 yields from the dataset. This was done because of the problems with soil disturbance from land leveling and high winds at harvest. Solving for zero yield increase from MSN application ($YLD=0$), we found that $107 \text{ lb N acre}^{-1}$ pre-flood was predicted to produce rice yields with no additional response to midseason N topdressing. This is 28% less N than the current University of Missouri total N recommendation to farmers for Francis and Cheniere varieties ($150 \text{ lb N acre}^{-1}$), but is much closer than predictions with Sharkey clay 2005 results included in the analyses. On an actual rice farm in the Delta, more urea N may be required than our predictions to compensate for N losses from volatilization and denitrification. Since it is difficult to know how much N is lost in a given field, developing one or more in-season plant indicators for predicting N response to MSN is needed.

Plant Measurements

Although plant height is used as an input for estimating rice crop canopy with the rice gauge, we found little value for this measurement for predicting rice N status at midseason. Regression coefficients of determination for plant height and rice yield change from midseason N applications were very low.

Most modern rice varieties have been selected for vertical leaf orientation for the uppermost leaves. This change in leaf orientation improves light penetration into the canopy compared to the more horizontal leaf position of older varieties. Cheniere and Francis are high-yielding rice varieties bred to maximize photosynthesis using vertical leaf orientation. Yardstick numbers showing and percent green pixels in digital images are indicators of crop leaf canopy closure and can be influenced by leaf orientation. Yardstick numbers visible and % green pixels were significantly affected by pre-flood N rates but did not have a variety x pre-flood N interaction. This is important because it indicates that the systems might be used for N management with both Cheniere and Francis, and perhaps across other varieties with vertical leaf orientation, without major adjustments.

Plant area measurements were made with yardstick and digital image systems on the Dewitt silt loam in 2005 and 2006 and Sharkey clay in 2005 and 2006. We found that an inexpensive low-resolution digital camera (640×480 pixels) produced similar green pixel percentages as more expensive digital cameras. Also low resolution images from a cheap camera can be processed faster in Sigma Scan than large high resolution files. As expected, a strong coefficient of determination ($R^2=0.73$) was found between the two monitoring systems (Figure 4). The main difference between the systems is that yardstick numbers indicate the outward overlapping of rice leaves from rows into the center of row middles in contrast to the green pixel method which evaluates the entire rice leaf area including the rows.

An infestation of aquatic weeds developed after the permanent flood was established on the silt loam soil at Glennonville in 2005. Digital images on the loam site in 2005 were not useable and were excluded from Figure 5 because of small duck salad weeds growing between the drill rows after flooding. An application of bensulfuron killed the weeds but Sigma Scan software could not distinguish between green pixels produced by rice plants and green pixels from the slowly dying aquatic weeds at the water surface. Fortunately, the duck salad was small enough that the plants did not interfere with our ability to place the yardstick between rice rows and collect visual inch-number-showing data.

Yardstick number showing, used as an independent variable with regression analysis did not perform as well as PFN rate for predicting yield change from topdressed MSN application. The best fit equation correlating yield change from MSN with yardstick digits was a quadratic equation (Figure 6). Although

MSN can help reduce deficiency, it is only a supplement to a good preflood N program. Rice rows with 30 to 35 yardstick numbers showing were severely deficient of N, and tillering was poor. Applying N at R1 growth stage on these plots was often too little N applied too late.

Using the regression equation for yardstick numbers in Table 4 with Sharkey clay 2005 data excluded, no yield response to MSN was produced when less than 13 inch numbers were showing. When the clay 2005 data were removed from the regression analysis because of the lodging problem, 64% pixels was the critical level for no yield response to MSN ($YLD = -25.38 \%PIXEL + 1630.3, R^2 = 0.418$).

Costs for equipment, software, and labor will influence which plant N-monitoring system are used by rice farmers, crop consultants or scouts. Commercial cost for Sigma Scan Pro 5.0 image software is approximately \$1375. A wooden yard stick can be purchased for less than \$5. A yardstick is lighter to carry than a pole and camera across muddy rice fields. Also, when using digital photography, image file names and field names must be matched, images processed in a computer, and aquatic weeds can make results unusable. However, using aerial digital photography of whole fields combined with scouting for weeds would minimize some of these problems.

Tests evaluating nitrogen fertilizer additives did not show a significant benefit for increasing rice yields in 2007 (Figures 7 and 8).

SUMMARY

No significant yield increase was produced from MSN when 105 lb N acre⁻¹ was applied preflood with small plot water management. However, in large rice grower fields managing to reduce volatilization and denitrification losses is more difficult. Critical plant area thresholds values for R1 growth stage rice were developed using visual and digital image measurements for predicting rice yield response to MSN. No yield response was produced from MSN when fewer than 13 numbers were showing on a yardstick floating between drill rows or more than 64 % of the pixels in digital images of plots were green. Information about this study and other crop production research at the Delta Center is posted at <http://www.plantsci.missouri.edu/deltacrops>.

Table 1. Rice grain yields from Francis and Cheniere varieties grown on Dewitt silt loam and Sharkey clay with pre flood and midseason N treatments in 2004-2006.

| Soil | Year | Variety | Midseason | Preflood N, lb N acre ⁻¹ | | | | | | | | | |
|------------------|----------|----------|-------------------------|---|--------|-------|-------|-------|-------|-------|-------|--------|-------|
| | | | N | 0 | | 35 | | 70 | | 105 | | 140 | |
| | | | lb N acre ⁻¹ | -----bu rice grain acre ⁻¹ ----- | | | | | | | | | |
| Dewitt silt loam | 2004 | Francis | 0 | 143 | ij † | 173 | efg | 186 | bcdef | 204 | abc | 213 | a |
| | | | 30 + 30 | 165 | gh | 193 | abcde | 202 | abc | 205 | ab | 195 | abcd |
| | | Cheniere | 0 | 142 | j | 152 | hij | 176 | defg | 183 | cdefg | 177 | defg |
| | | | 30 + 30 | 166 | fgh | 175 | defg | 181 | defg | 176 | defg | 163 | ghi |
| | 2005 | Francis | 0 | 126 | f | 149 | def | 174 | abcd | 187 | abc | 208 | a |
| | | | 30 + 30 | 151 | cdef | 173 | abcde | 199 | ab | 176 | abcd | 205 | a |
| | Cheniere | 0 | 135 | ef | 147 | def | 167 | bcde | 171 | abcde | 195 | ab | |
| | | 30 + 30 | 164 | bcde | 182 | abcd | 191 | ab | 200 | ab | 178 | abcd | |
| 2006 | Francis | 0 | 106 | h | 137 | defg | 138 | cdefg | 152 | bcde | 169 | a | |
| | | 30 + 30 | 139 | cdefg | 158 | abcd | 153 | bcd | 151 | bcde | 150 | bcdef | |
| | Cheniere | 0 | 123 | fgh | 147 | bcdef | 165 | ab | 147 | bcdef | 143 | bcdefg | |
| | | 30 + 30 | 126 | efgh | 150 | bcdef | 158 | abcd | 149 | bcdef | 130 | efgh | |
| Sharkey clay | 2004 | Francis | 0 | 110 | ef | 108 | f | 116 | def | 124 | cdef | 145 | abc |
| | | | 30 + 30 | 122 | cdef | 115 | def | 129 | bcdef | 135 | abcde | 156 | a |
| | | Cheniere | 0 | 111 | ef | 130 | bcdef | 135 | abcde | 139 | abcd | 146 | abc |
| | | | 30 + 30 | 131 | abcdef | 149 | ab | 146 | abc | 145 | abc | 131 | bcdef |
| | 2005 | Francis | 0 | 171 | ab | 193 | a | 212 | a | 209 | a | 203 | a |
| | | | 30 + 30 | 182 | a | 200 | a | 201 | a | 186 | a | 185 | a |
| | Cheniere | 0 | 176 | a | 195 | a | 201 | a | 206 | a | 186 | a | |
| | | 30 + 30 | 183 | a | 189 | a | 182 | a | 169 | ab | 125 | b | |
| 2006 | Francis | 0 | 162 | fg | 190 | cd | 212 | abc | 221 | a | 211 | abc | |
| | | 30 + 30 | 164 | efg | 192 | bcd | 215 | ab | 209 | abc | 209 | abc | |
| | Cheniere | 0 | 143 | g | 186 | de | 206 | abcd | 197 | abcd | 197 | bcd | |
| | | 30 + 30 | 184 | def | 193 | bcd | 198 | abcd | 202 | abcd | 195 | bcd | |

† Within soils and years, rice yield values followed by the same letter were not significantly different at the 0.05 probability level

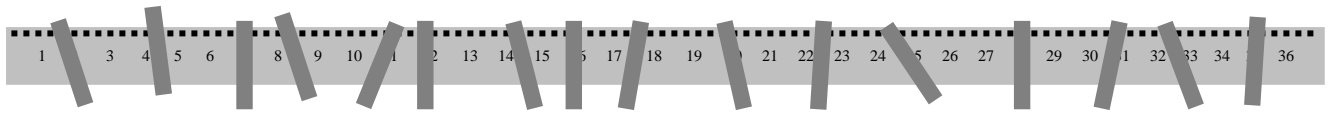


Figure 2. Illustration of rice leaves blocking the overhead view of inch numbers on a yardstick floating in floodwater parallel and halfway between two rice 7.5-inch spaced drill rows. In this example, 2, 7, 11, 12, 16, 20, 25, 28, 31, 33, and 35 would not be counted as showing.

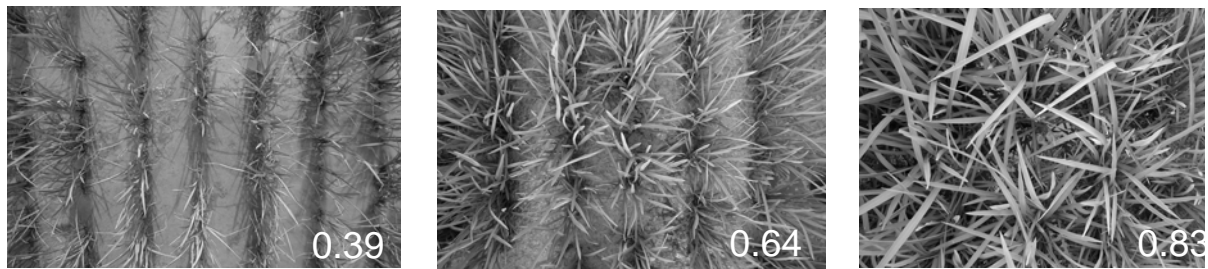


Figure 3. Example images (left to right- low PFN to high PFN,) collected at R1 growth stage with a digital camera from 32 inch X 45 inch areas in rice plots. Values in the lower left corner of photos were the proportion of green pixels in images.

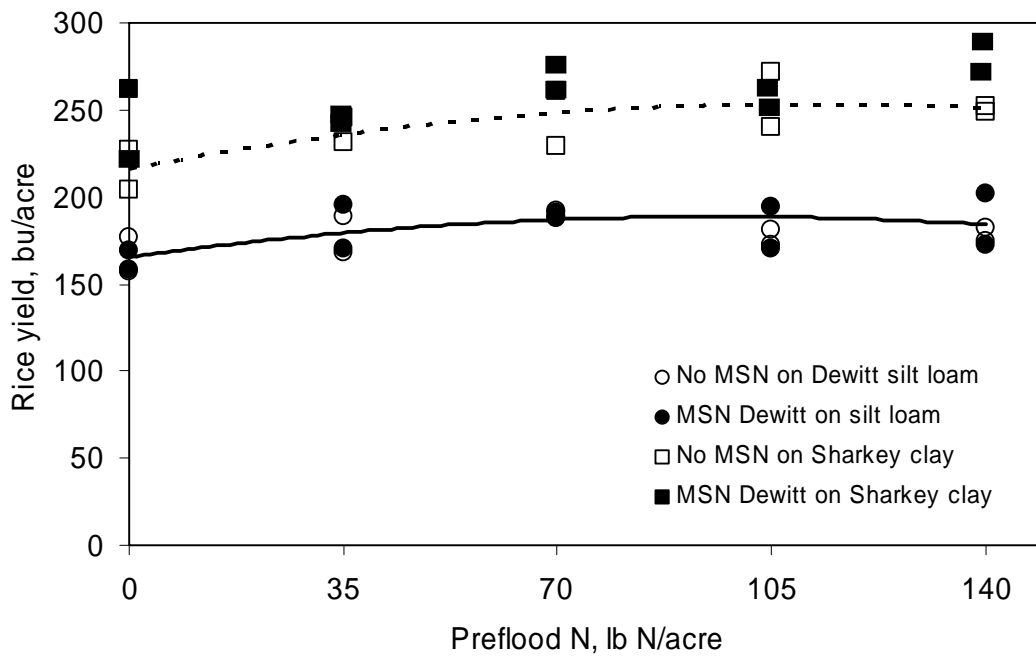


Figure 1. No significant rice yield response to preflood or midseason N was found in 2007 on Dewitt silt loam or Sharkey clay soils.

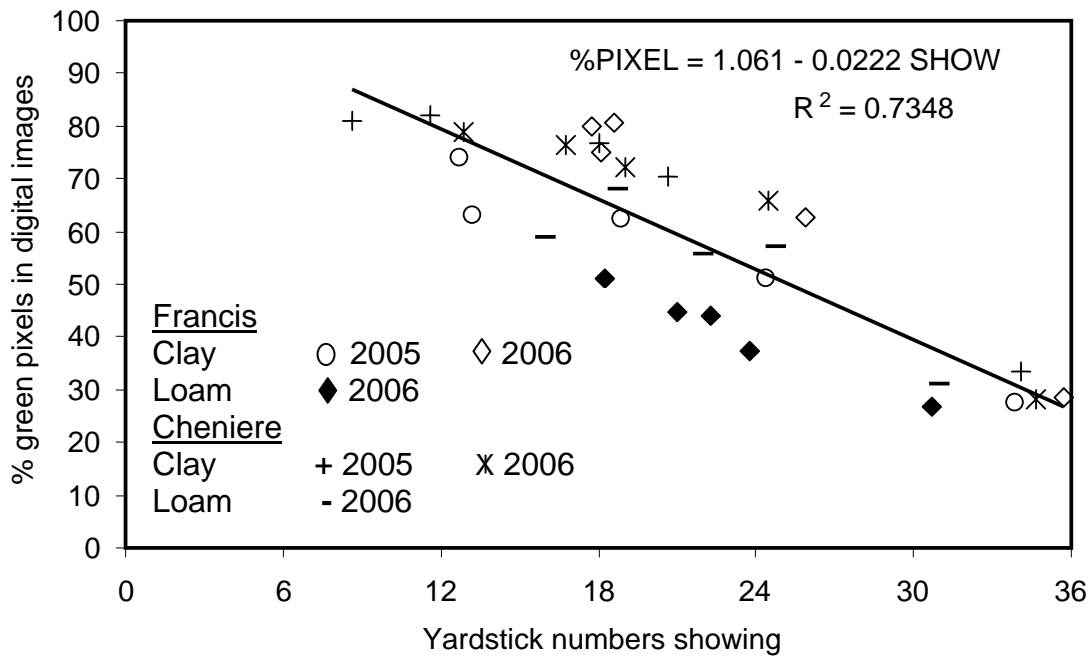


Figure 4. Relationship between visible numbers showing on yardstick and percent green pixels in digital images measured at R1 growth stage before midseason nitrogen was applied in 2005 and 2006 on Francis and Cheniere varieties.

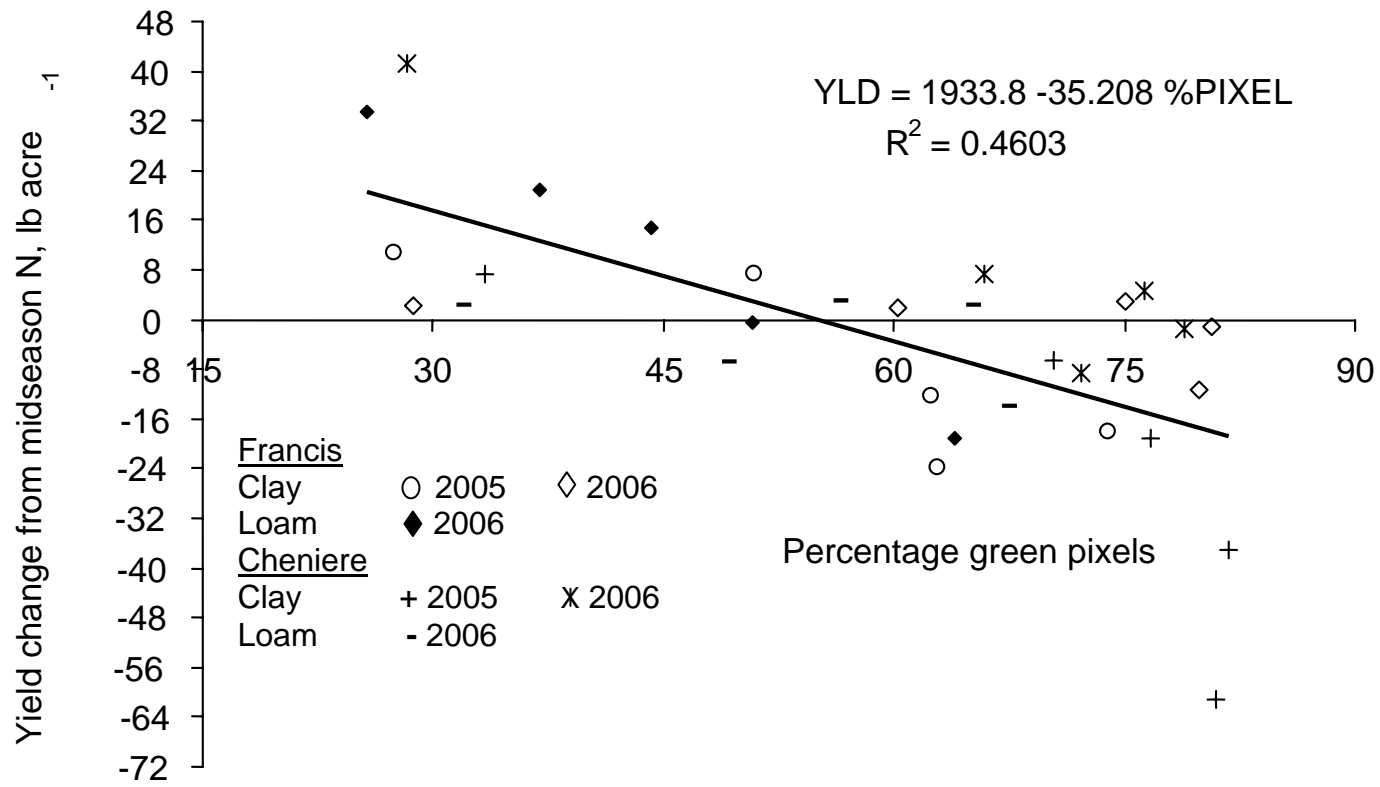


Figure 5. Rice yield response to midseason N applications relative to percentage of green pixels in digital images recorded at R1 stage from Francis and Cheniere varieties in 2005 and 2006 on Sharkey clay and 2006 on Dewitt silt loam soil.

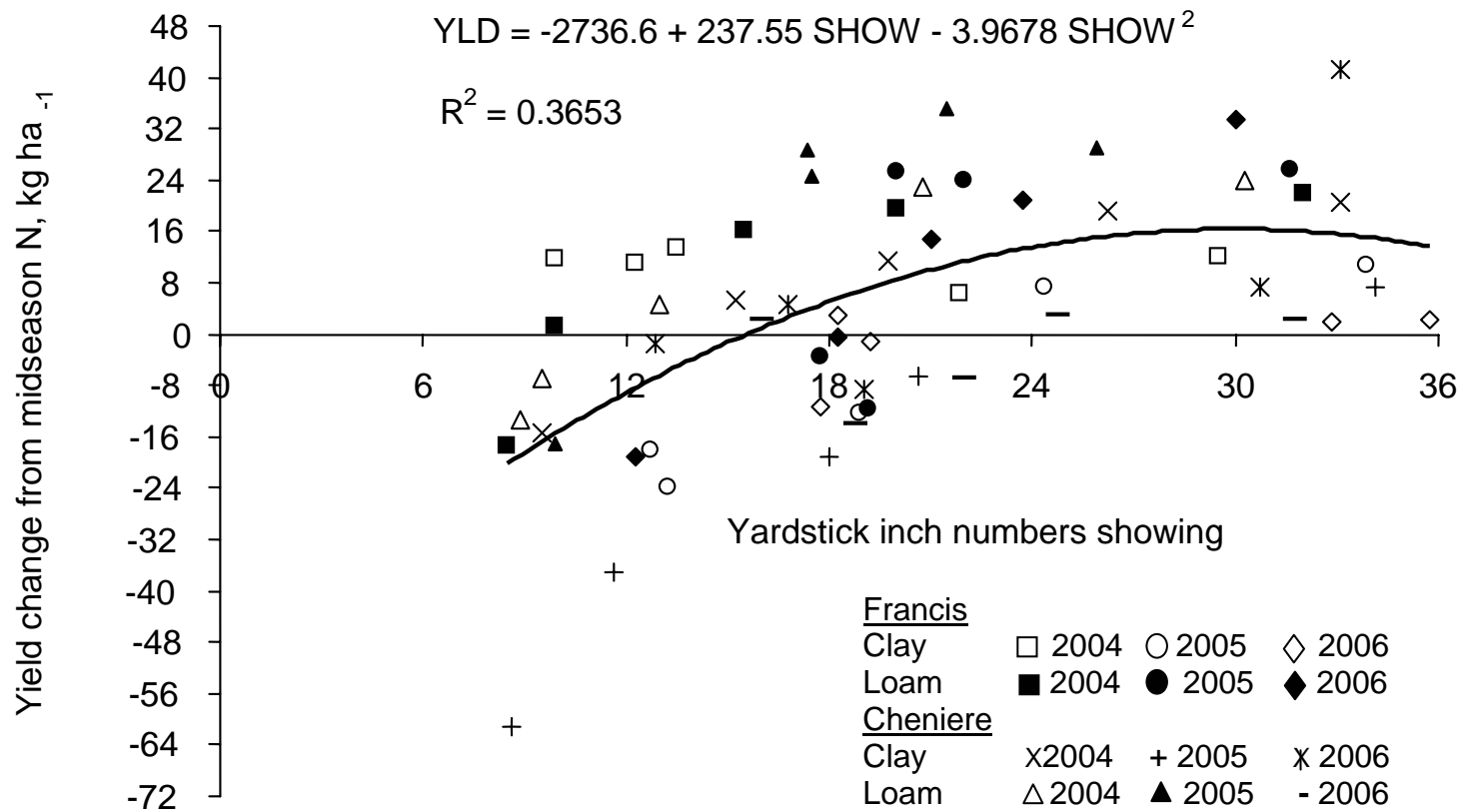


Figure 6. Rice yield response to midseason N applications relative to visual number of numbers showing on yardstick at R1 growth stage from Francis and Cheniere varieties in 2005 and 2006 on Sharkey clay and 2006 on Dewitt silt loam soil.

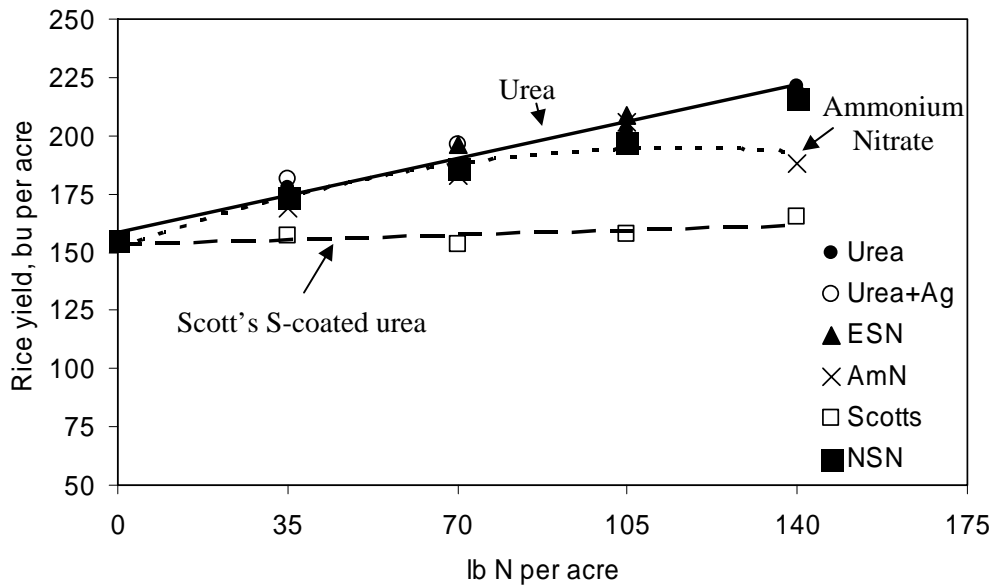


Figure 7. Rice yield response on Sharkey clay to urea applied with and without Agrotain, or applications of ESN, ammonium nitrate, Scotts slow release N, and NutriSphere-N.

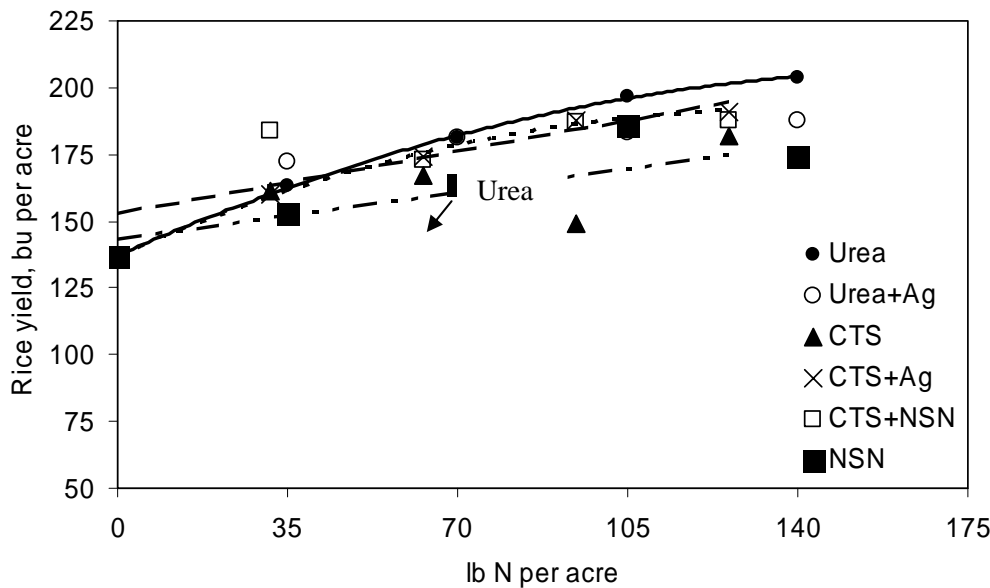


Figure 8. Rice yield response on Dewitt silt loam to urea applied with and without Agrotain, or applications of calcium thiosulfate, calcium thiosulfate with Agrotain, calcium thiosulfate with NutriSphere-N, and NutriSphere-N.

Cost-Effective N Management Using Reduced Rates of Polymer Coated Urea in Corn

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Introduction:

Poorly drained soils are common in Missouri. Farmers with poor drainage have additional options for N management using polymer coated urea (Merchán Paniagua et al., 2005; Schwab et al., 2005). Polymer coated urea has been shown to reduce N₂O flux in plots with poor drainage in relatively wet years (Merchán Paniagua et al., 2005). Performance of polymer coated urea has been equivalent to anhydrous ammonia in Northern Missouri (Motavalli et al., 2005) and less consistent in Central Missouri (Medeiros et al., 2005). Preliminary research in 2005 at Novelty indicated that polymer coated urea rates may be reduced up to 30% while maintaining corn grain yields similar to a 150 lb/a rate regardless of application timing. This may be a cost-effective management option for farmers to offset the cost of the polymer coating.

Availability of ammonium nitrate and anhydrous may be limited in the future. The slow-release properties of polymer coated urea have appealing characteristics for corn producers in watersheds with the potential of surface water runoff or soils with high leaching potential (Rosen and McNearney, 2005). Placement of polymer coated urea has demonstrated improved utility and yield of potato in Wisconsin (Rosen and McNearney, 2005) and corn in Minnesota (Randall, unpublished) compared to other N sources. Finally, incentive payments through the Conservation Security Program were available to producers in Missouri utilizing coated urea technology. This could impact over 1.8 million acres in qualified watersheds (NRCS, 2005). Recently, N prices have increased dramatically while corn prices have been variable. A polymer coating may increase cost of N up to \$0.11/lb; therefore, reduced rates of polymer coated urea need to be evaluated to balance the additional cost of the coating while maintaining the yield potential of corn. In addition, no published research has evaluated the release of the polymer coated urea for corn in field experiments on poorly drained soils. No research has evaluated degradation as affected by residue, tillage, or placement in the soil. No published research has reported the effects of reduced rates of polymer coated urea and determined the interaction with application timing as a cost-effective method to reduce N application rates.

The objectives of this study were to: 1) evaluate yield response of no-till corn with reduced rates of polymer coated urea compared with non-coated urea at different application timings, 2) determine the interaction between application timing and N source on ammonium-N and nitrate N in the soil profile, and 3) assess the impact of application timing and placement on polymer coated urea degradation.

Materials and Methods:

A field trial with four replications was established at the Greenley Research Center in plots 10 by 40 ft to evaluate crop response to polymer coated urea (ESN) compared to non-coated urea at 0, 50, 100, and 150 lbs N/acre. 'Asgrow RX752' was no-till planted on April 28, 2006 and April 23, 2007 at 30,000 seeds/acre. In the fall, 23-60-100 and 27-70-100 was applied as recommended by the University of Missouri soil test lab in 2006 and 2007, respectively. Nitrogen application timings included: 1) fall (November 4, 2005 and November 7, 2006), 2) early preplant (April 5, 2006 and March 16, 2007), 3) pre-emergence (April 28, 2006 and April 23, 2007), and 4) broadcast side-dress (1-2 ft corn on June 5, 2006 and May 29, 2007) treatments. An untreated and standard anhydrous treatment at 150 lbs N/acre was included as a control. The field trial was monitored for ammonium- and nitrate-N at three timings throughout the season (first rainfall after the side-dress timing, prior to silking, and harvest) and throughout the profile at three incremental depths (0-6, 7-12, 13-18 inches). The untreated control and 150 lb N/a rates of polymer coated urea, urea alone, and anhydrous treatments were monitored for N concentrations and are currently undergoing analysis.

An additional field study utilized buried bags to evaluate degradation of the polymer-coated urea to determine N release throughout the growing season. This method has been utilized in wheat research on poorly drained soils (Schwab et al., 2005) and potato research on sandy soils (Rosen and McNearney, 2005), but N release has not been evaluated on poorly-drained soils for corn planted in different residues common in Missouri. This study included a factorial arrangement of 3 residues (no-till wheat stubble with red clover, no-till soybean residue, and reduced till soybean residue), 3 application depths (surface applied, 2 inch depth, and 4 inch depth), 3 application timings (March, April, and May), and 5 removal timings (April, May, June, July, and black layer). An additional air exposed control was included in the design. Each treatment was replicated three times. A nylon window screen packet was constructed for each treatment. Each screen packet held approximately 10 grams of polymer coated urea. Packets were weighed prior to placement in the field. The packets were then recovered from each treatment, washed with ice water, dried and weighed. Release of urea was calculated as $(1 - (\text{removal date weight} / \text{weight at application})) * 100$. All data were subjected to an analysis of variance and means separated using Fisher's Protected LSD ($p=0.05$). An increase in returns with PCU was calculated as: $[\text{increase in average grain yield for 2006 and 2007 over urea or anhydrous ammonia} * \$3.50/\text{bu corn}] - [\text{application} + \text{N cost}]$. Nitrogen cost was estimated for urea at \$0.585/lb N, PCU at \$0.635/lb N, and anhydrous ammonia at \$0.415/lb N. Custom application cost was similar for urea and PCU at \$4.80/acre while anhydrous ammonia was \$10/acre.

Results in 2006:

Grain yields were above average at Novelty in 2006. No-till corn yield with polymer coated urea at 150 lb/a was similar to anhydrous at 150 lb/a at all four application timings while yields with anhydrous were 24 to 59 bu/acre greater than urea at the fall, early preplant, and side-dress timings (Figure 1). Rainfall following application of the pre-emergence N treatment probably contributed to grain yields that were similar among the N sources at this timing in this research. Reduced rates of polymer coated urea appear justified at later application timings when compared with urea alone. Polymer coated urea rates that were reduced by 30% had yields similar to the 150 lb/a rate at the pre-emergence and side-dress timings in 2006, and were similar to anhydrous at 150 lb/acre.

Release of nitrogen from polymer coated urea granules was greatest for deep placement followed by the 1-2 inch depth placement in no-till wheat/clover residue (Figure 3). Moisture content may be greater in this cropping system. Surface applied polymer coated urea release was ranked no-till soybean stubble > no-till wheat/clover residue = conventional tillage.

November applied polymer coated urea released 20-30% of the fertilizer by mid-April, 2006 (Figure 5). Fertilizer release was similar for nearly all of the 1-2 and 4 inch deep placements for all of the recovery dates except November applied polymer coated urea. Surface applied polymer coated urea was slower for March applied fertilizer from mid-May to mid-July, April applied fertilizer from mid-June to mid-July, and May applied fertilizer at the mid-July recovery dates. Air exposed packets were included as control treatments to determine the effect of sunlight, rainfall, and other conditions on the integrity of the polymer coating. Sunlight was probably a major factor affecting the coating and may help in the degradation of the polymer coating. In the absence of direct soil contact, release of fertilizer from the polymer coating was generally less than surface applied treatments.

Soil nitrate-N concentration was greater for anhydrous ammonia applied preplant or side-dressed than PCU or urea alone at the July and October sampling dates (Figure 7). Total ammonium-N concentration was greater when anhydrous was side-dressed than when PCU or non-coated urea were side-dress applied. Soil test nitrate- and ammonium-N concentrations with PCU were greater than or equal to non-coated urea at all application timings and soil sample dates, indicating greater N loss with urea for some application timings. Nitrate-N concentration at harvest indicated similar recovery with PCU and urea.

Results in 2007:

Grain yields were average in 2007 (Figure 2). Yield with polymer coated urea at 150 lb/a was similar to anhydrous at 150 lb/a at the fall application timing while grain yield with PCU was greater than urea at the early preplant timing at all rates and the pre-emergence timing at 100 lbs/acre. Moist soil at the time of application probably contributed to grain yield differences between urea and PCU. Similarly, moist subsoil conditions may have resulted in ammonia loss with anhydrous. Up to a 30% reduction in PCU rates had yields similar to the 150 lb/a rate at all application timings and yields greater than or equal to urea and anhydrous ammonia at all application timings.

Urea release was greatest for surface applied PCU in conventionally tilled soil followed by 1-2 inch and 4 inch placements (Figure 4). Surface applied PCU release was ranked conventional tilled soil > no-till wheat stubble > no-till soybean stubble. Differences in release in 2006 and 2007 may be related to the variation in soil temperature and moisture at the different depths for different tillage systems since spring conditions were wetter in 2007 than 2006.

PCU applied in November released less than 30% of the urea by mid-April (Figure 6). Minimal differences in urea release were observed among placement depths. Total release was nearly 90% for all application timings and placements when corn reached black layer. Air exposed packets released approximately 60% of the urea for the early application timings and 50% for late application timings.

Summary and Conclusions:

Reduced rates of polymer coated urea in no-till may be justified at early preplant, pre-emergence, and side-dress application timings when compared to urea alone. Tillage system and fertilizer placement affects the release of polymer coated urea. This may be related to the soil moisture content and temperature differences in these poorly drained soils. Limited differences in total urea release were observed in 2006 and 2007. Slower urea release was observed in 2006 when urea was surface applied compared to 1-2 and 4 inch placements. Release rates increase as PCU application timing is delayed. Polymer coated urea fertilizer release reached 70-90% by black layer while in the absence of direct contact with moist soil, fertilizer release was 50-60%. Dry conditions may limit release of urea from the polymer coating and affect N availability to the crop.

In general, yields with polymer coated urea were greater than or equal to non-coated urea in 2006 and 2007. PCU increased returns over urea alone for early preplant, pre-emergence, and side-dress application timings for all application rates except the preplant timing at 150 lbs/a when averaged over medium (2007) and high (2006) yielding years (Figure 8). PCU increased returns over anhydrous ammonia when applied at preplant and side-dress timings for no-till corn. Additional research evaluating deep placement of PCU in the fall or early preplant is needed to identify cost-effective uses of PCU when compared to anhydrous ammonia.

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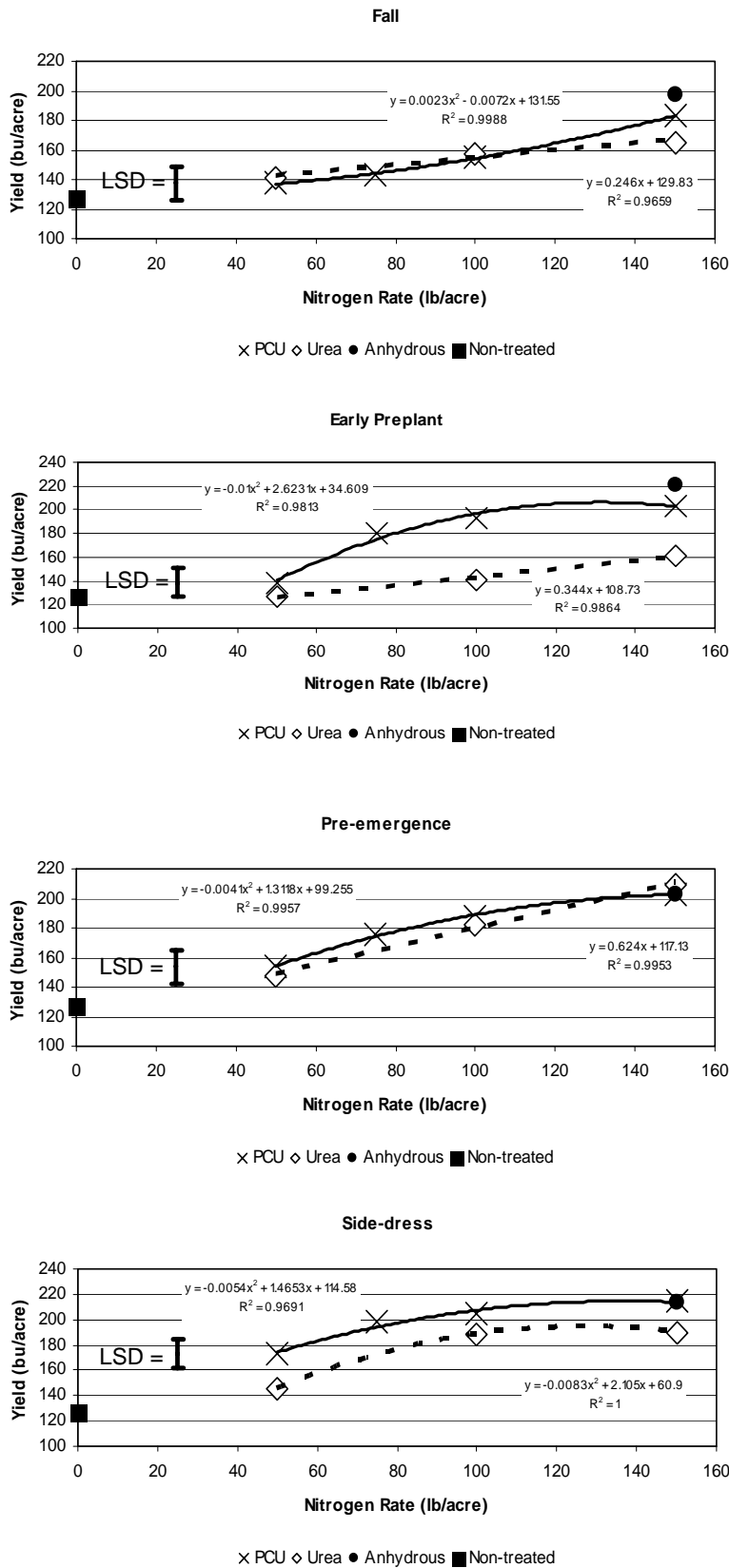


Figure 1. Yield response of no-till corn to reduced rates of polymer coated urea compared with non-coated urea at fall, early preplant, pre-emergence, and side-dress application timings in 2006.

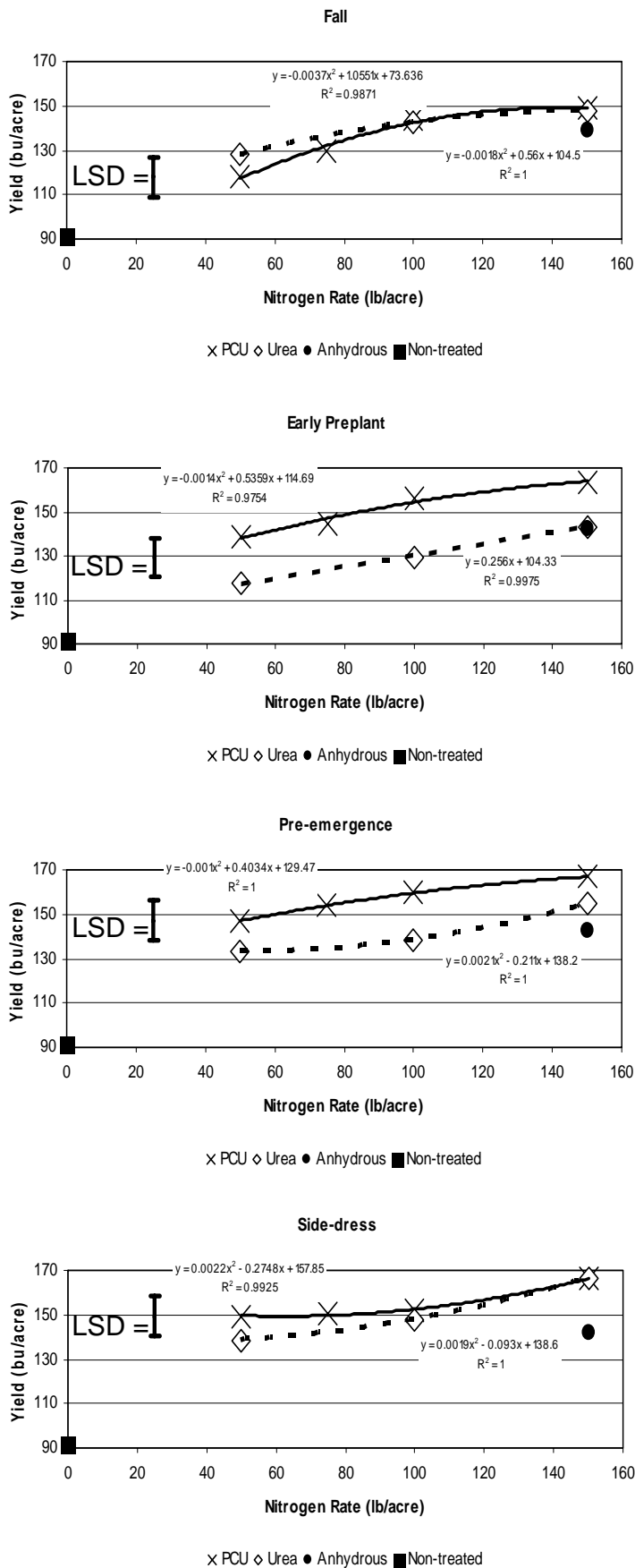


Figure 2. Yield response of no-till corn to reduced rates of polymer coated urea compared with non-coated urea at fall, early preplant, pre-emergence, and side-dress application timings in 2007.

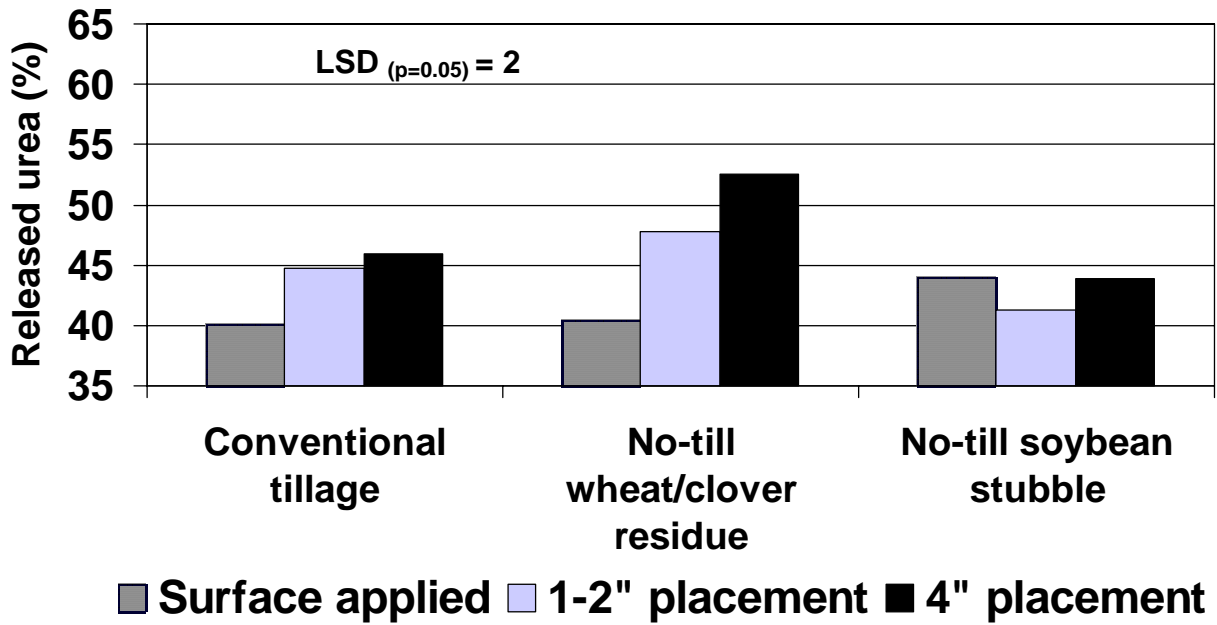


Figure 3. Effect of tillage and placement on release of fertilizer from polymer coated urea. Data were averaged over application and removal timings in 2006.

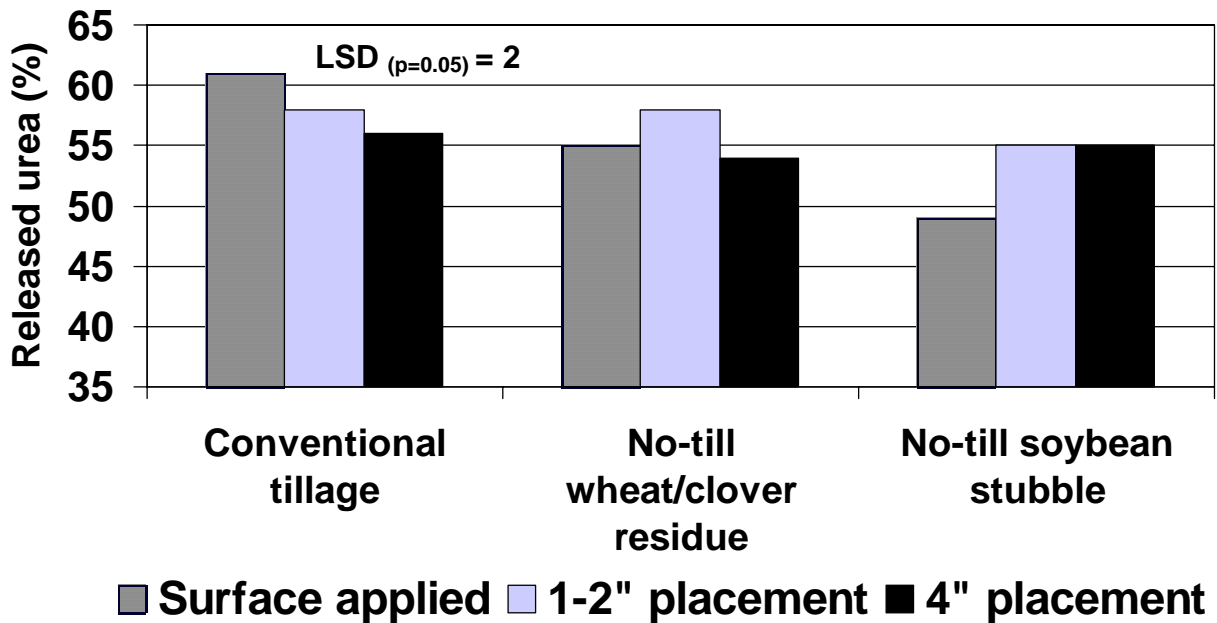


Figure 4. Effect of tillage and fertilizer placement on release of fertilizer from polymer coated urea. Data were averaged over application and removal timings in 2007.

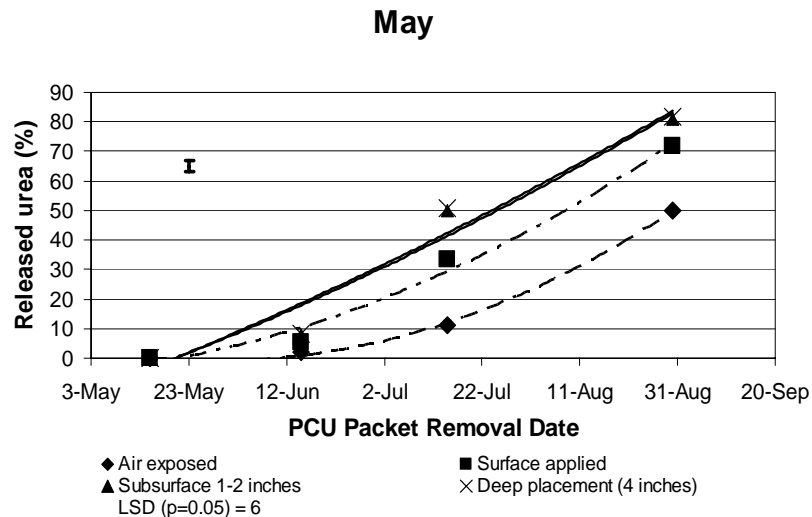
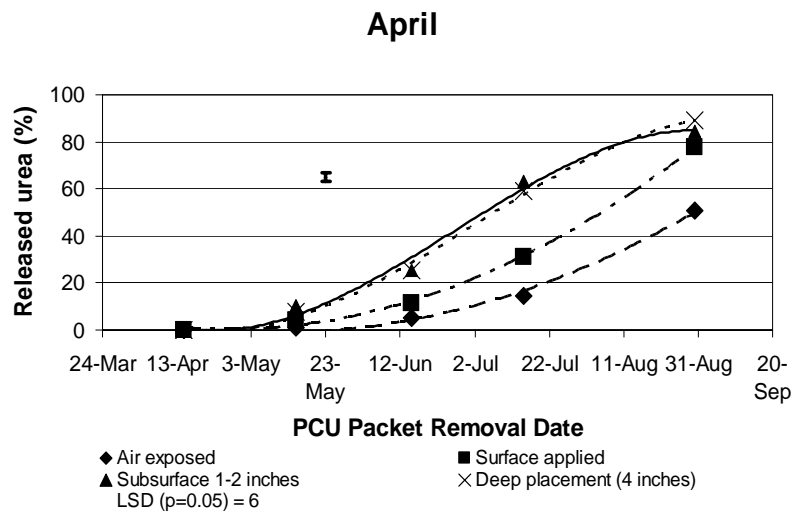
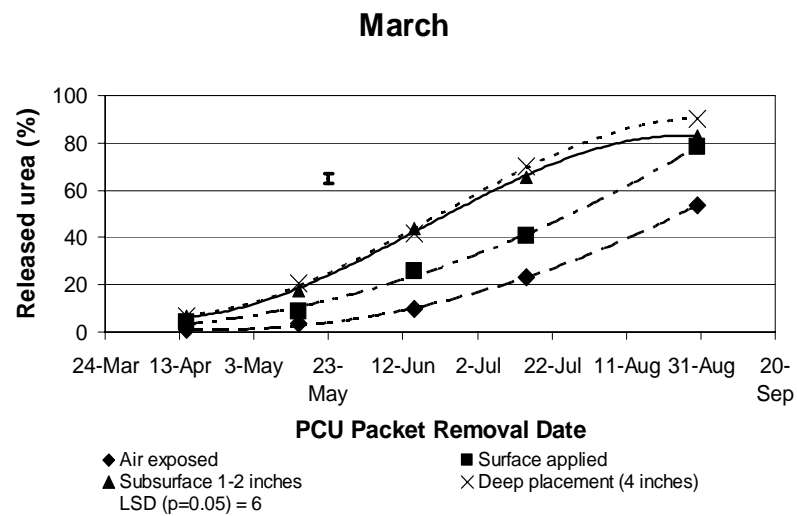
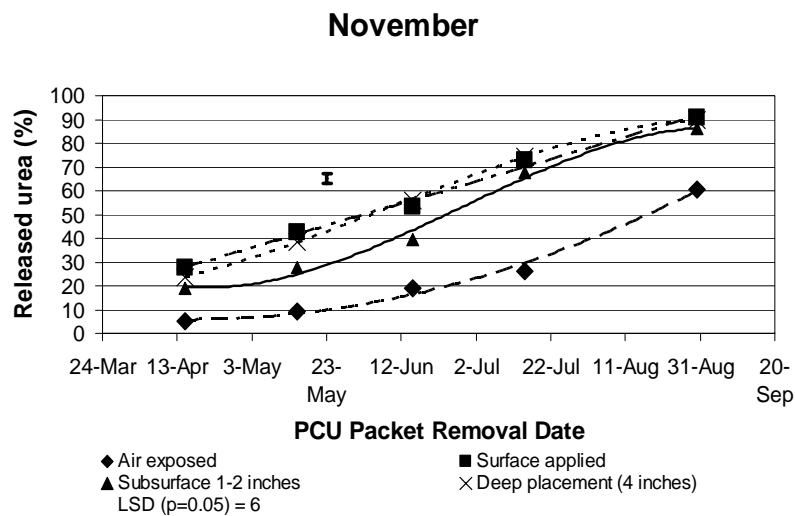


Figure 5. Polymer coated urea released from November 15, March 15, April 15, and May 15 application timings for 2006. PCU packets were removed on April 15, May 15, June 15, July 15, and August 31. Released urea values were calculated as $(1 - (\text{removal date weight} / \text{weight at application})) * 100$. Vertical bars represent LSD values ($p=0.05$).

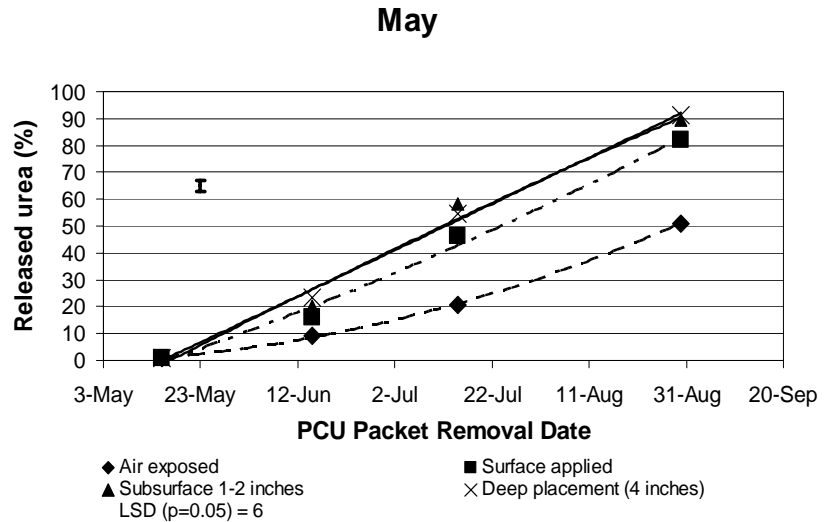
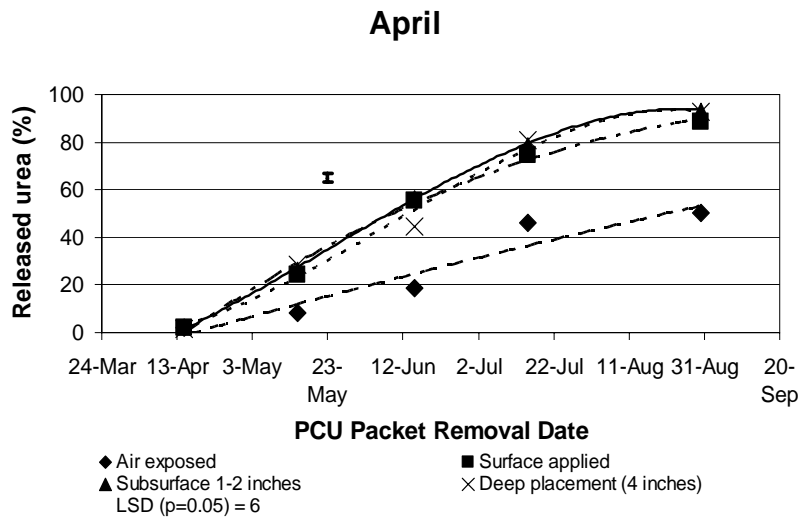
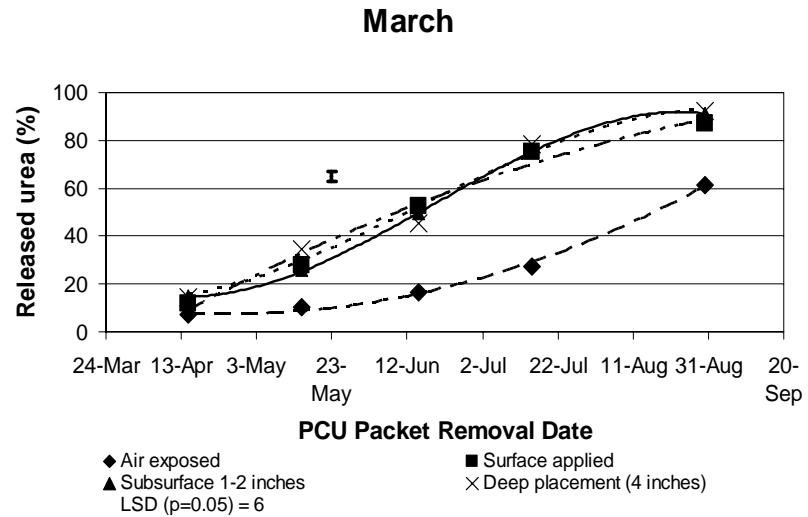
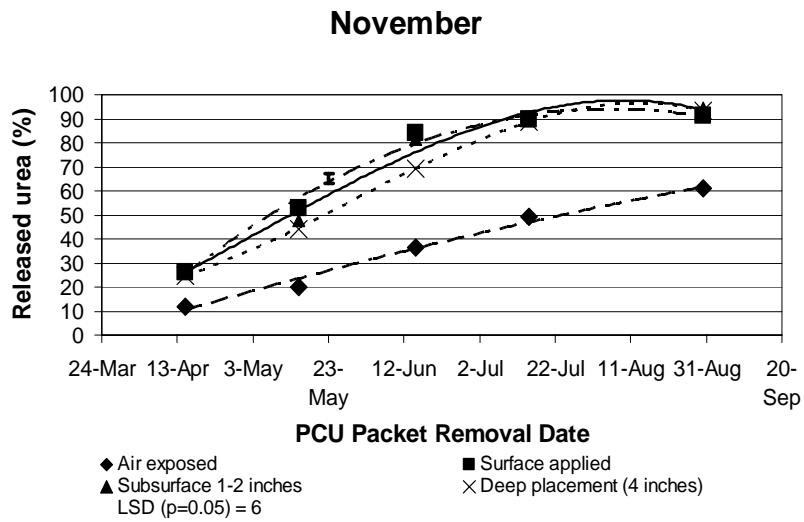


Figure 6. Polymer coated urea released from November 15, March 15, April 15, and May 15 application timings for 2007. PCU packets were removed on April 15, May 15, June 15, July 15, and August 31. Released urea values were calculated as $(1 - (\text{removal date weight} / \text{weight at application})) \times 100$. Vertical bars represent LSD values ($p=0.05$).

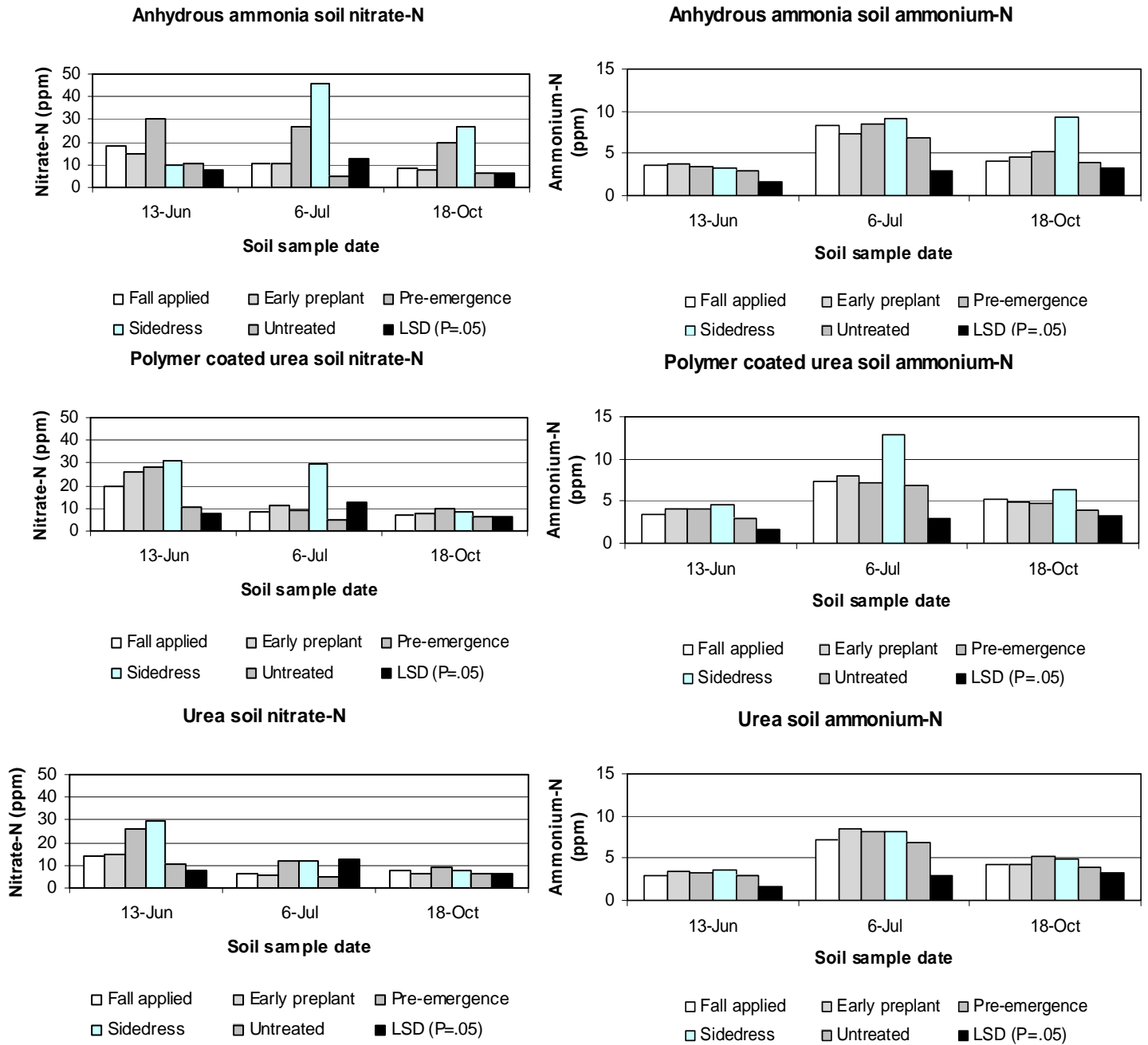


Figure 7. Anhydrous ammonia, polymer coated urea, and non-coated urea average soil nitrate- and ammonium-N concentration for soil samples 18 inches deep at Novelty in 2006. Comparisons between N sources within a soil sample date are valid

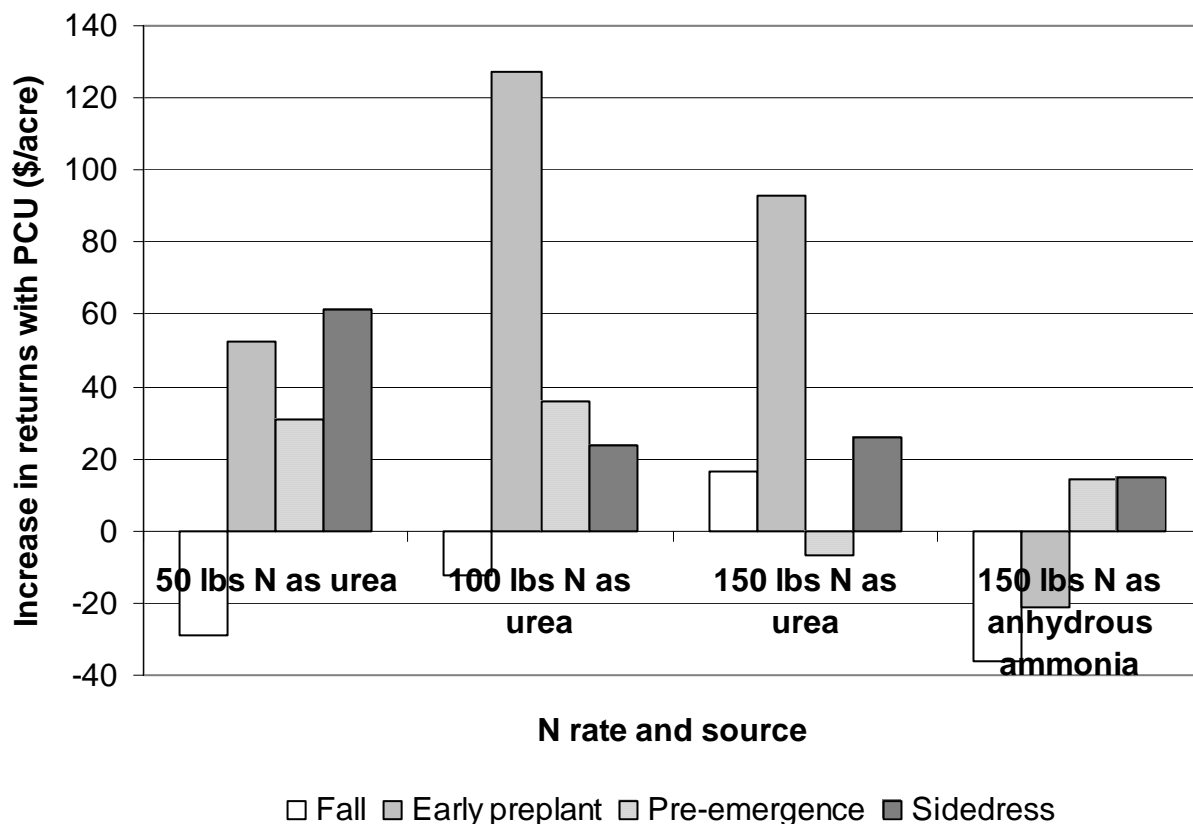


Figure 8. Increase in returns with PCU (ESN) at the same application rate as urea at 50, 100, and 150 lbs N/acre and anhydrous ammonia at 150 lbs N/acre for fall, early preplant, pre-emergence, and side-dress application timings in 2006 and 2007. Calculated as: [increase in average grain yield for 2006 and 2007 over urea or anhydrous ammonia * \$3.50/bu corn] – [application + N cost]. Nitrogen cost was estimated for urea at \$0.585/lb N, PCU at \$0.635/lb N, and anhydrous ammonia at \$0.415/lb N. Custom application cost was similar for urea and PCU at \$4.80/acre while anhydrous ammonia was \$10/acre.

Impact of N Fertilizer Source and Drainage on Spatial Variation in Nitrogen Use Efficiency and Environmental N Loss

Peter Motavalli, Kelly Nelson, and Steve Anderson

Research was conducted in 2006 and 2007 to compare the relative corn growth response and environmental N losses after application of different N fertilizer sources under a range of soil moisture conditions imposed by drainage and irrigation, to examine spatial differences in soil N transformations and N losses during the growing season between drainage tile and subirrigation lines, and to evaluate the relative cost-effectiveness of use of several N fertilizer sources and drainage and irrigation systems to control soil moisture conditions that may reduce N use efficiency.

Among the findings of the study were:

- The use of overhead irrigation, subirrigation, and tile drainage systems and N fertilizer applications consistently increased corn grain yields and gross returns compared to non-irrigated and non-drained plots over the two years of this study. The gross economic returns ranged from an average increase of \$35/acre in the tile drained plots with an application of anhydrous ammonia to an increase of \$354/acre in the overhead irrigated plots with an application of polymer-coated urea (PCU). In general, application of UAN solution did not appear to be as effective as other N sources, especially under conditions when the soil was not drained or irrigated.
- The effects of the tile drainage system on the soil profile distribution of soil water content over and above the tile lines compared to the non-drained plots were not consistent during the growing season. In contrast, the subirrigation lines did increase soil water content in the 0 to 6 and 6 to 12 inch depth, but this increase occurred primarily directly above the irrigation line. The subirrigation system with 20 foot spacing between the irrigation lines was not effective in wetting the entire soil profile between the lines resulting in higher grain yields above the lines but not between the lines. Modification of the subirrigation system would need to be made to make it more effective given the relatively low rate of soil water movement in claypan soils.
- Preliminary results for N uptake in the 2006 season indicate that N recovery efficiency varied widely among the treatments (0 to 47 % recovery of applied N) and did not explain the observed differences in grain yields among the treatments. Nitrogen analysis of soil and tissue samples has not been completed for the 2007 growing season, and these results are needed for determination of N distribution in the soil profile and N recovery efficiency due to the treatments in this study.

Materials and Methods

A field trial was conducted in 2006 and 2007 at the University of Missouri Drainage and Subirrigation (MUDS) trial. The MUDS trial was initiated in 2001 at the MU Ross Jones Farm in Northeast Missouri to evaluate the use of subsurface tile drainage at different drain tile spacings with or without subsurface irrigation to improve soybean and corn production. For this study, 150 ft long plots planted to corn (Roundup Ready and Bt resistant variety DKC61-68) containing treatments of: i) no drainage or subirrigation (NIN), ii) drainage with tile drains spaced 20 ft apart and no subirrigation (NID), iii) drainage with tile drains spaced 20 ft apart and subirrigation (SUB), and iv) no drainage and overhead sprinkler irrigation (OND) was split into a control and N fertilizer treatments of either spring-applied pre-

plant injected anhydrous ammonia, or broadcast-applied urea-ammonium nitrate (UAN) solution, urea, or polymer-coated urea (PCU) (ESN[®], Agrium) applied at a rate of 150 lbs N/acre. Each treatment combination had 3 replications. All plots were chisel plowed in the fall and N treatments incorporated in the spring with a field cultivator. Based on preliminary soil test results, no additional P and K fertilizer or lime were applied prior to planting.

Changes in soil inorganic N (NH₄⁺-N and NO₃⁻-N) content and soil gravimetric water content due to the irrigation/ drainage treatments were monitored by periodic soil sampling using a Gator-mounted Giddings hydraulic soil core sampler at depths of 0-6, 6-12, 12-18, and 18-24 inches. In the NID and SUB treatments, samples were collected by compositing 3 subsamples taken at a distance of 0, 5, and 10 ft from the drainage or subirrigation lines. For the anhydrous ammonia treatment, the subsamples were taken in the injection band and two distances towards the next band. All samples were collected in coolers and stored in a cold room before processing.

Silage yields were determined by harvesting 15 to 25 ft of corn plants at physiological maturity in one row either above the tile line or 10 ft from the tile line. All harvested plants were weighed and a subsample taken to determine moisture content and analyze for tissue N. Both the silage yield and N content will be used to calculate crop N uptake. Grain yields and grain moisture were determined on approximately 25 ft of row with a two row plot combine. The relative gross returns of the different N fertilizer and irrigation/drainage treatments were determined by calculating the difference between grain yields in the plots with the different irrigation/drainage treatments and the plots with no irrigation or drainage treatments and then taking the yield difference and multiplying it by an estimated price of corn (\$3.50/bu).

Results:

- Based on preliminary analysis of measurements of soil water content during the 2006 growing season, no consistent differences in soil water content were observed due to use of drainage tile either immediately above or between the tile lines compared to non-drained plots (Table 1). However, some increase in soil water content was observed above the subirrigation lines primarily in the 0 to 6 and 6 to 12 inch depths. In general, the highest water content in the claypan soil profile was observed in the 12 to 18 and 18 to 24 inch depths. Analysis of the inorganic N in the soil has not been completed but these data will be used to determine the effects of the N treatments, the irrigation/drainage system and the distance away from the tile line on soil N distribution in the soil profile.
- Grain yields were consistently higher in 2006 and 2007 with use of overhead sprinkler irrigation, subirrigation and tile drainage alone compared to a non-irrigated and non-drained control (Table 2). The highest yield response to subirrigation was directly above the subirrigation lines (spaced 20 feet apart) which by visual observation was probably due to the slow diffusion of water from the lines into the surrounding soil. Use of drainage tile spaced 20 feet apart generally increased grain yields both directly above and between the drainage tile.
- Some differences in grain yield response were observed among the different N fertilizer sources in interaction with the drainage/irrigation treatments (Table 2). In the plots with no irrigation and no installed drainage systems, all the N fertilizer treatments increased grain yields above the control in 2006 and 2007. However, in 2007, PCU had significantly higher yields compared to urea in those plots. In 2007 under overhead irrigation, PCU and anhydrous ammonia applications had higher yields compared to UAN solution. Directly above the subirrigation lines, PCU and urea

outyielded UAN solution in both 2006 and 2007.

- Preliminary analysis of plant aboveground N uptake does show the expected increase in plant N uptake with N fertilizer addition, but it does not completely explain the observed differences in yields under the different N fertilizer treatments and irrigation/drainage systems (Table 3). Estimates of the N recovery efficiency of the applied N fertilizer vary widely among the treatments from between 0 to 47% plant N recovery of the applied fertilizer N (data not shown). Further analysis of these data will be undertaken when N analysis of the 2007 silage tissue is completed.
- Economic analysis of the use of the different irrigation/drainage systems and N fertilizers indicates that the combination of overhead irrigation and N fertilization resulted in the highest average gross economic returns (Table 4). Gross returns were ranked OND > SUB > NID over the non-drained, non-irrigated control. With overhead irrigation, the PCU application averaged \$18/acre greater return than the urea treatment. Based on a price differential of 6¢/lb N between urea and PCU, the net return would be approximately \$9/acre using PCU over urea under overhead irrigation. In contrast, under tile drainage and subirrigation systems, no additional gross return was observed using PCU compared to urea. This may be due to reduced N loss due to denitrification in the presence of subsurface drainage. In general, the results indicate that use of irrigation and drainage systems in combination with N fertilization can increase gross returns in claypan soils. However, due to the varying costs of installation and maintenance of these systems, further calculations would have to be made to determine if they would be economically profitable for a specific location.

Outreach and Training:

Two M.S. graduate student in soil science and undergraduate students majoring in environmental science were involved in working on this project as part of their training. The research results were presented to growers and agricultural professionals at the 2007 Greenley Center Field Day in Northeast Missouri.

Publications:

Motavalli, P., K. Nelson, S. Anderson, and J. Sadler. 2007. Use of slow-release N fertilizer to control nitrogen losses due to spatial and climatic differences in soil moisture conditions and drainage. Greenley Field Day Report, Aug. 2, 2007, Novelty, MO. Available on the web at <http://aes.missouri.edu/greenley/fieldday/2004/page52.stm>.

Table 1. Soil water content on June 28th, 2006 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines.

| N treatment | NIN [†] | NID [‡] | | | | SUB [¶] | | | |
|-----------------------------|------------------|------------------|-------|-------|--------------------------|------------------|-------|-------|-----------------------|
| | | 0* | 5 | 10 | LSD _(0.05) ** | 0 | 5 | 10 | LSD _(0.05) |
| ----- % by dry weight ----- | | | | | | | | | |
| ----- | | | | | | | | | |
| 0 – 6 inch depth | | | | | | | | | |
| Control | 14.05 | 17.82 | 14.90 | 16.46 | 1.73 | 17.61 | 16.08 | 15.37 | NS |
| Anhydrous | 11.48 | 17.33 | 14.75 | 16.33 | 1.20 | 16.08 | 14.96 | 14.64 | NS |
| Urea | 12.93 | 18.39 | 14.18 | 14.00 | 4.18 | 17.84 | 13.29 | 15.67 | 3.20 |
| PCU | 13.69 | 15.94 | 13.95 | 15.74 | NS | 15.87 | 13.74 | 13.57 | NS |
| LSD _(0.05) | 2.34 | NS | NS | NS | | NS | 2.57 | NS | |
| 6 – 12 inch depth | | | | | | | | | |
| Control | 16.36 | 18.21 | 17.22 | 21.02 | NS | 24.08 | 16.15 | 17.72 | NS |
| Anhydrous | 12.83 | 16.01 | 15.09 | 16.70 | NS | 16.75 | 17.01 | 17.28 | NS |
| Urea | 14.97 | 24.46 | 16.00 | 15.10 | NS | 25.59 | 17.27 | 18.13 | NS |
| PCU | 15.29 | 23.81 | 15.47 | 20.77 | NS | 20.61 | 16.74 | 23.47 | NS |
| LSD _(0.05) | NS | NS | NS | NS | | NS | NS | NS | |
| 12 – 18 inch depth | | | | | | | | | |
| Control | 32.02 | 29.72 | 28.12 | 28.18 | NS | 33.35 | 34.47 | 35.24 | NS |
| Anhydrous | 31.71 | 27.57 | 27.15 | 27.15 | NS | 28.77 | 31.15 | 32.57 | NS |
| Urea | 32.72 | 26.77 | 26.95 | 26.82 | NS | 34.13 | 32.71 | 36.32 | NS |
| PCU | 33.90 | 26.46 | 24.64 | 27.04 | NS | 34.62 | 31.91 | 33.24 | NS |
| LSD _(0.05) | 1.41 | NS | 3.33 | NS | | NS | NS | 2.88 | |
| 18 – 24 inch depth | | | | | | | | | |
| Control | 29.14 | 25.41 | 24.74 | 27.34 | NS | 31.53 | 29.10 | 29.26 | NS |
| Anhydrous | 27.08 | 24.59 | 25.15 | 24.33 | NS | 31.84 | 26.86 | 28.58 | NS |
| Urea | 31.07 | 23.96 | 26.68 | 25.69 | NS | 29.75 | 37.48 | 26.69 | NS |
| PCU | 32.40 | 24.03 | 23.25 | 24.08 | NS | 30.53 | 27.66 | 28.60 | NS |
| LSD _(0.05) | 2.76 | NS | 2.49 | NS | | NS | NS | NS | |

* Distance in feet from the tile or subirrigation lines.

** LSD_(0.05) = Least Significant Difference at p < 0.05; NS = Not statistically significant

† NIN = No irrigation, no drainage

‡ NID = No irrigation, drainage

¶ SUB = Subirrigation, drainage

Table 2. Grain yields in 2006 and 2007 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines. “Over” refers to harvest rows over the tile line and “Between” refers to harvest rows between the tile lines

| N treatment | NIN [†] | OND [§] | NID [‡] | | | SUB [¶] | | |
|-----------------------|------------------|------------------|------------------|---------|------------------------------------|------------------|---------|-----------------------|
| | | | Over | Between | LSD _(0.05) [*] | Over | Between | LSD _(0.05) |
| ----- bu/acre ----- | | | | | | | | |
| 2006 | | | | | | | | |
| Control | 81.3 | 113.8 | 96.1 | 97.5 | NS | 104.9 | 99.9 | NS |
| Anhydrous | 135.3 | 240.0 | 135.3 | 137.5 | NS | 202.8 | 157.9 | NS |
| Urea | 130.7 | 237.9 | 145.1 | 141.9 | NS | 239.0 | 160.8 | 12.6 |
| PCU | 126.9 | 240.5 | 149.1 | 138.3 | NS | 253.5 | 152.6 | 16.6 |
| UAN | 121.8 | 231.5 | 141.3 | 145.9 | NS | 208.8 | 148.6 | 30.0 |
| LSD _(0.05) | 27.0 | 17.6 | 28.2 | 18.8 | | 22.9 | 10.0 | |
| 2007 | | | | | | | | |
| Control | 78.3 | 111.0 | 101.9 | 120.2 | NS | 106.7 | 118.6 | 8.1 |
| Anhydrous | 124.0 | 215.6 | 139.2 | 146.5 | NS | 188.9 | 143.6 | NS |
| Urea | 113.6 | 198.4 | 139.0 | 154.2 | 8.4 | 194.9 | 148.9 | 33.8 |
| PCU | 130.1 | 218.3 | 139.5 | 133.5 | NS | 199.2 | 148.4 | NS |
| UAN | 106.2 | 169.6 | 131.9 | 147.3 | NS | 168.9 | 137.9 | NS |
| LSD _(0.05) | 15.8 | 33.0 | 24.3 | NS | | 22.3 | NS | |

* LSD_(0.05) = Least Significant Difference at p < 0.05; NS = Not statistically significant

† NIN = No irrigation, no drainage

§ OND = Overhead irrigation, no drainage

‡ NID = No irrigation, drainage

¶ SUB = Subirrigation, drainage

Table 3. Nitrogen uptake in 2006 at the Ross Jones Farm due to differences in N fertilizer sources, drainage and irrigation systems and the distance between tile lines. “Over” refers to harvest rows over the tile line and “Between” refers to harvest rows between the tile lines.

| N treatment | NIN [†] | OND [§] | NID [‡] | | | SUB [¶] | | |
|-----------------------|------------------|------------------|------------------|---------|------------------------------------|------------------|---------|-----------------------|
| | | | Over | Between | LSD _(0.05) [*] | Over | Between | LSD _(0.05) |
| ----- lb N/acre ----- | | | | | | | | |
| Control | 39.2 | 52.4 | 60.1 | 63.2 | NS | 52.8 | 50.9 | NS |
| Anhydrous | 79.2 | 114.8 | 60.8 | 71.5 | 6.9 | 81.0 | 113.3 | NS |
| Urea | 95.2 | 92.2 | 93.5 | 62.1 | 29.1 | 118.0 | 87.1 | NS |
| PCU | 81.9 | 121.5 | 93.1 | 86.4 | NS | 123.2 | 101.8 | NS |
| UAN | 90.9 | 92.5 | 74.6 | 74.3 | NS | 82.2 | 76.3 | NS |
| LSD _(0.05) | 40.2 | 66.4 | NS | NS | | 35.3 | 30.4 | |

* LSD_(0.05) = Least Significant Difference at p < 0.05; NS = Not statistically significant

† NIN = No irrigation, no drainage

§ OND = Overhead irrigation, no drainage

‡ NID = No irrigation, drainage

¶ SUB = Subirrigation, drainage

Table 4. Increase in gross returns over the non-drained, non-irrigated control[†] with use of different N fertilizer sources and drainage and irrigation systems at the Ross Jones Farm in 2006 and 2007.

| N treatment | OND [§] | | | NID [‡] | | | SUB [¶] | | |
|-------------|---------------------|------|---------|------------------|------|---------|------------------|------|---------|
| | 2006 | 2007 | Average | 2006 | 2007 | Average | 2006 | 2007 | Average |
| | ----- \$/acre ----- | | | | | | | | |
| Control | 114 | 114 | 114 | 54 | 114 | 84 | 74 | 120 | 97 |
| Anhydrous | 366 | 321 | 344 | 4 | 66 | 35 | 158 | 148 | 153 |
| Urea | 375 | 297 | 336 | 45 | 116 | 80 | 242 | 204 | 223 |
| PCU | 398 | 309 | 354 | 59 | 22 | 40 | 266 | 153 | 210 |
| UAN | 384 | 222 | 303 | 76 | 117 | 96 | 199 | 165 | 182 |

[†] Gross returns for difference in yield between unirrigated and undrained plots (NIN) and irrigation/drainage treatments were based on a corn price of \$3.50/bu. Approximate costs for fertilizers would be urea = \$0.58/lb N, anhydrous ammonia = \$0.42/lb N, PCU = \$0.64/lb N and UAN = \$0.42/lb N. Costs for irrigation and drainage systems will vary by location.

[§] OND = Overhead irrigation, no drainage

[‡] NID = No irrigation, drainage

[¶] SUB = Subirrigation, drainage

Progress Reports

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

Peter Motavalli, Kelly Nelson and Steve Anderson

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Accomplishments for First Year:

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

A field trial was established in 2007 at the University of Missouri Greenley Experiment Station in Northeastern Missouri. This field was previously mapped for elevation with a total station surveying instrument and apparent electrical conductivity (EC_a) using an EM-38 sensor. Measurement of soil EC_a gives an indication of relative depth to the claypan subsoil layer (Kitchen et al., 1999). The field was selected because it contained contrasting landscape positions, including low-lying areas, and differences in depth to the claypan layer.

The field was separated into 10 x 750 foot plots which passed through the low-lying and sideslope areas in the field. Nitrogen fertilizer treatments of a control and 150 lb N/acre of urea, polymer-coated urea (ESN, Agrium, Inc.), urea + NBPT (N-(n-butyl) thiophosphoric triamide) urease inhibitor at 1 gal/ton (Agrotain, Agrotain International), and urea + nitrapyrin nitrification inhibitor at 1 qt/acre (N-Serve, Dow AgroSciences) were applied in the spring prior to planting of corn. All the N fertilizer treatments were incorporated using a cultivator immediately after application. The experimental design was a randomized complete block with 4 replications.

In each plot, sampling points were set up every 30 feet across the field to allow for periodic collection of soil samples from the 0 to 6 and 6 to 12 inch depths during the growing season for determination of soil water content and soil inorganic N (ammonium and nitrate-N). Three subsamples were taken at each point and composited. All the sampling points were georeferenced using a differential GPS. Figure 1 shows the distribution of soil water content on June 4th indicating the variation in soil water content that occurred across this field. Two additional soil samplings were taken during the growing season.

Chlorophyll readings were taken using a SPAD 502 Chlorophyll meter (Minolta Corp.) on 10 ear leaf subsamples per 28 foot row between the sampling points on July 30th. Ear leaf samples were also collected on the same day for determination of tissue N concentration. Corn grain was harvested from the 28 foot row length between the sampling points on Sept. 19th using a two-row plot combine. Table 1 shows the average grain yields and chlorophyll meter readings across each plot. Based on this analysis, all the N fertilizer applications significantly increased grain yields over the control but only polymer-coated urea (PCU) had higher grain yields compared to urea. The chlorophyll meter readings, which are a relative measure of the N status of the plant, were significantly higher when N fertilizer was applied. The

PCU treatment was the only enhanced N fertilizer treatment which had a significantly higher average chlorophyll reading compared to the urea treatment.

A problem with this analysis is it does not show the variation in grain yields that occurred across the field. Figure 2 shows the large variation in grain yield that was observed at the different elevations in the field in response to the N fertilizer treatments. The highest yields tended to occur in the lowest landscape positions of the field. An initial approach we are using to determine the areas in the field which would have the greatest grain yield response to the enhanced efficiency fertilizers is to map the differences in yields between urea and the enhanced efficiency fertilizer. Figure 3 shows the results of mapping the difference in yield between the PCU-treated plots and the urea-treated plots. Yield differences which are positive indicate that the PCU-treated area outperformed the urea-treated plots. When this yield difference is zero or negative then urea was equivalent to or outyielded PCU. Based on these yield differences and the relative price difference between urea and PCU, we also mapped the net economic return from using PCU versus urea (Figure 3). The result shows a low-lying region in the field which had greater yield response to the PCU fertilizer and which provided greater net economic return. The areas determined by yield and economic difference will be compared to the areas that will be delineated using software that predicts where soil water content will be higher in the field based on differences in the field's topography. This comparison will allow for a validation of the ability of the software to predict where the enhanced efficiency fertilizer can optimally be applied in the field using a multi-bin spreader.

Outreach and Training:

A M.S. graduate student in soil science and undergraduate students majoring in environmental science have been involved in working on this project as part of their training. The first year research results were presented to growers and agricultural professionals by the M.S. student at the 2007 Greenley Center Field Day in Northeast Missouri.

Objectives for Year 2:

The objectives for the second year of this research will be similar to the first year. These objectives are:

1. To collect information related to spatial and temporal differences in soil water content and soil N availability across a field containing low-lying or depressional areas.
2. To determine the spatial variability in crop response and N use efficiency due to application of different N fertilizer sources including conventional urea and polymer-coated urea.
3. To develop and validate a computer program that would delineate the high risk N loss areas in a form that could be imported into the controllers of multiple bin spreaders to allow for variable source N fertilizer application.

The field studies will be repeated for a second year to assess variation in climate on crop response to the enhanced efficiency N fertilizers. In addition, we will develop the software or procedures to delineate the region in fields with claypan soils which have the greatest potential to respond to the enhanced efficiency fertilizers. An economic analysis will be included since the difference in relative price for the enhanced efficiency N fertilizer and urea may also affect the area in which that enhanced efficiency fertilizer may be applied in order to optimize economic return and reduce environmental N losses.

Table 1. Average grain yields and chlorophyll readings across the field in 2007 due to applications of different enhanced efficiency N fertilizers.

| N treatment | Grain yield | Chlorophyll reading |
|------------------------------------|---------------|---------------------|
| | -- bu/acre -- | - Spad units - |
| Control | 70.0 | 33 |
| Urea | 130.1 | 51 |
| PCU | 150.5 | 55 |
| Urea + UI [†] | 133.4 | 53 |
| Urea + NI [§] | 136.8 | 52 |
| LSD _(0.05) [*] | 15.0 | 3 |

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

[†] Urea + urease inhibitor

[§] Urea + nitrification inhibitor

Greenley Project Area

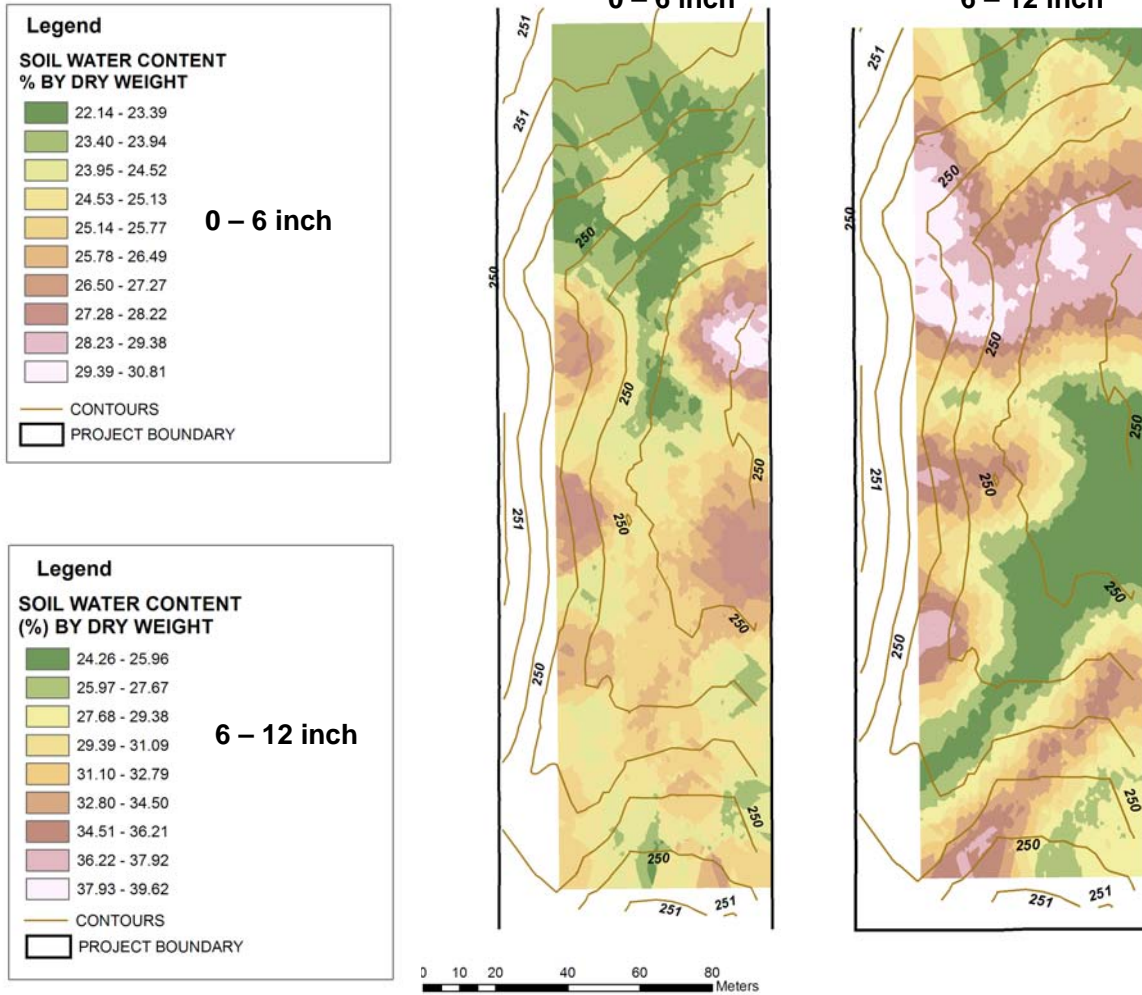


Figure 1. Map of soil water content distribution in the 0 to 6 and 6 to 12 inch depths in the experimental field on June 4, 2007. Lines represent the contour intervals with elevations above sea level given in meters.

Greenley Project Area

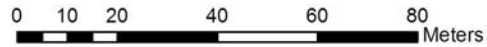
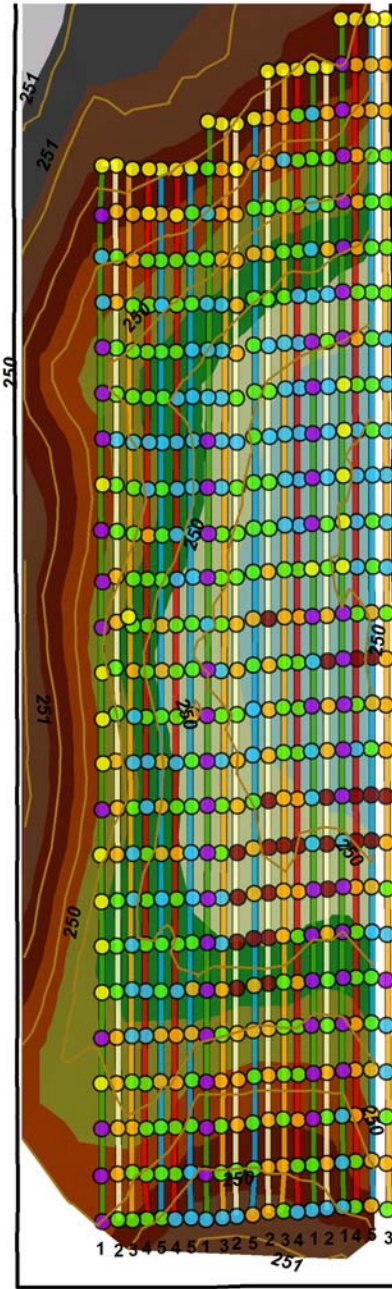
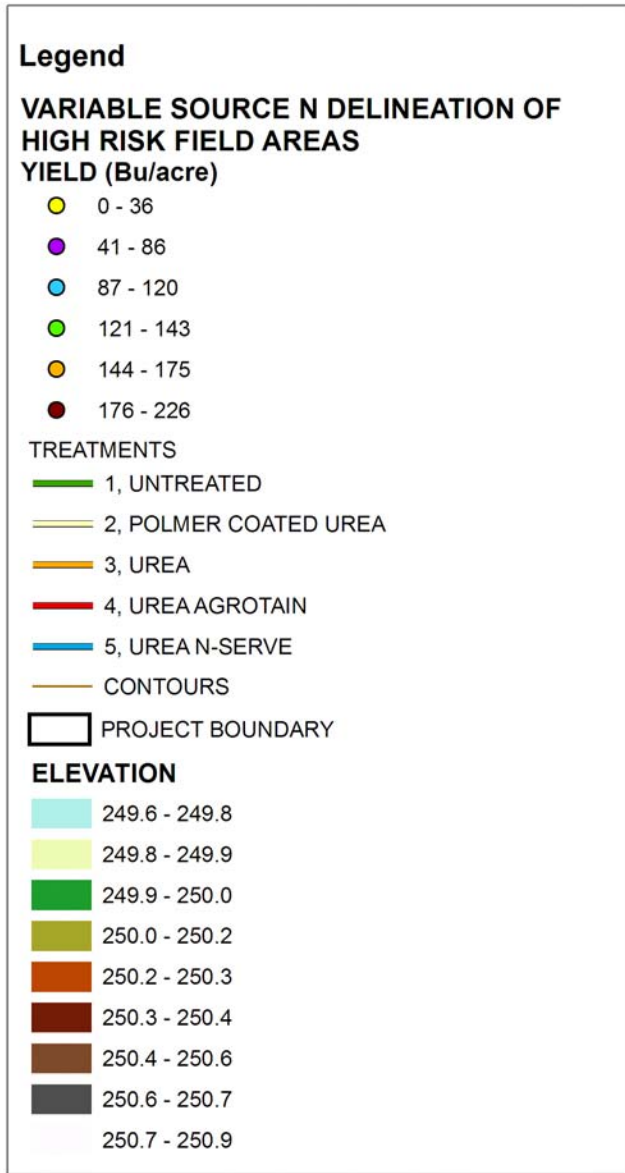


Figure 2. Map of variation in corn grain yields across the experimental field due to differences in N fertilizer treatment and landscape position. Contour lines and color shading show differences in elevation relative to the yields.

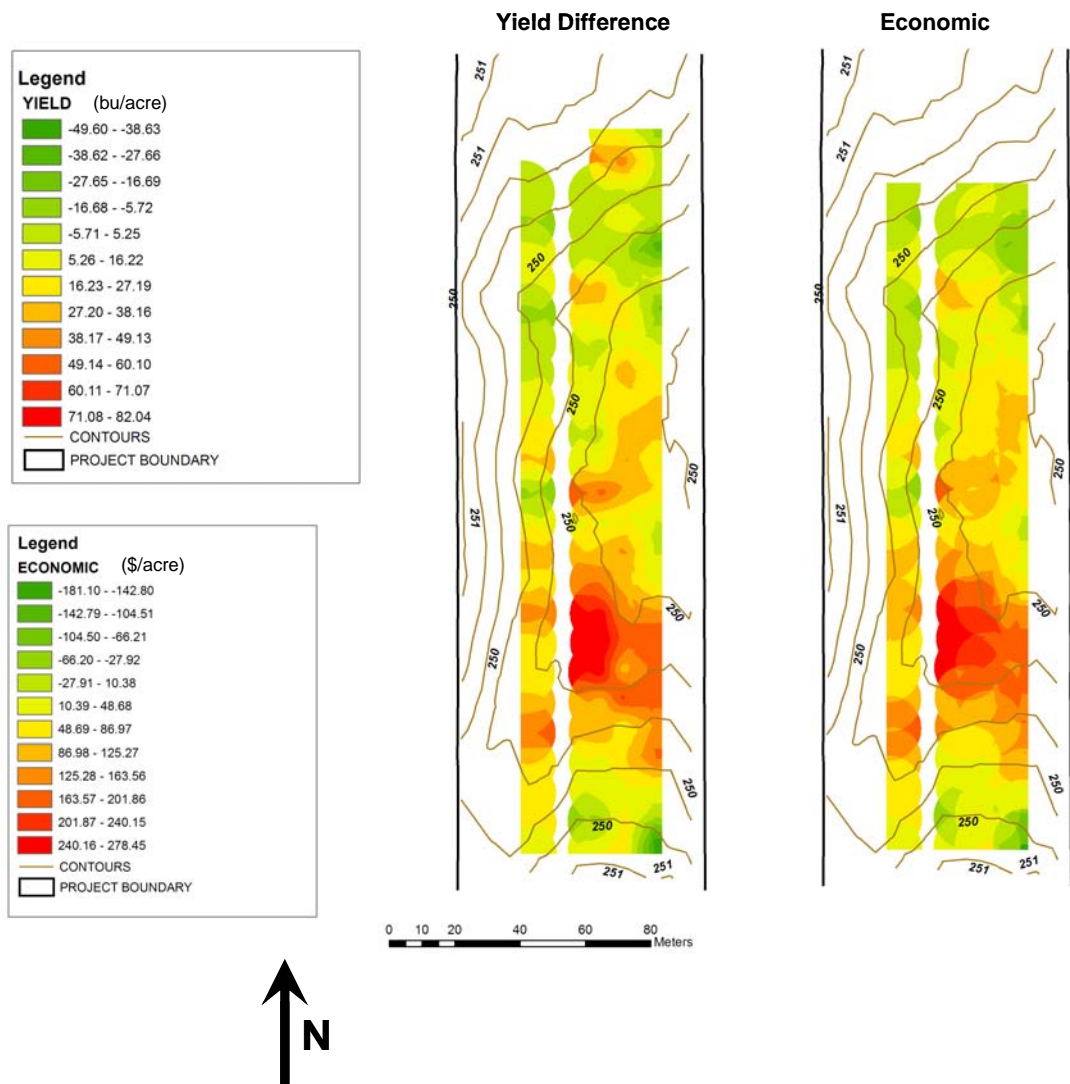


Figure 3. Map of grain yield differences between the PCU- and urea-treated plots across the field. Second map shows the variation in net economic return for applying PCU versus urea. These maps will be used for validating the method for delineating the area for application of the enhanced efficiency N fertilizer. Numbers along contour lines are elevation in meters above seas level.

Alternative Nitrogen Fertilizers for Tall Fescue Pastures

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

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

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

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

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

Procedures:

Experiment 1 (Spring applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-March at the Southwest Research and Education Center near Mount Vernon, MO and at the Bradford Research and Extension Center near Columbia, MO. Products were tested in 2005, 2006, and 2007 at Mt. Vernon and in 2006 and 2007 at Columbia. The sources of N are listed in Table 1 and include several urea based products already on the

market, mixtures of some of these products, as well as untreated urea, ammonium sulfate, and ammonium nitrate as checks. The 75 lb/acre N rate was selected because it is a common fertilization rate for producers. Soil P and K levels were maintained at levels recommended by the University of Missouri Soil Testing Laboratory.

Experiment 2 (Late-summer applied N treatments).

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

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

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

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

Results:

Experiment 1

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

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

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

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

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

Forage Quality. Only samples collected in Mt. Vernon from 2005 have been analyzed for nutrient content. Averaged over the three harvests, *in vitro* true digestibility of tall fescue was equal for nearly all treatments and averaged 69.8%. For crude protein, plots fertilized with ESN, ammonium sulfate, and mixtures of ESN and ammonium sulfate had about 1.0 percentage unit more crude protein at the first harvest (data not shown) than plots fertilized with other N sources. Averaged over the three harvests and all treatments, crude protein was 9.5%.

Soil pH(s). It is well documented that using ammonium sulfate decreases soil pH more rapidly than most other sources of N. Thus we were interested in measuring the change in soil pH as successive applications of these different N sources were applied to the same plots. The final soil pH for each location is shown in Table 3. Only at Mt. Vernon did soil pH respond to the fertilizer treatments where plots fertilized with ammonium sulfate had lower pH than most of the other N sources. However, the magnitude of the response shows that soil pH did not change markedly. For instance, the amount of lime needed to bring the plots fertilized with ammonium sulfate to be equal with the untreated control would be about 50 ENM units which have a value of approximately \$2.00/acre. Soil pH in plots fertilized with urea treated with Agrotain was greater than almost every other treatment. Perhaps the slow release technology of Agrotain provides a microenvironment with a continuous amount of highly alkaline ammonia in the soil solution.

Experiment 2

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

Conclusions:

1. Using untreated urea is risky. Fertilizing tall fescue with untreated urea worked as well as ammonium nitrate in 4 of 5 site-years in spring. However, for late-summer applications, untreated urea yielded less than ammonium nitrate about half the time.
2. Urea treated with Agrotain provided growth responses equal to ammonium nitrate.
3. Applying ESN or mixtures of ESN with urea or ESN mixed with ammonium sulfate often lagged behind other products.
4. Ammonium sulfate was a consistently good product, with yields equal to or in a few cases, better than those from urea or ammonium nitrate.

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

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

Table 2. Forage yield in late May of tall fescue fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year.

| Fertilizer Source | ----- Mt. Vernon ----- | | | --- Columbia --- | |
|---|------------------------|--------|--------|------------------|--------|
| | 2005 | 2006 | 2007 | 2006 | 2007 |
| | -----lbs/acre----- | | | | |
| Ammonium nitrate | 8080 | 3972 | 3647 | 4601 | 4826 |
| Urea | 7779 | 3680 | 3139 | 4037 | 4716 |
| Ammonium sulfate | 8832 | 3987 | 4183 | 4407 | 4915 |
| Urea treated with Agrotain | 8298 | 3873 | 3787 | 4186 | 4686 |
| ESN polymer coated urea | 7133 | 2114 | 3371 | 2738 | 3673 |
| Nurea | 8140 | 3408 | 3400 | 4195 | 4564 |
| Nurea with 10% polymer N | 7366 | 3624 | 3401 | 3918 | 4308 |
| Ammonium sulfate (10S)/urea | 7925 | 3716 | 3577 | 3899 | 4537 |
| Ammonium sulfate (20S)/urea | 7572 | 3920 | 3744 | 4303 | 4397 |
| Ammonium sulfate (40S)/urea | 7809 | 3842 | 3490 | 3548 | 4646 |
| Ammonium sulfate (10S)/ESN | 7042 | 2285 | 3599 | 3375 | 3872 |
| Ammonium sulfate (20S)/ESN | 6674 | 2610 | 3670 | 3149 | 4104 |
| Ammonium sulfate (40S)/ESN | 7611 | 3493 | 3765 | 3803 | 4702 |
| Equal N from urea, ammonium sulfate and ESN | 7498 | 3236 | 3829 | 3988 | 4831 |
| Unfertilized control | 4231 | 1653 | 1565 | 1688 | 2166 |
| LSD (0.05) | 1023 | 626 | 420 | 790 | 553 |
| <u>Orthogonal Contrasts</u> | | | | | |
| Urea vs. ammonium nitrate | 0.51 | 0.30 | 0.009 | 0.12 | 0.66 |
| Urea vs. ammonium sulfate | 0.03 | 0.23 | <0.001 | 0.30 | 0.42 |
| Ammonium sulfate vs. ammonium nitrate | 0.11 | 0.81 | 0.007 | 0.58 | 0.72 |
| Urea vs. urea treated with Agrotain | 0.26 | 0.49 | 0.001 | 0.67 | 0.90 |
| Urea vs. Nurea | 0.43 | 0.33 | 0.17 | 0.66 | 0.54 |
| ESN mixtures vs. urea mixtures | 0.02 | <0.001 | 0.50 | 0.02 | 0.04 |
| Unfertilized control vs. all others | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

Table 3. Final soil pH of plots treated with different sources of N fertilizer for three (Mt. Vernon) or two (Columbia) successive springs. Each fertilizer source was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year.

| Fertilizer Source | Mt. Vernon | Columbia |
|---|-------------------|----------|
| | ----- pH(s) ----- | |
| Ammonium nitrate | 5.92 | 6.92 |
| Urea | 5.86 | 6.92 |
| Ammonium sulfate | 5.62 | 6.76 |
| Urea treated with Agrotain | 6.08 | 7.16 |
| ESN polymer coated urea | 5.92 | 6.84 |
| Nurea | 5.94 | 6.90 |
| Nurea with 10% polymer N | 5.70 | 6.92 |
| Ammonium sulfate (10S)/urea | 5.80 | 6.94 |
| Ammonium sulfate (20S)/urea | 5.92 | 6.95 |
| Ammonium sulfate (40S)/urea | 5.70 | 6.86 |
| Ammonium sulfate (10S)/ESN | 6.04 | 7.02 |
| Ammonium sulfate (20S)/ESN | 5.88 | 6.92 |
| Ammonium sulfate (40S)/ESN | 5.56 | 6.86 |
| Equal N from urea, ammonium sulfate and ESN | 5.38 | 6.86 |
| | | |
| Unfertilized control | 5.84 | 6.96 |
| | | |
| LSD (0.05) | 0.33 | NS |
| | | |
| <u>Orthogonal Contrasts</u> | | |
| Urea vs. ammonium nitrate | 0.69 | 0.99 |
| Urea vs. ammonium sulfate | 0.11 | 0.20 |
| Ammonium sulfate vs. ammonium nitrate | 0.05 | 0.20 |
| Urea vs. urea treated with Agrotain | 0.59 | 0.87 |
| Urea vs. Nurea | 0.14 | 0.06 |
| ESN mixtures vs. urea mixtures | 0.82 | 0.93 |
| Unfertilized control vs. all others | 0.77 | 0.65 |

Table 4. Autumn forage yield of tall fescue fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-August to deliver 75 lb/acre of actual N to the same plots each year.

| | --- Mt. Vernon --- | | | Columbia |
|---|--------------------|--------|--------|----------|
| Fertilizer Source | 2005 | 2006 | 2006 | 2007 |
| | -----lb/acre----- | | | |
| Ammonium nitrate | 1932 | 1918 | 2700 | 2483 |
| Urea | 1245 | 2201 | 2865 | 1935 |
| Ammonium sulfate | 1579 | 2245 | 2787 | 2325 |
| Urea treated with Agrotain | 1523 | 1880 | 2696 | 2287 |
| ESN polymer coated urea | 1249 | 1549 | 2117 | 1826 |
| Nurea | 1437 | 2188 | 2738 | 2167 |
| Nurea with 10% polymer N | 988 | 2176 | 2725 | 2003 |
| Ammonium sulfate (10S)/urea | 1696 | 2282 | 2539 | 2041 |
| Ammonium sulfate (20S)/urea | 1259 | 2137 | 2877 | 2018 |
| Ammonium sulfate (40S)/urea | 1903 | 2327 | 2763 | 2288 |
| Ammonium sulfate (10S)/ESN | 1856 | 1664 | 2378 | 2110 |
| Ammonium sulfate (20S)/ESN | 1741 | 2079 | 2243 | 2044 |
| Ammonium sulfate (40S)/ESN | 1761 | 1882 | 2547 | 2298 |
| Equal N from urea, ammonium sulfate and ESN | 1822 | 2312 | 2819 | 2212 |
| | | | | |
| Unfertilized control | 492 | 834 | 1721 | 1370 |
| | | | | |
| LSD (0.05) | 582 | 668 | 629 | 430 |
| | | | | |
| <u>Orthogonal Contrasts</u> | | | | |
| Urea vs. ammonium nitrate | 0.01 | 0.35 | 0.58 | 0.01 |
| Urea vs. ammonium sulfate | 0.21 | 0.89 | 0.79 | 0.05 |
| Ammonium sulfate vs. ammonium nitrate | 0.18 | 0.28 | 0.77 | 0.42 |
| Urea vs. urea treated with Agrotain | 0.46 | 0.96 | 0.67 | 0.07 |
| Urea vs. Nurea | 0.29 | 0.29 | 0.57 | 0.23 |
| ESN mixtures vs. urea mixtures | 0.27 | 0.04 | 0.05 | 0.75 |
| Unfertilized control vs. all others | <0.001 | <0.001 | <0.001 | <0.001 |

Timetable for proposed research: These studies began in March 2005 and the field portion ended in December 2007 (three years of study). As planned from the start, in 2008 we will analyze the last year's samples in the laboratory and develop recommendations from this research. The table below gives a brief summary of the remaining activities to be completed.

| | |
|--|---------|
| Incorporate latest findings into soil testing reports, grazing school curriculum and educational workshops. Work with popular press on articles. | 8/2008 |
| Prepare updated MU guide on fertilization of pastures with different N sources. | 9/2008 |
| Prepare and submit an article on this research to a peer-reviewed journal. | 10/2008 |

Application/transfer of knowledge: As we develop a more complete data set, we intend to transfer our results in four ways. First, we will incorporate the results and recommendations from this study into the curriculum of the Missouri Grazing Schools. Second, we will work with the Soil Fertility Working Group and the MU Soil Testing Laboratory to refine the recommendations printed on soil testing results. Third, we will publish a guidesheet on N fertilization of pastures in Missouri that incorporates the findings from this research. Finally, we will prepare articles to be published in statewide and national magazines such as Missouri Ruralist, Graze, Stockman Grass Farmer and scientific (peer-reviewed) journals.

Budget for 2008

We are not requesting any additional funding for 2008. However, as planned from the beginning, we are requesting to use the residual funding for this project to complete the laboratory portion of the project and a final report.

Phosphorus Management

Progress Reports

Profitability of P and K Fertilizer With and Without Lime

David Dunn and Gene Stevens

University of Missouri-Delta Research Center

Objective: Measure corn/soybean phosphorus and potassium uptake, yield, and profitability of phosphorus and potassium fertilizer applications as affected by liming on fields with low pH soils. Economics will be calculated for each fertilization/lime system.

Introduction: Missouri farmers often request information to help convince their landlords that applying lime will net both parties added profits in a crop share agreement. Some cost share rental agreements call for fertilizer, but not lime costs to be shared by each party. Producers are reluctant to solely bear the costs of liming in situations where their rental agreements are for less than three years. For decades, extension soil scientists have taught that maintaining proper soil pH based on soil test recommendations is necessary to maximize availability of P and K to crops. Unfortunately, these education programs are primarily based on liming research studies conducted at least 35 years ago. These studies were largely conducted on soil testing adequate in P & K. Conversely most P & K studies have been conducted on soils with an optimal pH level. Also, many of those tests were done in laboratories and greenhouses. The proposed research project will help demonstrate that more “bang for the buck” can be achieved with P and K fertilizer in combination with good liming practices.

Research Methods: In 2007 two separate experiments were conducted.

Experiment 1: Corn and soybean field plots were established on a Tiptonville silt loam soil located at the University of Missouri Lee Farm at Portageville, MO. The soil pH_(s) at this location was 5.3, the P level was 52 lbs/a, and the K level was 169 lbs/a. The recommended limestone rate for both corn and soybeans was 1 ½ tons/a. For corn 60 lbs P₂O₅ & 90 lbs K₂O was recommended, for soybeans 35 lbs P₂O₅ & 120 lbs K₂O was recommended. The experimental design was a split plot with crop as the main plot and fertilizer treatment as the sub plot. Five replications were employed. Three rates of aglime (0, 1, 2 ton/a) and one rate of pelletized lime (200 lb/a) were evaluated. Five rates of P & K (0, 25, 50, 75, & 100% of the recommended rate) were evaluated. These rates were based on the greater of the two crops (60 lbs P₂O₅ & 120 lbs K₂O).

Experiment 2: Rice and soybean field plots were established on a Crowley silt loam soil located at the Missouri Rice Research Farm at Qulin, MO. The soil pH_(s) at this location was 5.1, the P level was 23 lbs/a, and the K level was 181 lbs/a. The recommended limestone rate for both rice and soybeans was 1 ½ tons/a. For rice 70 lbs P₂O₅ & 30 lbs K₂O was recommended, for soybeans 80 lbs P₂O₅ & 120 lbs K₂O was recommended. The experimental design was a split plot with crop as the main plot and fertilizer treatment as the sub plot. Four replications were employed. Two rates of aglime (0 & 1 ½ ton/a) and one rate of pelletized lime (200 lb/a) were evaluated. Two rates of P & K (0 & 100% of the recommended rate) were evaluated. These rates were based on the individual recommendations for each crop. Each plot was harvested and grain yield determined. Net returns to producers were calculated based on grain prices of corn @ \$4.00, soybeans @ \$10.00, and rice @ \$5.00. Input costs were based on lime @ \$25.00/ton, pelletized lime @ \$110.00/ton, P @ \$0.25/lb, and K @ \$0.35/lb

Project Accomplishments 2007:

Experiment 1: Overall yields for both corn and soybeans were acceptable considering the adverse environmental conditions experienced in 2007. Both crops were replanted in this evaluation. Corn was replanted due to the freezing temperatures on April 6-8, 2007. Soybeans were replanted due to dry soil conditions following planting in May 2007. Soybean yields also were further impacted by hot & dry weather conditions in July and August.

The average grain yields and net returns to producers for lime and fertilizer treatments for 2007 are presented in Tables 1, 2, & 3. When averaged for all fertilizer treatments, the 1 ton/a lime rate produced the greatest corn yields. When averaged for all lime treatments, the 45-90 rate of P & K produced the greatest yields for corn. When averaged for all fertilizer treatments, the 2 ton/a lime rate produced the greatest soybean yields. When averaged for all lime treatments, the 45-90 rate of P & K produced the greatest yields for soybean. For both corn and soybeans the 200 lb/a pelletized lime treatment increased yields relative to the no lime treatment. However it produced yields less than either lime treatment. When averaged for all fertilizer treatments, the no lime treatment produced the greatest returns to producers for corn. When averaged for all lime treatments, the 45-90 rate of P & K produced the greatest returns to producers for corn. When averaged for all fertilizer treatments, the 1 ton/a lime rate produced the greatest returns to producers for soybeans. When averaged for all lime treatments, the 15-30 rate of P & K produced the greatest returns to producers for soybeans.

Experiment 2: The average grain yields and net returns to producers for lime and fertilizer treatments for 2007 are presented in Tables 4, 5, & 6. When averaged for all fertilizer treatments, the 1.6 ton/a lime rate produced the greatest rice yields. When averaged for all lime treatments, the 70-30 rate of P & K produced the greatest yields for rice. When averaged for all fertilizer treatments, the 1.6 ton/a lime rate produced the greatest soybean yields. When averaged for all lime treatments, the 80-120 rate of P & K produced the greatest yields for soybean. For both rice and soybeans the 200 lb/a pelletized lime treatment increased yields relative to the no lime treatment. When averaged for all fertilizer treatments, the 0.4 t lime treatment produced the greatest returns to producers for rice. When averaged for all lime treatments, the 30-70 rate of P & K produced the greatest returns to producers for rice. When averaged for all fertilizer treatments, the 0.8 ton/a lime rate produced the greatest returns to producers for soybeans. When averaged for all lime treatments, the 80-120 rate of P & K produced the greatest returns to producers for soybeans.

Preliminary results for this experiment were resented to 150 rice and soybean producers at the Missouri Rice Farm Field Day August 21, 2007. A manuscript detailing the 2007 results is being prepared for inclusion in the 2007 Missouri Rice Research update. This manuscript will then be posted on the Missouri Rice Home Page (<http://www.ext.missouri.edu/agebb/rice/>).

Table 1. Average grain yields, input costs, gross and net returns for lime and fertilizer treatments for corn and soybeans, Portageville, MO in 2007.

| 2007 Corn | | | | | | |
|-----------|---------------|---------------|-----------------|-------------------------|-------------------------|-----------------------|
| # | P+K (lb/a) | Lime (t/a) | Yield (bu/a) | Gross return* (\$/a) | Input costs** (\$/a) | Net returns (\$/a) |
| 1 | 0 | 0 | 132 | 528.00 | 0.00 | 528.00 |
| 2 | 15-30 | 0 | 148 | 592.00 | 14.25 | 577.75 |
| 3 | 30-60 | 0 | 150 | 600.00 | 28.50 | 571.50 |
| 4 | 45-90 | 0 | 175 | 700.00 | 42.75 | 657.25 |
| 5 | 60-120 | 0 | 137 | 548.00 | 57.00 | 491.00 |
| 6 | 0 | 1.0 | 158 | 632.00 | 25.00 | 607.00 |
| 7 | 15-30 | 1.0 | 145 | 580.00 | 39.25 | 540.75 |
| 8 | 30-60 | 1.0 | 151 | 604.00 | 53.50 | 550.50 |
| 9 | 45-90 | 1.0 | 162 | 648.00 | 67.75 | 580.25 |
| 10 | 60-120 | 1.0 | 150 | 600.00 | 82.00 | 518.00 |
| 11 | 0 | 2.0 | 147 | 588.00 | 50.00 | 538.00 |
| 12 | 15-30 | 2.0 | 138 | 552.00 | 64.25 | 487.75 |
| 13 | 30-60 | 2.0 | 145 | 580.00 | 78.50 | 501.50 |
| 14 | 45-90 | 2.0 | 147 | 588.00 | 92.75 | 495.25 |
| 15 | 60-120 | 2.0 | 132 | 528.00 | 107.00 | 421.00 |
| 16 | 0 | 200 lb pel | 123 | 492.00 | 11.00 | 481.00 |
| 17 | 15-30 | 200 lb pel | 151 | 604.00 | 25.25 | 578.75 |
| 18 | 30-60 | 200 lb pel | 145 | 580.00 | 39.50 | 540.50 |
| 19 | 45-90 | 200 lb pel | 159 | 636.00 | 53.75 | 582.25 |
| 20 | 60-120 | 200 lb pel | 123 | 492.00 | 68.00 | 424.00 |

| 2007 Soybeans | | | | | | |
|---------------|---------------|---------------|-----------------|-------------------------|-------------------------|-----------------------|
| # | P+K (lb/a) | Lime (t/a) | Yield (bu/a) | Gross return* (\$/a) | Input costs** (\$/a) | Net returns (\$/a) |
| 1 | 0 | 0 | 36 | 360.00 | 0.00 | 360.00 |
| 2 | 15-30 | 0 | 47 | 465.00 | 14.25 | 450.75 |
| 3 | 30-60 | 0 | 41 | 405.00 | 28.50 | 376.50 |
| 4 | 45-90 | 0 | 42 | 420.00 | 42.75 | 377.25 |
| 5 | 60-120 | 0 | 41 | 405.00 | 57.00 | 348.00 |
| 6 | 0 | 1.0 | 39 | 390.00 | 25.00 | 365.00 |
| 7 | 15-30 | 1.0 | 44 | 435.00 | 39.25 | 395.75 |
| 8 | 30-60 | 1.0 | 44 | 435.00 | 53.50 | 381.50 |
| 9 | 45-90 | 1.0 | 47 | 465.00 | 67.75 | 397.25 |
| 10 | 60-120 | 1.0 | 53 | 525.00 | 82.00 | 443.00 |
| 11 | 0 | 2.0 | 47 | 465.00 | 50.00 | 415.00 |
| 12 | 15-30 | 2.0 | 44 | 435.00 | 64.25 | 370.75 |
| 13 | 30-60 | 2.0 | 48 | 480.00 | 78.50 | 401.50 |
| 14 | 45-90 | 2.0 | 50 | 495.00 | 92.75 | 402.25 |
| 15 | 60-120 | 2.0 | 47 | 465.00 | 107.00 | 358.00 |
| 16 | 0 | 200 lb pel | 41 | 405.00 | 11.00 | 394.00 |
| 17 | 15-30 | 200 lb pel | 47 | 465.00 | 25.25 | 439.75 |
| 18 | 30-60 | 200 lb pel | 42 | 420.00 | 39.50 | 380.50 |
| 19 | 45-90 | 200 lb pel | 48 | 480.00 | 53.75 | 426.25 |
| 20 | 60-120 | 200 lb pel | 39 | 390.00 | 68.00 | 322.00 |

*Based on corn @ \$5.00/bu and soybeans @ \$10.00/bu

**Based on lime @ \$25.00/ton, pelletized lime @ \$110.00/ton, P @ \$0.25/ lb P₂O₅ and K @ \$0.35/ lb K₂O.

Table 2. Average corn and soybean yields and net returns for fertilizer treatments averaged for all lime rates, Portageville, MO in 2007.

| P&K | Corn | | Soybeans | |
|--------|-----------------|--------------------------|-----------------|--------------------------|
| | Yield (bu/a) | Net returns (\$/a) | Yield (bu/a) | Net returns (\$/a) |
| 0 | 140 | 538.50 | 40.5 | 383.50 |
| 15-30 | 146 | 546.25 | 45.0 | 414.25 |
| 30-60 | 148 | 541.00 | 43.5 | 385.00 |
| 45-90 | 161 | 578.75 | 46.5 | 400.75 |
| 60-120 | 136 | 463.50 | 44.6 | 367.75 |

Table 3. Average corn and soybean yields and net returns for lime treatments averaged for all fertilizer rates, Portageville, MO in 2007.

| Lime | Corn | | | Soybeans | |
|------------|--------------|--------------------|--|--------------|--------------------|
| | Yield (bu/a) | Net returns (\$/a) | | Yield (bu/a) | Net returns (\$/a) |
| 0 | 148 | 565.00 | | 41.0 | 383.00 |
| 1 t | 153 | 559.00 | | 45.0 | 397.00 |
| 2 t | 142 | 489.00 | | 47.8 | 390.00 |
| 200 lb pel | 140 | 521.00 | | 43.2 | 393.00 |

Table 4. Average grain yields, input costs, gross and net returns for lime and fertilizer treatments for rice and soybeans, Qulin, MO in 2007.

| 2007 Rice | | | | | | |
|---------------|------------|------------|--------------|----------------------|----------------------|--------------------|
| # | P+K (lb/a) | Lime (t/a) | Yield (bu/a) | Gross return* (\$/a) | Input costs** (\$/a) | Net returns (\$/a) |
| 1 | 0 | 0 | 141 | 705.00 | 0.00 | 705.00 |
| 2 | 0 | 0.4 | 141 | 705.00 | 9.40 | 695.60 |
| 3 | 0 | 0.8 | 149 | 745.00 | 18.75 | 726.25 |
| 4 | 0 | 1.2 | 140 | 700.00 | 28.20 | 671.80 |
| 5 | 0 | 1.6 | 144 | 720.00 | 37.50 | 682.50 |
| 6 | 0 | 200 lb pel | 142 | 710.00 | 11.00 | 699.00 |
| 7 | 70-30 | 0.4 | 141 | 705.00 | 37.40 | 667.60 |
| 8 | 70-30 | 0.8 | 159 | 795.00 | 46.75 | 748.25 |
| 9 | 70-30 | 1.2 | 151 | 755.00 | 56.20 | 698.80 |
| 10 | 70-30 | 1.6 | 153 | 765.00 | 65.50 | 699.50 |
| 11 | 70-30 | 200 lb pel | 157 | 785.00 | 39.00 | 746.00 |
| 2007 Soybeans | | | | | | |
| # | P+K (lb/a) | Lime (t/a) | Yield (bu/a) | Gross return* (\$/a) | Input costs** (\$/a) | Net returns (\$/a) |
| 1 | 0 | 0 | 36 | 360 | 0.00 | 360.00 |
| 2 | 0 | 0.4 | 38 | 380 | 9.40 | 370.60 |
| 3 | 0 | 0.8 | 39 | 390 | 18.75 | 371.25 |
| 4 | 0 | 1.2 | 41 | 410 | 28.20 | 381.80 |
| 5 | 0 | 1.6 | 42 | 420 | 37.50 | 382.50 |
| 6 | 0 | 200 lb pel | 39 | 390 | 11.00 | 379.00 |
| 7 | 80-120 | 0.4 | 46 | 460 | 71.40 | 388.60 |
| 8 | 80-120 | 0.8 | 49 | 490 | 80.75 | 409.25 |
| 9 | 80-120 | 1.2 | 43 | 430 | 90.20 | 339.80 |
| 10 | 80-120 | 1.6 | 49 | 490 | 99.50 | 390.50 |
| 11 | 80-120 | 200 lb pel | 45 | 450 | 73.00 | 377.00 |

*Based on rice @ \$5.00/bu and soybeans @ \$10.00/bu

**Based on lime @ \$25.00/ton, pelletized lime @ \$110.00/ton, P @ \$0.25/ lb P₂O₅ and K @ \$0.35/ lb K₂O.

Table 5. Average rice and soybean yields and net returns for fertilizer treatments averaged for all lime rates, Qulin, MO in 2007.

| P&K | Rice | | | Soybeans | |
|----------|--------------|--------------------|--|--------------|--------------------|
| | Yield (bu/a) | Net returns (\$/a) | | Yield (bu/a) | Net returns (\$/a) |
| No P & K | 143.2 | 695.00 | | 39.8 | 377.00 |
| + P & K | 155.4 | 728.00 | | 46.4 | 443.0.0 |

Table 6. Average Rice and soybean yields and net returns for lime treatments averaged for all fertilizer rates, Qulin, MO in 2007.

| Lime | Rice | | | Soybeans | |
|------------|--------------|--------------------|--|--------------|--------------------|
| | Yield (bu/a) | Net returns (\$/a) | | Yield (bu/a) | Net returns (\$/a) |
| 0 | 141 | 705.00 | | 36.0 | 360.00 |
| 0.4 t | 150 | 726.60 | | 42.0 | 410.60 |
| 0.8 t | 150 | 717.25 | | 44.0 | 421.25 |
| 1.2 t | 146.5 | 690.30 | | 42.0 | 391.80 |
| 1.6 t | 150.5 | 701.00 | | 44.5 | 417.50 |
| 200 lb pel | 149.5 | 722.50 | | 42.0 | 409.00 |

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

Dale G. Blevins

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

Objective: To determine if phosphorus (P) and magnesium (Mg) concentrations in leaves of stockpiled tall fescue during winter can be increased by fertilization with both P and Mg. The acreage involved makes this research important to the Missouri fertilizer industry. Missouri leads the nation in tall fescue production and is second in beef calf production (Missouri Farm Facts, 2005). Of the 13 million acres of tall fescue pasture in Missouri, much of it grows on soils low in plant available P (Bray I). When forage is produced on these soils, there may be a problem with macronutrient quality of leaf tissue. Our previous work on low Bray I P soils has shown that P fertilization of tall fescue pastures improved leaf P and Mg concentrations (Reinbott and Blevins 1997). Currently, it is recommended that cattle producers stockpile tall fescue to reduce winter feeding costs. However, there is very little information available on the macronutrient quality of stockpiled tall fescue and management practices that can be used to improve it.

Procedure: During summer 2006, an established stand of tall fescue (K31, endophyte infected) was selected at the University of Missouri, Southwest Research Center near Mt. Vernon. Soil samples were taken and sent to the University of Missouri Soil Testing Lab for analysis. The soil test results were used for making the final site selection. On September 20, forage was removed from the plot area and plots of 10' x 25' with 5' foot alleys were treated with combinations of 0, 50, 100, or 200 lbs P/acre (as 0-46-0) and 0 or 50 lbs Mg/acre (K-Mag). The use of K-Mag required that potassium (K) and sulfur (S) be added separately to all treated plots to balance K and S added in the K-Mag treatments. Each treatment combination was replicated six times. From mid-October through mid-April (2007), 20 of the most recently collared leaves were harvested monthly from each plot. Samples were dried, ground and digested in nitric acid in a microwave accelerated digestion system (CEM Corp.). Digested samples were filtered, diluted and macro- and micronutrient concentrations were determined by ICP analysis.

Results: During the first stockpiling season, P fertilization increased leaf P concentrations, as expected (Fig. 1). The increasing P treatment levels clearly increased the leaf P concentrations with each increment added. Interestingly, at the 0, 50 and 100 P treatments levels, Mg fertilization tended to increase leaf P concentrations, as well. When Mg fertilizer was applied without also applying P fertilizer, the Mg was ineffective at increasing leaf Mg concentrations above control levels in February, March and April (Fig. 2). When Mg fertilizer was applied with P fertilizer, leaf Mg concentrations were increased. However, with all treatments, except the 200P 100Mg treatment, leaf Mg levels in February fell below the 0.2% level required by lactating beef cows. Leaf Ca concentrations also increased with P fertilization treatments (Fig. 3). With 0 P and 50 P treatments, Mg fertilization decreased leaf Ca concentrations below the target 3.0% level

during winter months (Fig. 3). In Nov and Dec 2006, P treatments increased leaf K concentrations above control levels, but there were no clear treatment affect in winter and spring months of 2007 (Fig. 4). Leaf concentrations of most essential micronutrient elements showed only limited response to the P and Mg treatments, Mn was an exception however. Leaf Mn concentrations increased significantly with increasing P treatments, and the addition of Mg tended to lessen this response (Fig. 5).

Discussion: Clearly the combination of P and Mg fertilization was effective in increasing leaf Mg concentrations in the stockpiled tall fescue. However, in February, only the high treatment levels produced leaf Mg concentrations that were about 0.2%. Our hypothesis is that tall fescue naturally mobilizes “mobile” nutrients, like Mg, and moves them out of leaves down to roots and rhizomes during winter. These nutrients are then available to support new growth in the early spring, even when soil temperatures are low. Experiments are underway to test this hypothesis. In addition to the interest in wintertime leaf Mg and Ca concentrations, increased leaf Mn concentrations with P fertilization should be mentioned. In Missouri soils, we have found that leaf Mn concentrations can be greatly increased with P fertilization and greatly decreased with liming! These are important points since different crop species seem to have very different Mn requirements. For example, soybean and switchgrass seem to have high Mn requirements, while corn and sorghum do not. Therefore we can use P fertilization or liming to increase or decrease leaf Mn concentrations in specific crops.

Last six month schedule: Leaf samples were collected from Oct to Dec 2007, and will be collected monthly through April 2008. Hay will be harvested for yield determinations in late May 2008. All second year samples will be analyzed for macro- and micronutrients using ICP, and the effects of P and Mg fertilization will be determined. Of special interest will be fertilization treatment responses of leaf P and Mg concentrations during the late winter months.

Figure 1. Response of leaf P concentrations in stockpiled tall fescue to P and Mg fertilization.

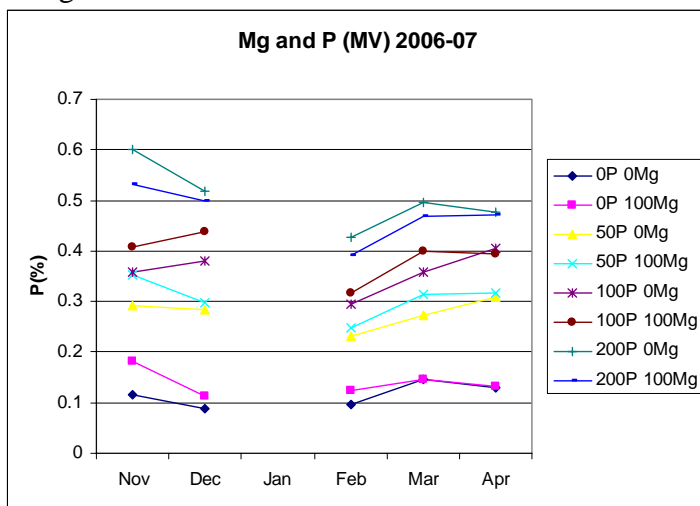


Figure 2. Response of leaf Mg concentrations in stockpiled tall fescue to P and Mg fertilization.

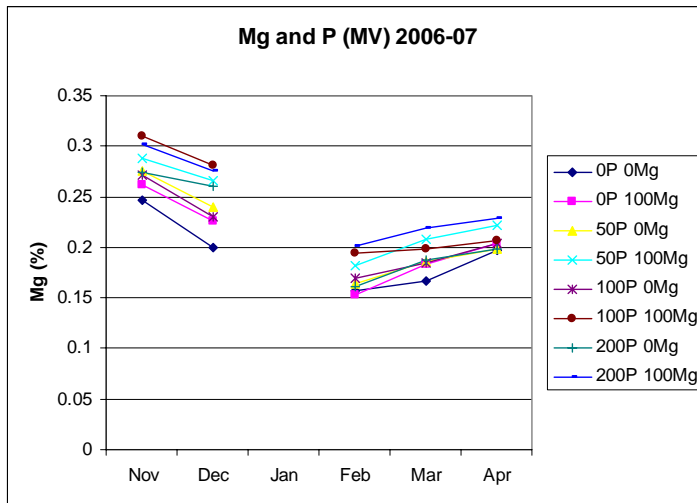


Figure 3. Response of leaf Ca concentrations in stockpiled tall fescue to P and Mg fertilization.

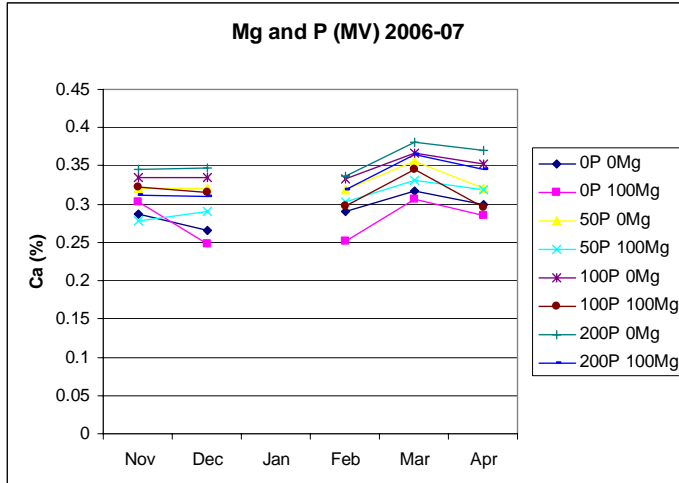


Figure 4. Response of leaf K concentrations in stockpiled tall fescue to P and Mg fertilization.

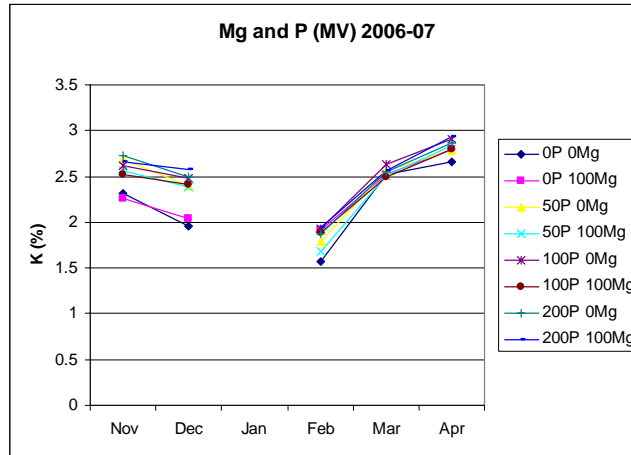
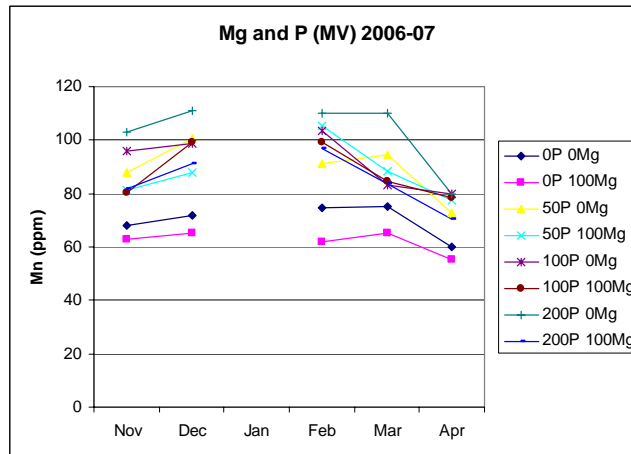


Figure 5. Response of leaf Mn concentrations in stockpiled tall fescue to P and Mg fertilization.



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

Rich Hoormann, Charlie Ellis, and Peter Scharf

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

Introduction:

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

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

The objectives of this study are:

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

Methods and Materials:

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

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

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

Equipment used for planting and fertilizer application was a six row Case 950 Cyclo planter with dry fertilizer and liquid fertilizer attachments. Targeted planting rate was 26,000 seed/A, planted on May 9 using a no-till system. Dry fertilizer was metered through a standard, auger style fertilizer box and applied four inches to the side and four inches deep through a coulter and knife unit. Each fertilizer box supplied three rows with the boxes being driven through a ground driven chain and sprocket configuration. Prior to planting calibration was conducted on each fertilizer box with multiple fertilizers of different bulk densities to insure accuracy in the field. The balance of nitrogen fertilizer was applied in the row middle with UAN behind a coulter attached to the planter.

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

| Treatment | Nitrogen Sources | | | P ₂ O | K ₂ O ₅ |
|-------------------|------------------|------|-----|------------------|-------------------------------|
| | UAN | Urea | DAP | | |
| 0 P and K | 70 | 45 | 0 | 0 | 0 |
| Broadcast P and K | 70 | 45 | 0 | 115 | 130 |
| 1 X Band | 70 | 0 | 45 | 115 | 130 |
| 0.5 X Band | 92 | 0 | 23 | 58 | 65 |

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

Harvesting was conducted on September 18, 2007, using a six-row combine with an Ag Leader PF 3000 yield monitor attached to a receiver for yield mapping and data collection. This allowed for the middle six rows of the twelve row plots to be harvested. Prior to harvesting of the plots a calibration load was harvested with a targeted flow rate of 1000 bu. per hour. The harvested area for the calibration load was similar in yield to the plots. The resulting calibration load had a measured weight of 4800 lbs. and an actual weighed weight of 4820 lbs. Each treatment was collected as an individual load for analysis.

Observations and Results:

The plots were scouted during the growing season for weeds, insects and diseases. No pest problems were found during the growing season.

The plots were located in an area that experienced drought and high temperature conditions during the growing season. Plots received little rainfall after early July and high daytime temperatures were experienced during August continuing into September. In spite of stress conditions, pollination was very good. Ear fill was nearly to the tip. However, the outer one-third of ears aborted due to lack of late season moisture, resulting in yield loss some 25-30 percent below long term field average. The stress conditions may have contributed to poor treatment yield separation.

The plot treatment yields ranged from 91.5 – 107.8 bu/A, with the mean being 98.5 bu/A. There was no significant difference in treatments at the 5% probability level.

| Treatment | Replications | | | | Trt Mean |
|---|--------------|-------|------|------|----------|
| | 1 | 2 | 3 | 4 | |
| 0 | * | 103.2 | 97.2 | 99.8 | 100.1 |
| 0.5 | 107.8 | 99.4 | 91.5 | 91.7 | 97.6 |
| 1 | 99.5 | 105.0 | 93.5 | 97.6 | 98.9 |
| Broadcast | 106.5 | 98.0 | 89.7 | 97.0 | 97.8 |
| Rep Mean | 104.6 | 101.4 | 93.0 | 96.5 | 98.5 |
| No significant treatment differences (P=0.05) | | | | | |
| * Missing data point | | | | | |

One of the production concerns was the high salt loading in proximity to the seed during dry years. Population counts at V1 stage of growth (not shown) and at harvest were not significantly different and when analyzed for yield impact by treatment was not significantly different.

| Treatment | Replications | | | | Trt Mean |
|---|--------------|-------|------|-------|----------|
| | 1 | 2 | 3 | 4 | |
| 0 | * | 103.2 | 97.2 | 100.0 | 100.1 |
| 0.5 | 107.8 | 99.2 | 91.5 | 92.1 | 97.7 |
| 1 | 99.5 | 105.2 | 93.3 | 97.8 | 99.0 |
| Broadcast | 106.3 | 97.8 | 89.5 | 97.2 | 97.7 |
| Rep Mean | 104.5 | 101.3 | 92.9 | 96.8 | 98.5 |
| No significant treatment differences (P=0.05) | | | | | |
| * Missing data point | | | | | |

Objectives for 2008:

Soybeans will be planted as part of the rotation, using a RTK corrected auto steer to drop seed within 4 inches of banded fertilizer. No fertilizer application is scheduled for 2008.

Potassium Management

Progress Reports

Use of Pre-plant or Foliar-Applied Potassium Chloride with Fungicides to Improve Soybean Response and Disease Resistance

Kelly Nelson, Peter Motavalli, Gene Stevens and David Dunn

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Introduction:

An increased occurrence of K deficiency in soybeans and the potential widespread onset of Asian rust (SBR) (*Phakopsora pachyrhiza*) in soybeans have stimulated interest in new management practices that may improve K nutrition and lower incidence of disease. In 2004, SBR was reported in nine states including Louisiana, other Gulf-coast and southeastern states, and Missouri (APHIS, 2005). Yield loss estimates for this fungal disease range from 10 to 80% in areas where rust is established and could result in economic losses between \$640 to \$1,341 million the first year of infestation (Sweets et al., 2004). Since current soybean varieties grown in the U.S. have little or no resistance to SBR, a primary method of controlling the spread of the disease has been to use fungicides. Currently, four families of fungicides are available for SBR management: triazoles, strobilurins, chloronitriles, and carboxamides. In addition, extensive research has established a link between plant nutrition and disease incidence including the disease suppressing effects of K, Cl, Mn, B and P (Fixen et al, 2004). Therefore, combining K, Cl and other nutrients either as a pre-plant or foliar application with a fungicide may improve disease management. Recent research by Bradley and Sweets (2005) in Missouri indicates that several fungicides can be tank mixed with glyphosate without significant injury or reduction in yields of soybeans, but the limited penetration of the combined spray into the plant canopy may reduce potential SBR control. Nelson et al. (2004) has also established the KCl and several other K fertilizer sources can be combined with glyphosate without reducing weed control or causing significant foliar injury. This “weed and feed” system could also serve as an example for a system that combines disease control and nutrient management. The possible benefits of this approach include reduction in application costs, improved disease suppression and nutrient response, and flexibility in management response to environmental conditions during the growing season.

The objectives of this study were:

4. Determine soybean yield response, disease incidence and K and Cl tissue concentrations from application of KCl alone or in combination with several fungicides.
5. Examine the effects of application timing of KCl or the fungicides on crop response and disease incidence.

Materials and Methods:

This study evaluated the effects of either pre-plant or foliar-applied KCl fertilizer sources and rates of application on glyphosate-resistant soybean response. Field trials were established at the Greenley and Delta Centers on soils with medium to low soil test K. Roundup-Ready® soybeans were no-till planted at 180,000 seeds/acre in 15 inch rows at Novelty and 30 inch rows at Portageville. The study was arranged as a randomized complete block design with four replications. Treatments consisted of a non-treated control, a recommended pre-plant rate of K₂O as KCl based on soil test (455 and 505 lbs K₂O/acre at Novelty in 2006 and 2007, respectively; 203 and 216 lbs K₂O/acre at Portageville in 2006 and 2007, respectively), or a foliar application of 16 lb K/acre (as KCl) in a factorial arrangement combined with

and without fungicide applications of 6 oz/acre of pyraclostrobin (Headline[®]), 6.4 oz/acre of azoxystrobin (Quadris[®]) or 6.4 oz/acre Quadris[®] + 2.6 oz/acre of Warrior[®] (lambda-cyhalothrin insecticide) applied either at V4 or R4 growth stages.

Foliar injury was rated 3, 7, 10, 14, or 28 days after foliar application. Treatments were evaluated for the incidence of Septoria brown spot (*Septoria glycines*), frogeye leaf spot (*Cercospora sojina*), sudden death syndrome (*Fusarium solani*), and Asian rust. Soybeans were harvested and data analyzed to determine the influence of the treatments on crop response and grain yield. Data were subjected to an analysis of variance and means separated at p=0.05 unless otherwise specified. Main effects were generally presented in the absence of interactions.

Results and Discussion:

Injury. Soybean injury was primarily temporary necrosis that was less than 3% at Novelty 3 and 7 days after treatment (DAT) (Table 1). Foliar applied KCl at the R4 stage of development injured soybean up to 30% at Portageville, but plants had recovered by 14 DAT (data not presented).

Table 1. Soybean response to preplant and foliar applied KCl averaged over application timing, fungicide treatment, and year at Novelty, and averaged over fungicide treatment and year at Portageville.

| Treatment | Novelty | | Portageville | | | |
|--------------|---------------|---------|--------------|----|-----------|----|
| | | | 3 DAT | | 10 DAT | |
| | 3 DAT | 7 DAT | V4 | R4 | V4 | R4 |
| | ----- % ----- | | | | | |
| Non-treated | 0 | 0 | 0 | 0 | 0 | 0 |
| Preplant KCl | 0 | 0 | 1 | 0 | 0 | 0 |
| Foliar KCl | 3 | 2 | 1 | 30 | 1 | 12 |
| LSD (p=0.05) | ---1--- | ---1--- | ----3---- | | ----2---- | |

Abbreviations: DAT, days after treatment; LSD, least significant difference.

Incidence of disease. Asian soybean rust spores were detected at physiological maturity in Northeast and Southeast Missouri in 2007. Asian soybean rust was monitored in this research, but spores were not detected in either of these locations. The incidence of Septoria brown spot, frogeye leaf spot, or sudden death syndrome (SDS) was less than 10% in 2006 and 2007 at both locations. Preplant KCl reduced the incidence of Septoria brown spot and frogeye leaf spot 4 and 6%, respectively, at Novelty (Table 2).

There was an interaction between application timing and fungicide treatment at Novelty (Table 3). Quadris, Quadris plus Warrior, or Headline applied at R4 reduced the incidence of Septoria brown spot and frogeye leaf spot when compared to the non-treated or V4 application timing.

There was an interaction between KCl fertility, fungicide treatment, and application timing at Portageville (Table 4). At the R4 application timing, there was a greater incidence of Septoria brown spot while there was a lower incidence of SDS when fungicides were combined with KCl. In general, the incidence of Septoria brown spot, frogeye leaf spot, and SDS was similar for preplant KCl and non-treated KCl.

Table 2. Effect of KCl fertility on the incidence of Septoria brown spot and Frogeye leaf spot at Novelty in 2006 and 2007.

| KCl fertility | Septoria brown spot | | Frogeye leaf spot | |
|---------------|---------------------|--|-------------------|--|
| | ----- % ----- | | | |
| Non-treated | 7 | | 8 | |
| Preplant KCl | 3 | | 2 | |
| Foliar KCl | 7 | | 6 | |
| LSD (p=0.05) | ----- 1 ----- | | ----- 1 ----- | |

Table 3. Effect of fungicide and timing on the incidence of Septoria brown spot and Frogeye leaf spot at Novelty in 2006 and 2007.

| Fungicide treatment | Septoria brown spot | | Frogeye leaf spot | |
|--|---------------------|----|-------------------|----|
| | V4 | R4 | V4 | R4 |
| ----- % ----- | | | | |
| Non-treated | 7 | 7 | 6 | 6 |
| Quadris at 6.4 oz/a | 7 | 6 | 6 | 4 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 6 | 5 | 6 | 4 |
| Headline at 6 oz/a | 6 | 4 | 6 | 4 |
| LSD (p=0.05) | ----- 1 ----- | | ----- 1 ----- | |

Table 4. Effect of KCl fertility, fungicide, and application timing on the incidence of Septoria brown spot, frogeye leaf spot, and sudden death syndrome at Portageville in 2006 and 2007.

| Treatment | Septoria brown spot | | Frogeye leaf spot | | Sudden death syndrome | |
|--|---------------------|----|-------------------|----|-----------------------|----|
| | V4 | R4 | V4 | R4 | V4 | R4 |
| ----- % ----- | | | | | | |
| Non-treated | | | | | | |
| Non-treated | 7 | 3 | 4 | 2 | 2 | 5 |
| Quadris at 6.4 oz/a | 0 | 6 | 3 | 1 | 8 | 3 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 6 | 4 | 0 | 2 | 3 | 3 |
| Headline at 6 oz/a | 4 | 4 | 3 | 3 | 3 | 4 |
| Preplant KCl | | | | | | |
| Non-treated | 5 | 5 | 1 | 2 | 2 | 4 |
| Quadris at 6.4 oz/a | 6 | 5 | 2 | 5 | 5 | 3 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 5 | 6 | 0 | 1 | 1 | 2 |
| Headline at 6 oz/a | 3 | 5 | 0 | 2 | 3 | 1 |
| Foliar KCl | | | | | | |
| Non-treated | 8 | 8 | 2 | 3 | 5 | 1 |
| Quadris at 6.4 oz/a | 6 | 10 | 1 | 3 | 6 | 1 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 4 | 9 | 0 | 1 | 4 | 1 |
| Headline at 6 oz/a | 2 | 8 | 4 | 0 | 3 | 14 |
| LSD (p=0.05) | ----- 4 ----- | | ----- 2 ----- | | ----- 6 ----- | |

Leaf tissue analysis. Leaves were removed approximately 10 days after the R4 application timing and evaluated for P, N, K, and Cl concentration. There was no effect of fungicides or KCl fertility on leaf P concentration (data not presented).

Quadris and Headline treated plants had lower leaf N concentrations at Portageville (Table 5). However, Quadris and Headline had no effect on leaf N concentration when compared to the non-treated check at Novelty. Quadris plus Warrior treated plants at the R4 application timing had increased leaf N concentrations when compared to the non-treated check and the V4 application timing of Quadris plus Warrior. Differences in leaf N concentrations may be related to a low infestation of soybean aphids (<80/plant). The Quadris plus Warrior treated plants at the R4 timing averaged less than 14 aphids/plant up to 29 DAT while the non-treated or Quadris only treated plants averaged 35-72 aphids/plant up to 29 DAT (data not presented). Control of soybean aphids with Quadris plus Warrior may have resulted in increased leaf tissue N concentrations at Novelty. There was no effect of KCl fertility on soybean aphid populations.

Leaf tissue K was affected by KCl fertility (Table 6). Preplant KCl increased leaf tissue K 0.1 and 0.9% at Portageville and Novelty, respectively. No interactions between fungicide treatment, KCl, or fungicide treatment were observed.

Leaf Cl concentration was three times greater at Portageville than Novelty in 2006. There was an interaction between KCl fertility and application timing which was due to the foliar application of KCl. Preplant KCl increased Cl concentration in the leaves of soybean when compared to the non-treated check at Portageville, but had no effect at Novelty. Foliar applied KCl at the R4 application timing increased leaf Cl concentrations 2,770 to 3,740 ppm when compared to the non-treated check at both locations. The R4 foliar application also increased leaf Cl concentration 1,500 to 3,370 ppm when compared to preplant KCl at both locations.

Yield. Grain yield at Novelty and Portageville increased 3.5 to 5.8 bu/a with preplant KCl when compared with the non-treated control and foliar applied KCl (Table 7). Grain yield was ranked preplant KCl > foliar KCl > non-treated at Novelty and preplant KCl > foliar KCl = non-treated at Portageville. At Novelty, fungicide treatments applied at the R4 stage of development increased yields 3 to 5 bu/acre. However, there was no significant effect of fungicide treatments or application timing on soybean grain yield at Portageville.

Summary and Conclusions:

This research indicates that preplant KCl fertility reduced the incidence of Septoria brown spot and frogeye leaf spot at Novelty, and increased grain yield 3.5 to 5.1 bu/acre. Foliar applied KCl increased grain yield 1.6 bu/a at Novelty, and when KCl was foliar applied at the R4 stage of development leaf tissue Cl concentrations increased at both locations. An R4 application of fungicides increased grain yields 3 to 5 bu/acre when compared to a V4 application timing at Novelty. Since there was a light incidence of disease and multiple diseases present, the effects of these foliage diseases may be additive; however, the effects of KCl and fungicide treatments on these diseases and grain yield were also additive which may explain increased yields at the Novelty location.

Soybean grain yield increased 5.4 to 5.8 bu/a with a preplant application of KCl at Portageville. There were variable effects of fungicides on the incidence of disease and no yield response due to fungicides or foliar KCl at this location. This may be due to increased crop injury with foliar applied KCl which may provide infection locations for foliar diseases especially at the R4 application timing, or three fold greater Cl concentrations in soybean leaves when compared to Novelty. Crop injury and leaf Cl concentrations may interact with fungicide treatments causing no additive yield benefit and variable effects on the incidence of foliage diseases.

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Table 5. The effect of fungicide treatment on soybean leaf tissue N concentration at Portageville and Novelty in 2006.

| Fungicide treatment | Portageville | Novelty | |
|--|--------------|---------------|-----|
| | | V4 | R4 |
| | | ----- % ----- | |
| Non-treated | 5.1 | 5 | 5 |
| Quadris at 6.4 oz/a | 4.5 | 5.2 | 5.1 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 5.1 | 4.7 | 5.5 |
| Headline at 6 oz/a | 4.4 | 5.2 | 5.1 |
| LSD (p=0.1) | ----0.3---- | ----0.5---- | |

Table 6. The effect of KCl fertilization on leaf tissue K and Cl concentrations at Portageville and Novelty in 2006.

| KCl fertility | Leaf tissue K | | Leaf tissue Cl | | | |
|---------------|---------------|---------|-----------------|--------|---------------|-------|
| | | | Portageville | | Novelty | |
| | Portageville | Novelty | V4 | R4 | V4 | R4 |
| | ----- % ----- | | ----- ppm ----- | | | |
| Non-treated | 1.8 | 1.6 | 12,490 | 12,150 | 3,960 | 3,670 |
| Preplant KCl | 1.9 | 2.5 | 14,390 | 14,360 | 3,690 | 3,360 |
| Foliar KCl | 1.8 | 1.6 | 12,750 | 15,890 | 3,650 | 6,730 |
| LSD (p=0.05) | --0.1-- | --0.3-- | -----810----- | | ----1,475---- | |

Table 7. Effect of KCl fertility and fungicide*application timing on yields at Novelty and Portageville in 2006 and 2007.

| Treatment | Yield | |
|--|---------------------|--------------|
| | Novelty | Portageville |
| | ----- bu/acre ----- | |
| KCl fertility | | |
| Non-treated | 57.3 | 45.4 |
| Preplant at 455 lb K/a | 62.4 | 51.2 |
| Foliar at 16 lb K/a | 58.9 | 45.8 |
| LSD (p=0.01) | 1.2 | 3.4 |
| Fungicide*application timing | | |
| V4 | | |
| Non-treated | 58 | 47 |
| Quadris at 6.4 oz/a | 59 | 48 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 58 | 45 |
| Headline at 6 oz/a | 58 | 51 |
| R4 | | |
| Non-treated | 58 | 46 |
| Quadris at 6.4 oz/a | 61 | 47 |
| Quadris at 6.4 oz/a + Warrior at 2.6 oz/a | 63 | 48 |
| Headline at 6 oz/a | 62 | 49 |
| LSD (p=0.01) | 1.9 | NS |

Miscellaneous Tests

Progress Reports

Title:

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

Investigators:

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

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

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

Procedure:

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

The April freeze significantly reduced spring forage growth rate. This may have affected first cutting yields and the establishment of red clover and lespedeza.

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

2007 Results – Yield, nutrient analysis, economic analysis and education and outreach:

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

Nutrient Analysis: Nutrient analysis for protein and fiber have been completed, but the statistical analysis has not been completed. In addition to yield, the production of nutrients, especially energy and protein, are important to beef cattle producers. We will further analyze the yield and quality data by estimating animal performance from each fertilizer treatment.

The results of the mineral profiles from the first two harvests are completed however the results of the October harvest are still pending. A full statistical analysis will be completed to compare and contrast not only the treatments, but also mineral interactions and correlations. High mineral concentrations of one mineral can negatively impact another, so the affected mineral is “tied up” and cannot be digested and utilized fully.

When comparing treatment phosphorus levels of the first two harvests verses requirements of growing/lactating (0.3%) cattle and mature/non-lactating cattle (0.2%), the only treatment meeting the requirements for a mature cow was Treatment 7 from the first harvest. However, this still falls short in fulfilling P requirements for growing/ lactating cattle (Table 3 and 4). While P is not the only mineral we will be analyzing, it will be very interesting to see how soil pH will affect mineral availability as the lime works into the soil over time.

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

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

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

The agronomy specialists, Todd Lorenz, Joni Ross and Rich Hoormann continue to field questions and hear comments about the plots and the results being obtained there. Rich plans on bringing producers from the Montgomery City area in the spring to view the plots. There are additional opportunities at regional meetings, winter workshops and grazing schools to highlight the results being obtained from this study.

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

Table 1. Plot layout and treatment identification.

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

rcl= Red Clover, lesp = Lespedeza

Table 2. 2007 Yield Results.

| Treatment | May | August | October | Total |
|----------------|-------------------|--------------------|-------------------|--------------------|
| 7 – Soil Test | 6370 ^a | 4421 ^a | 1239 ^a | 12029 ^a |
| 5 - Dealer | 3357 ^b | 3178 ^{cd} | 633 ^{cd} | 7168 ^{bc} |
| 8 – Red Clover | 3198 ^b | 2762 ^e | 586 ^{cd} | 6546 ^{cd} |
| 9 - Lespedeza | 3125 ^b | 3234 ^{cd} | 926 ^b | 7285 ^b |
| 6 - Check | 3124 ^b | 3354 ^{bc} | 752 ^{bc} | 7230 ^b |
| 1 - Nitrogen | 3084 ^b | 2591 ^e | 500 ^{de} | 6175 ^{de} |
| 2 - Synergy | 2550 ^c | 2926 ^{de} | 352 ^e | 5828 ^e |
| 4 - Potassium | 1988 ^d | 3443 ^{bc} | 564 ^{cd} | 5994 ^{de} |
| 3 - Phosphorus | 1578 ^e | 3667 ^b | 334 ^e | 5577 ^e |
| | | | | |
| Lime | 3227 ^a | 3302 | 608 | 7229 |
| No Lime | 3078 ^b | 3269 | 699 | 6956 |

Means within each column with different superscripts differ, P<.05.

Table 3. Phosphorus concentration in harvested forage samples taken May 18, 2007.

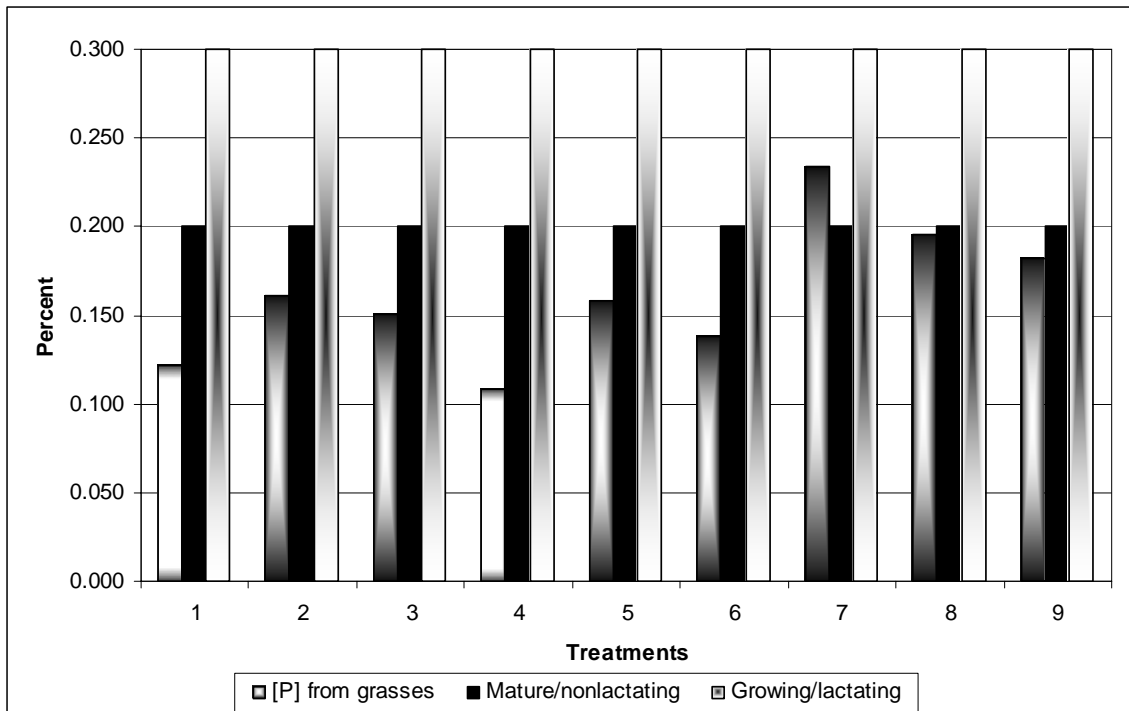


Table 4. Phosphorus concentration in harvested forage samples taken August 9, 2007.

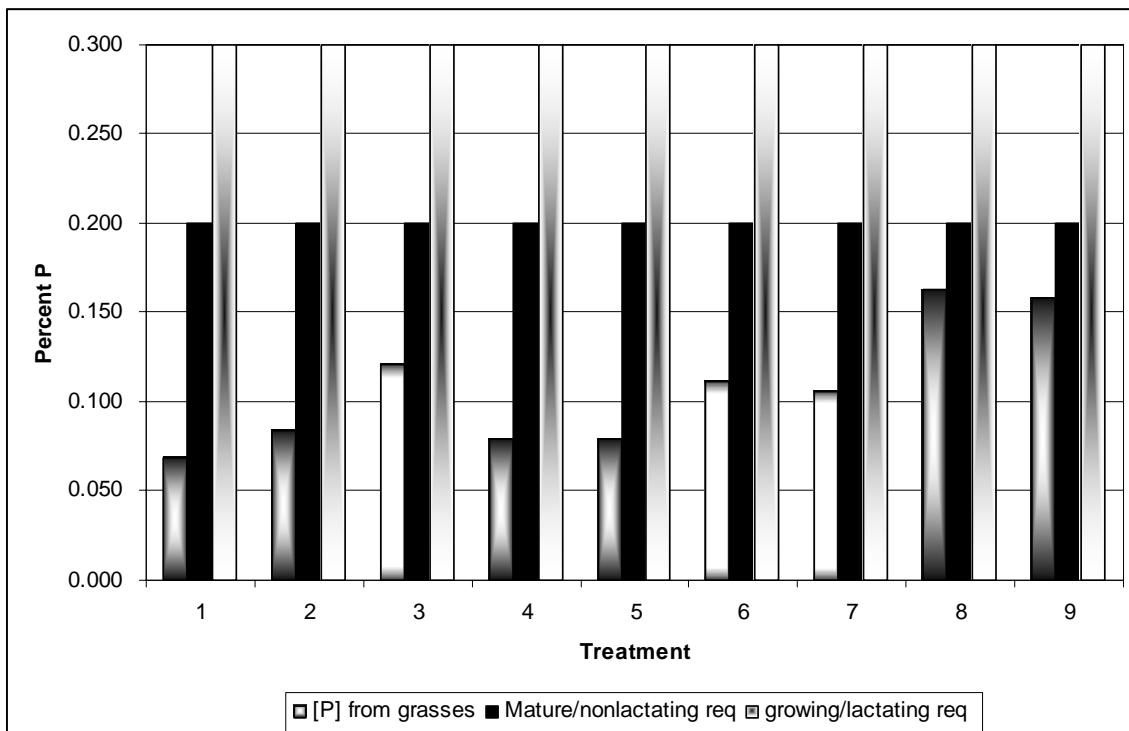


Table 5. 2007 Forage Budget.

| 2007 Forage Budget - Clifton City Forage Plot | | | | | | | | | | |
|---|------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|------------------|-------------------|------------------|
| | | N only | Synergy | P only | K only | Dealer | Check | Soil Test | Red Clover | Lespedeza |
| | | 50-0-0 | 50-30-0 | 0-30-0 | 0-0-30 | 50-30-30 | 0-0-0 | 100-65-60 | 0-65-60 | 0-65-60 |
| Estimated Income/Acre | | | | | | | | | | |
| May yield | lbs/acre | 3084 | 2550 | 1578 | 1988 | 3357 | 3124 | 6370 | 3198 | 3125 |
| August yield | lbs/acre | 2591 | 2926 | 3667 | 3443 | 3178 | 3354 | 4421 | 2762 | 3234 |
| October yield | lbs/acre | 500 | 352 | 334 | 564 | 633 | 752 | 1239 | 586 | 926 |
| Total yield | lbs/acre | 6175 | 5828 | 5578 | 5994 | 7168 | 7230 | 12030 | 6546 | 7285 |
| Income/acre | \$70.59 per ton | \$217.94 | \$205.69 | \$196.87 | \$211.57 | \$253.00 | \$255.17 | \$424.58 | \$231.04 | \$257.11 |
| Operating costs/acre | | | | | | | | | | |
| N - Urea (46% N) | \$0.50 | 25.00 | 25.00 | 0.00 | 0.00 | 25.00 | 0.00 | 70.00 | 0.00 | 0.00 |
| P - Phosphate | \$0.34 | 0.00 | 10.20 | 10.20 | 0.00 | 10.20 | 0.00 | 22.10 | 22.10 | 22.10 |
| K - Potash | \$0.23 | 0.00 | 0.00 | 0.00 | 6.90 | 6.90 | 0.00 | 13.80 | 13.80 | 13.80 |
| Application charge | \$5.00/acre | 5.00 | 5.00 | 5.00 | 5.00 | 5.00 | 0.00 | 10.00 | 5.00 | 5.00 |
| Fertilizer cost/Acre | | \$30.00 | \$40.20 | \$15.20 | \$11.90 | \$47.10 | \$0.00 | \$115.90 | \$40.90 | \$40.90 |
| Crop supplies | | 4.45 | 4.45 | 4.45 | 4.45 | 4.45 | 4.45 | 4.45 | 4.45 | 4.45 |
| Custom hire & rental | | 13.50 | 13.50 | 13.50 | 13.50 | 13.50 | 13.50 | 13.50 | 13.50 | 13.50 |
| Machinery fuel | | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 | 4.94 |
| Machinery repairs & maintenance | | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 |
| Operator & hired labor | | 6.38 | 6.38 | 6.38 | 6.38 | 6.38 | 6.38 | 6.38 | 6.38 | 6.38 |
| Operating interest @ 8.75% x 1/2 year | | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 | 3.79 |
| Total Operating Costs/Acre | | \$69.72 | \$79.92 | \$54.92 | \$51.62 | \$86.82 | \$39.72 | \$155.62 | \$80.62 | \$80.62 |
| Income Over Operating Cost/Acre | | \$148.22 | \$125.77 | \$141.95 | \$159.95 | \$166.18 | \$215.45 | \$268.96 | \$150.42 | \$176.49 |
| Ownership Costs/Acre | | | | | | | | | | |
| Farm business overhead | | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 | 2.63 |
| Machinery overhead | | 7.86 | 7.86 | 7.86 | 7.86 | 7.86 | 7.86 | 7.86 | 7.86 | 7.86 |
| Machinery depreciation | | 8.31 | 8.31 | 8.31 | 8.31 | 8.31 | 8.31 | 8.31 | 8.31 | 8.31 |
| Real estate charge | | 28.71 | 28.71 | 28.71 | 28.71 | 28.71 | 28.71 | 28.71 | 28.71 | 28.71 |
| Total Ownership Cost/Acre | | \$47.51 | \$47.51 | \$47.51 | \$47.51 | \$47.51 | \$47.51 | \$47.51 | \$47.51 | \$47.51 |
| Income Over Total Cost/Acre | | \$100.71 | \$78.26 | \$94.44 | \$112.44 | \$118.67 | \$167.94 | \$221.45 | \$102.91 | \$128.98 |
| Hay yields and hay price are on a 100% dry matter basis. Hay valued at \$70.59 dry matter basis equals \$60 per ton as-fed at 85% dry matter. | | | | | | | | | | |
| Prepared by Randa Brunkhorst, MU Extension Agricultural Business Specialist | | | | | | | | | | |

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

Kevin Bradley and Peter Scharf

Investigators:

| | |
|--------------------------------|---------------------------------|
| Kevin Bradley | Peter Scharf |
| Assistant Professor | Associate Professor |
| State Weed Scientist | State Soil Fertility Specialist |
| Division of Plant Sciences, MU | Division of Plant Sciences, MU |

Accomplishments in 2007:

- Lime and iron sulfate applications were made in late winter/early spring to maintain the desired range in soil pH levels. The soil pH treatments in this experiment are: 1) high lime, 2) low lime, 3) high acid (iron sulfate), 4) low acid (iron sulfate), and 5) 'no amendment' (limed just enough to maintain initial pH). Lime was applied to the 'high lime' plots and iron sulfate was applied to the 'high acid' plots. These applications were made based on the fall 2006 pH in each plot, as these plots had been maintained with varying soil pH levels at the Bradford Research and Extension Center for a number of years. A small lime application was also made to the 'no amendment' treatment (the first in 9 years) to counteract the acidifying effect of nitrogen fertilizer over that span and return the treatment to its original pH.
- One-half of the research area was no-till planted into corn while the other half of the research area was no-till planted into soybeans. The experiments were arranged in a split-plot design with four replications of four herbicide treatments and five soil amendment treatments/pH ranges. Soon after corn planting, a preemergence application of Dual II Magnum[®] (*S*-metolachlor) was made to reduce early season weed competition and reduce overall weed pressure. Dual II Magnum[®] is also labeled for use in soybean, thus there is no chance of carryover injury to soybean in 2008 as a result of applications of this herbicide. A Roundup Ready[®] corn and soybean hybrid was also utilized in these experiments in order to keep all plots weed-free throughout the season with applications of glyphosate (Roundup[®]).
- Herbicide treatments evaluated for carryover potential in 2008 were applied on June 21st to corn that was 29- to 30-inches tall. The herbicide treatments applied to each soil amendment treatment were 1) Callisto[®] at 3 fluid ounces per acre, 2) Impact[®] at 0.75 fluid ounces per acre, 3) Laudis[®] at 3 fluid ounces per acre, and 4) an untreated control.
- One month after the herbicide treatments, soil pH was measured in each plot. Results from the soil testing laboratory indicate that the soil amendment treatments listed above provided the following average soil salt pH values for the various treatments: 1) high lime = 7.1, 2) low lime = 6.6, 3) high acid = 4.3, 4) low acid = 5.0, 5) no amendment = 5.9.
- Corn and soybeans were harvested from all plots with a small plot combine and grain yields determined. Although this first year was a set-up year in this experiment, yields were taken in order to determine the response of corn and soybean yields to the varying soil pH's that have been established. As expected, the only factor that had a significant influence on corn or soybean yield in the 2007 experiments was soil pH. The following table provides these results:

| Treatment | Yield ^a | |
|---|--------------------|---------|
| | Corn | Soybean |
| | ----- Bu / A ----- | |
| Low Lime (avg. pH _s 6.6) | 157 a | 43 b |
| High Lime (avg. pH _s 7.1) | 155 a | 45 a |
| Low Acid (avg. pH _s 5.0) | 156 a | 44 ab |
| High Acid (avg. pH _s 4.3) | 147 b | 38 c |
| No Soil Amendment (avg. pH _s 5.9) | 150 ab | 43 b |
| ^a Means followed by the same letter are not different, P ≤ 0.05. | | |

Objectives for 2008:

- All corn plots from 2007 will be rotated into soybeans. A Roundup Ready[®] soybean variety will be no-till planted and early-season soybean stunting and injury in response to the previous corn herbicide treatments and pH levels will be evaluated visually and by measuring the heights of soybeans in response to each treatment. All soybean plots will be maintained weed-free throughout the season and soybeans will be harvested with a small plot combine.
- Conversely, all soybean plots from 2007 will be no-till planted with corn and the same four triketone herbicide treatments discussed previously will be applied to plots having the variation in soil pH values. As in the first year experiments, corn will be harvested and grain yields determined.

Sensor-based Sidedressing for Cotton

Peter Scharf, Gene Stevens and David Dunn

Plant Sciences Division, University of Missouri

Collaborator: Earl Vories

USDA Agricultural Research Service, Columbia/Portageville, MO

Luciane Oliveira, Graduate Student

Objectives:

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

- Extend promising results from 2006.
- Determine sensor model, wavelength, and height that give the best prediction of sidedress N need.
- Determine the best growth stage for sensor-based sidedressing; depends on:
 - Accuracy of prediction (probably will be better later)
 - Ability to produce full yield (need to be careful not to wait too long).

Accomplishments for 2007:

- The 2007 experiments were conducted at the University of Missouri Delta Center and Rhodes farm on fields with 3 soil textures: sandy loam, silt loam, and clay.
- The N treatments consisted of:
 - Check plot received no N.
 - One treatment received a high N rate at planting (reference plot).
 - Most treatments received 50lbs N /acre at planting.
 - At the early square stage, treatments received 0 to 150 lbs of N/acre.
 - Some treatments received N applications at early flower.
- Sensors used: Cropscan passive sensor (Cropscan), Crop Circle active light sensor (Holland Scientific), and Greenseeker active light sensor (N-Tech).
- Sensor Readings taken at 3 growth stages: early square, mid square and early bloom.
- Chlorophyll meter readings and samples for leaf N and petiole tests were taken for the three growth stages.
- Sensor readings taken at 10, 20, and 30 inches height above the cotton canopy.
- Analysis to relate optimal N rate to sensor readings are currently being done on the 2007 data:
 - Quadratic-plateau regression used to describe yield response to N rate.
 - Optimal N rate calculated from the response functions.
 - Optimal N rate regressed against sensor readings to determine the sensor type, wavelength, and growth stage that give the best prediction of optimal N rate.

Expected Results for 2007

Since we are still working on the 2007 analysis to relate optimal N rate to sensor readings, we can only comment on what we are expecting the results to be based on the 2006 results.

- Reflectance sensor readings will probably relate well to optimum N rate.
 - Potential for accurate on-the-go prediction.
 - All three sensor types will be potentially useful.
 - All three heights will be suited for N sidedressing, but 20" will seem more reliable.
- Visible/NIR ratios or NIR alone (relative to values from high-N plots) will have the strongest relationship to optimal N rate.

- Early square sensor readings might be too early to use and will generally not be well correlated to optimal N rate.
- Mid square or early flower sensor readings will produce more accurate N rate predictions on the go.

Objectives for 2008:

- Repeat the experiments from 2006 and 2007.
- Relate optimal N rate to sensor readings for the 2007 and 2008 data.
- Determine the best growth stage, sensor height, model, and wavelength for sensor-based sidedressing for both 2007 and 2008.
- Develop accurate on-the-go sidedress N rate recommendations based on sensor readings for 2006, 2007, and 2008 results.

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

Dale Blevins

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

Objective: to determine if tall fescue seed production in Missouri can be increased by late summer phosphorus (P) and ammonium (NH_4^+) applications in a strip-kill management system. In several plant species, a fall NH_4^+ application increased production of the hormone, cytokinin, by root tips, and this hormone triggered reproductive growth that culminated in greater seed production (Marschner 1995). This project is important, in that, Missouri has 13 million acres of tall fescue pastures, and leads the nation in common tall fescue seed production. This problem is that our seed yields are much lower than those in Oregon. In Oregon, tall fescue is grown in rows, like wheat, solely for seed production, whereas in Missouri most of our seed production comes from tall fescue pastures. In earlier experiments, we dug tall fescue roots from established pasture monthly from October to April, and found an extremely thick root mass. The mass of roots was so thick that the plant looked “root-bound” and pastures needed to be aerated, like lawns, in the fall. In these earlier studies, we used stripkill to renovate the dense root system of tall fescue pastures, and restore new root growth. New root tips make the hormone, cytokinin, that is important for seed production.

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

2007 Results: The sprayer designed to kill approximately 7.5” strips in 10’ wide plots of tall fescue was used in fall 2006 and worked well (strips were clearly visible in spring 2007). Unfortunately, a late winter ice storm damaged plants, especially at Bradford Farm, and this undoubtedly lower seed yields. Burn on the top 1/3 of leaf blades was clearly visible in plants from the plots at Bradford Farm (Figs. 1 & 2). Although the ice storm lowered yields at both sites, seed yields at the SWC were much above the state average, and responded to treatments (Fig. 3). At the SWC, some stripkill plots produced over 500 lbs seed/area with an average yield of almost 400 lbs/acre. Seed yield from the N and P treated stripkill plots was about 250 lbs/acre greater than that of the control plots. At \$0.53/lb, that is an increase of \$132.50/acre! At Bradford Farm, none of the treatments produced positive results and seed yields were low, reflecting the winter ice damage (Fig. 4). The 100 seed weights were not altered by treatments, although seed from the SWC were slightly heavier than those from Bradford Farm (Figs. 5 & 6). The weight of 100 seeds from the SWC averaged 0.2 g and those from Bradford averaged just less than 0.2 g.

Final six months of the study: The main thing left to do in the study is the second year seed harvest in June 2008. Seed will be harvested with the 5' plot combine and seed yield will be calculated. The 100 seed weight will also be determined. Then results of this two year study will be used for preparation of a refereed journal article.

Figure 1. Tall fescue leaf tip burn following the ice storm in stripkill seed production plots at Bradford Farm near Columbia in spring 2007.



Figure 2. Close-up pictures of winter damage to tall fescue in the strip-kill plots at Bradford Fall in early spring of 2007.



Figure 3. Tall fescue seed year from stripkill N and P plots at the SW Center near Mt Vernon. On the x-axis, the top row 0 = no N added, 1 = 100 lbs N/acre as urea beads, 2 = 100 lbs N as NH_4NO_3 and 3 = 100 lbs N/acre as urea, the middle row 0 and 100lb P/acre and the lowest row, cont = control and sk = stripkill.

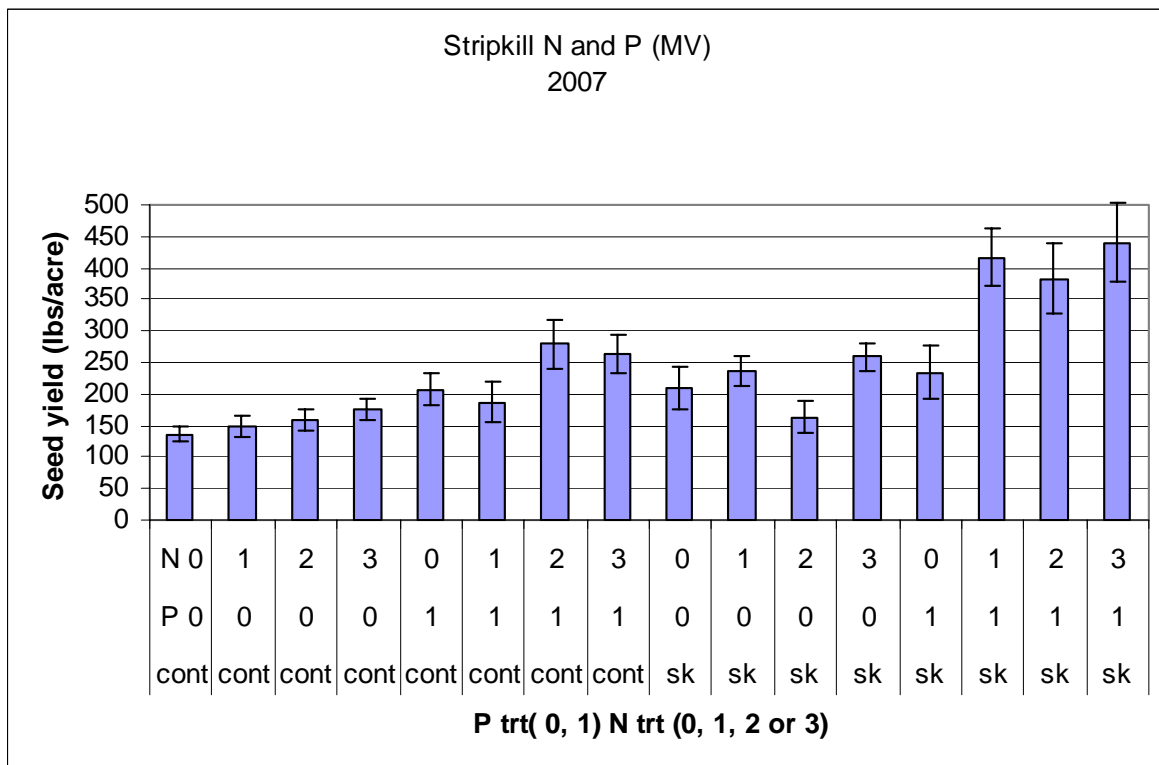


Figure 4. Tall fescue seed yield from stripkill N and P plots at the Bradford Farm near Columbia. . On the x-axis, the top row 0 = no N added, 1 = 100 lbs N/acre as urea beads, 2 = 100 lbs N as NH_4NO_3 and 3 = 100 lbs N/acre as urea, the middle row 0 and 100lb P/acre and the lowest row, cont = control and sk = stripkill.

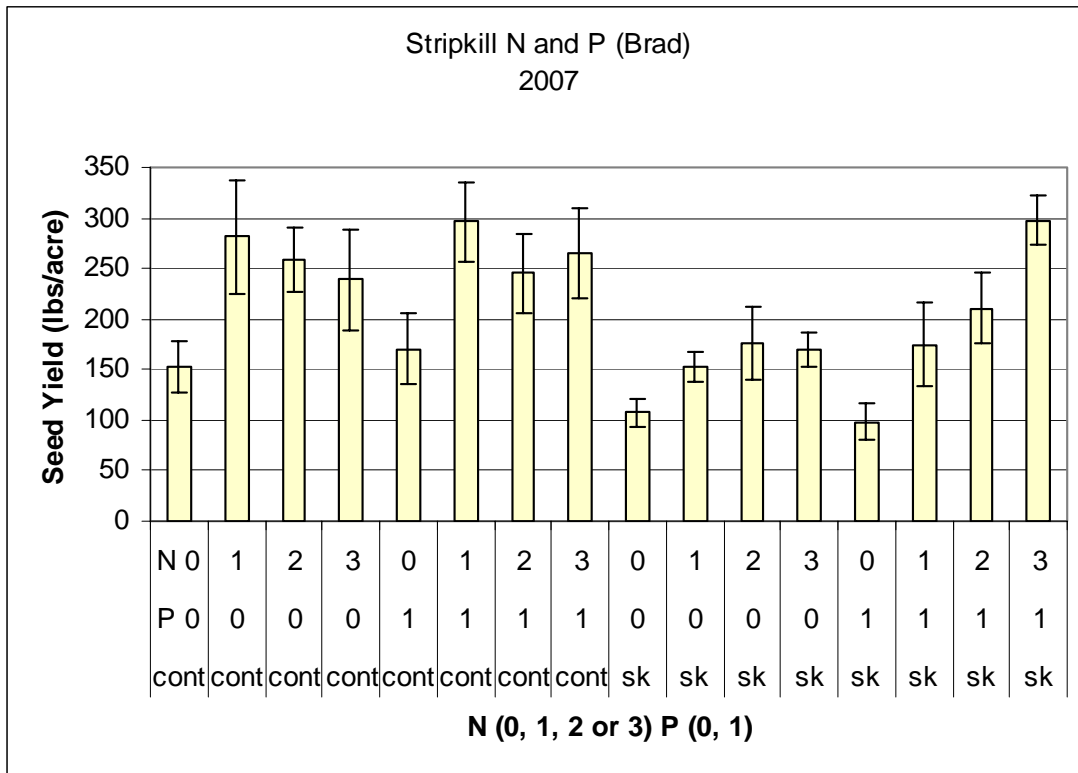


Figure 5. Seed weight of tall fescue harvested from the stripkill N and P experiments at the SWC near Mt Vernon. . On the x-axis, the top row 0 = no N added, 1 = 100 lbs N/acre as urea beads, 2 = 100 lbs N as NH₄NO₃ and 3 = 100 lbs N/acre as urea, the middle row 0 and 100lb P/acre and the lowest row, cont = control and sk = stripkill.

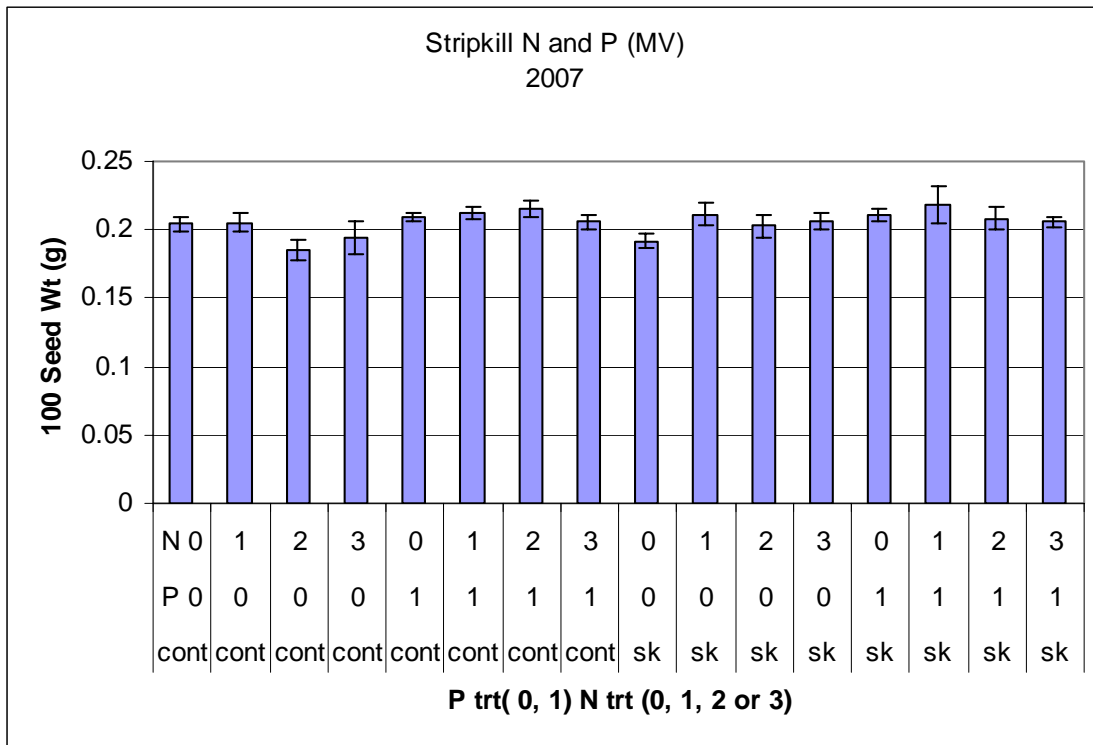
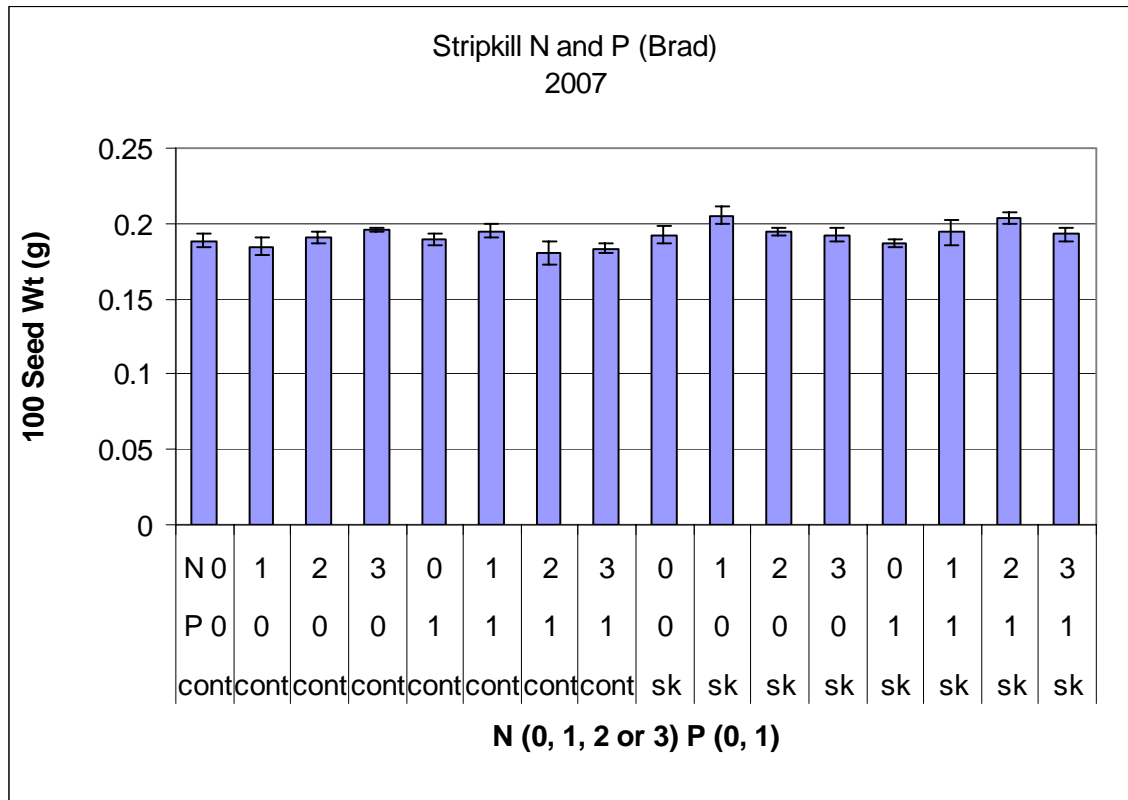


Figure 6. Seed weight of tall fescue harvested from the stripkill N and P experiments at Bradford Farm near Columbia. . On the x-axis, the top row 0 = no N added, 1 = 100 lbs N/acre as urea beads, 2 = 100 lbs N as NH₄NO₃ and 3 = 100 lbs N/acre as urea, the middle row 0 and 100lb P/acre and the lowest row, cont = control and sk = stripkill.



Soil Sampling and Fertility Build-up Management

Gene Stevens and David Dunn

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

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

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

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

Materials and Methods

Rice/Soybean Rotation

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

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

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

collected from each plot and oven dried to calculate moisture content and analyzed for N, P, and K content, crude protein, and acid and neutral detergent fiber (ADF and NDF, respectively).

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

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

$$\text{Build-up P}_2\text{O}_5 = \frac{110(X_d^{1/2} - X_o^{1/2})}{\text{Years}} \quad \text{Build-up K}_2\text{O} = \frac{75.5(X_d^{1/2} - X_o^{1/2})}{\text{Years}}$$

X_d = target soil test level in lb P or K per acre

X_o = observed soil test level in lb P or K per acre

Years = desired time period for build-up

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

Results and Discussion

Rice/Soybean Rotation

The 2007 growing season is the last buildup year for the four year program. In 2008, we will begin a maintenance program equivalent to crop removal as we did with the one year buildup beginning in 2005. Averaged across years, the nitrogen only untreated check produced 16 to 24 bushels per acre less rice than buildup programs and 10 to 13 bushels per acre less soybean (Table 2). Initially, we were concerned that using rice target thresholds would decrease soybean yields and that shorter buildup time would produce higher yields than long buildups but that does not appear to be happening.

Fescue. After three years, fertilizer treatments increased soil test P levels in plots compared to the untreated and N only checks, with soil test levels for plots with 1-year build-up being above the target 40 lb Bray-1 P/acre (Table 3). The 4 and 8-year build-up P treatments were below the target levels; however, they are on track to be above the target level by the end of their respective build-up periods. Soil K levels for all treatments, including the one year build-up program, were below the original 162 lb K/acre levels measured in 2004 (Table 3).

Tissue P and K contents in first cutting hay from 2004 through 2006 are shown in Table 4.

Converting % K into pounds K_2O per ton, the average observed K removal across treatments and years was 54 lb K_2O /ton compared to the MU removal estimate of 34 lb K_2O /ton. This difference was a contributing factor to the failure of the one year build-up program to raise soil test K values above the target level. The highest K removal occurred in the first year (2004) with the 1-year build-up program (75 lb K_2O /ton). In 2007, 1-year, 4-year, and 8-year programs produced about 1 ton per acre more hay than untreated plots and 0.4 to 0.7 tons more than the N only check (Table 5).

Converting % P in hay to pounds P_2O_5 /ton shows that the MU removal value for P (9 lb P_2O_5 /ton) is close to the observed average across three years in this study (7 lb P_2O_5 /ton). The highest P removal also

occurred in the first year (2004) with the 1-year build-up program (14 lb P₂O₅/ton). These results suggest that luxury plant consumption of P and K may occur when large amounts of fertilizer are applied at one time to correct low soil test levels.

Crude protein in the harvested forage was significantly lower in untreated check plots compared with the average crude protein in fertilized treatments (Table 6). Crude protein in hay from N only plots was not different from plots receiving P and K; however, hay from N only plots contained lower ADF and NDF than hay from plots receiving P and K fertilizer. This result suggests that farmers with high fertility fescue fields should cut hay earlier and more often to maximize quality.

Rainfall at the test site was unusually low in July and August of 2005 and 2006. In 2006, nitrogen fertilizer alone increased fescue dry matter yields 33 percent compared to the untreated check (Table 3). Applying P and K fertilizer with nitrogen increased hay yields an additional 35 percent, suggesting that P and K fertilizer helped produce fescue plants with healthy root systems that withstood drought better than plants in low fertility plots.

We concluded that a 4-year build-up program can be used by farmers without sacrificing hay yields in the first three years. No significant fescue hay yield increase was observed when using a 1-year build-up program compared to the 4-year build-up program (Table 3). However, in 2004, hay yield was significantly higher with 1-year build-up P and K than the 8-year build-up program. Cumulative costs of fertilizer build-up programs for the first three years are shown in Table 4. The most expensive program for the first three years was the 1-year build-up program. However, most of this cost occurred in 2004 and for the rest of the study, the only fertilizer that will be applied according to the 1-year build-up program will be to off-set crop removal. By the end of the study, the total P and K fertilizer costs, not including interest, should be about the same for 1, 4, and 8-year programs. However, a farmer could have part of the large up-front money used to purchase fertilizer in the 1-year program earning interest in the bank or invested in some other enterprise on the farm.

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

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

† Only crop removal P and K applied.

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

| Planted Crop | Buildup program Soil crop target | 2007 rates | | 2004 | 2005 | 2006 | 2007 | Avg. |
|--------------|-------------------------------------|-------------------------------|------------------|-------------------|------|------|------|------|
| | | P ₂ O ₅ | K ₂ O | | | | | |
| Rice | | ---lb/acre--- | | -----bu/acre----- | | | | |
| | N only check | 0 | 0 | 168 | 142 | 136 | 133 | 145 |
| | 1-year/rice target | 41† | 38† | 192 | 160 | 133 | 192 | 169 |
| | 4-year/rice target | 52 | 69 | 193 | 161 | 136 | 175 | 166 |
| | 8-year/rice target | 45 | 67 | 187 | 159 | 143 | 174 | 166 |
| | 1-year/soybean target | 41† | 38 | 172 | 149 | 138 | 189 | 162 |
| | 4-year/soybean target | 74 | 130 | 170 | 161 | 150 | 188 | 167 |
| | 8-year/soybean target | 56 | 97 | 165 | 155 | 134 | 190 | 161 |
| Soybean | Untreated check | 0 | 0 | 40 | 39 | 53 | 37 | 42 |
| | 1-year/rice target | 38† | 65† | 53 | 47 | 63 | 44 | 52 |
| | 4-year/rice target | 38 | 65 | 53 | 49 | 60 | 45 | 52 |
| | 8-year/rice target | 38 | 65 | 51 | 45 | 62 | 43 | 50 |
| | 1-year/soybean target | 38† | 65 | 58 | 54 | 57 | 49 | 55 |
| | 4-year/soybean target | 58 | 39 | 51 | 46 | 55 | 44 | 49 |
| | 8-year/soybean target | 50 | 32 | 51 | 43 | 57 | 48 | 50 |

† Only crop removal P and K was applied to 1-yr buildup treatment in 2005 and 2006.

Table 3. Soil test P and K levels after three years of P and K build-up treatments. Samples were collected in March 2007 before spring fertilizer treatments were applied.

| Build-up Program† | Soil test levels after 3 years | |
|-------------------|--------------------------------|-----|
| | P | K |
| | ---lb/acre--- | |
| Check | 13 | 108 |
| N only | 14 | 97 |
| 1 yr build-up | 50 | 149 |
| 4 yr build-up | 35 | 110 |
| 8 yr build-up | 26 | 108 |

† Targets are 40 lb Bray-1 P/acre and 193 lb ammonium acetate-extractable K/acre.

Table 4. Annual dry matter hay yields and P and K content in first cutting hay in 2004, 2005, and 2006.

| Build-up Program | 2004 | | | 2005 | | | 2006 | | |
|--------------------|----------|--------|--------|----------|--------|--------|----------|--------|--------|
| | Hay | P | K | Hay | P | K | Hay | P | K |
| | ton/acre | -----% | -----% | ton/acre | -----% | -----% | ton/acre | -----% | -----% |
| Check | 1.5 | 0.08 | 2.0 | 0.9 | 0.08 | 2.2 | 0.7 | 0.05 | 1.8 |
| N only | 2.1 | 0.13 | 2.4 | 1.3 | 0.07 | 1.6 | 1.0 | 0.09 | 1.9 |
| 1-year | 3.0 | 0.31 | 3.1 | 2.0 | 0.18 | 2.2 | 1.6 | 0.18 | 2.2 |
| 4-year | 2.8 | 0.25 | 2.7 | 2.0 | 0.16 | 2.2 | 1.6 | 0.18 | 2.0 |
| 8-year | 2.6 | 0.19 | 2.7 | 1.9 | 0.15 | 2.3 | 1.5 | 0.15 | 2.3 |
| LSD _{.05} | 0.4 | 0.07 | 0.8 | 0.3 | 0.05 | 0.5 | 0.2 | 0.05 | n.s. |

N.S.= not significant at the 0.05 probability level.

Table 5. Dry matter hay yields from two cuttings in 2007.

| Build-up Program | June 7 | Oct 30 | Average |
|------------------|--------------------|--------|---------|
| | -----ton/acre----- | | |
| Check | 0.4 | 0.6 | 1.0 |
| N only | 0.6 | 0.8 | 1.4 |
| 1-year | 0.9 | 0.9 | 1.8 |
| 4-year | 1.1 | 1.0 | 2.1 |
| 8-year | 1.0 | 1.1 | 2.1 |

Table 6. Cumulative effect of build-up programs (2004+2005+2006) on total fertilizer cost and fescue hay yield.

| Build-up Program | Cumulative for three years | | | | | Mean across years†† | | |
|--------------------|----------------------------|-------------------------------|------------------|----------|-----------|---------------------|------|------|
| | N | P ₂ O ₅ | K ₂ O | Cost† | Hay Yield | CP | ADF | NDF |
| | | ---lb/acre--- | | per acre | ton/acre | | | |
| Check | 0 | 0 | 0 | \$0 | 3.1 | 9.0 | 34.5 | 63.6 |
| N only | 240 | 0 | 0 | \$89 | 4.4 | 11.6 | 33.2 | 62.5 |
| 1-year build | 240 | 441 | 291 | \$282 | 6.6 | 10.8 | 35.3 | 64.2 |
| 4-year build | 240 | 351 | 270 | \$251 | 6.4 | 10.8 | 34.9 | 64.0 |
| 8-year build | 240 | 195 | 237 | \$197 | 6.1 | 12.8 | 35.2 | 63.9 |
| LSD _{.05} | | | | | 0.4 | 2.3 | 1.1 | 1.2 |

† Costs are based on \$0.37 per lb N, \$0.30 per lb P₂O₅, \$0.21 per lb K₂O.

†† Mean hay analyses values from subsamples collected at first cutting each year.

CP=crude protein, ADF= acid detergent fiber, NDF= neutral detergent fiber.

Summary of Soil Fertility Status in Missouri by County, Soil Region and Cropping Systems

M. V. Nathan, Y. Sun, and D. Dunn

Abstract:

The soil fertility summary provides a valuable index of the soil fertility status of Missouri farmland by county, soil region, and cropping system, and identifies broad soil fertility trends in the state over years. The soil fertility summary also helps in evaluating fertilizer, lime, and manure management practices, in identifying areas that need additional soil fertility research, and in recognizing areas which pose a potential threat to water quality. The soil fertility summary of over 252,000 agronomic crop soil samples analyzed by the University of Missouri Soil Testing labs for the period of 1996-2006 are presented in this report. Soil test summaries for pHs, phosphorus and potassium based on cropping system, soil region, and county and statewide trends are discussed. A higher percentage of adequately fertilized fields occurs in the intensively cropped Bootheel region. Alternatively, the highest percentage of low fertility soils occurs in the highly weathered Ozarks region. Soil fertility summary by cropping options clearly indicates that corn, soybeans and wheat fields are better managed than forage crops.

Introduction:

During the past decade considerable emphasis has been placed on nutrient management and water quality. Soil testing is a tool that allows growers to plan their nutrient and soil amendment (lime) inputs based on soil test levels. The soil test summary provides invaluable information regarding soil test status at the county, soil region and at the state wide levels. These data will be helpful to researchers and educators for developing educational programs and working on state and federal regulatory programs.

For soils to be productive, they must be fertile. Soil tests indicate the relative capacity of soil to provide nutrients to plants. Therefore, the soil test summary can be viewed as an indicator of the nutrient supplying capacity of soils in Missouri. The summary of soil test data from 1996-2006 provides a comparison of soil test levels over the years. The value of statewide soil test summaries lies in calling attention to broad nutrient needs and challenges and in motivating educational action programs. (Fixen, et. al., 2005).

Two major uses of soil test summaries are (i) to evaluate fertilizer and lime recommendations, and (ii) to encourage the proper use of fertilizer and lime. (Donahue, 1987). Various types of soil test summaries can be prepared to convey the information on soil nutrient levels. Soil fertility status can be expressed using “low”, “medium” and “high” nutrient ranges by comparing the percent needing fertilizer and lime. One can make single-year comparisons to evaluate the need for fertilizer and lime or make multi-year comparisons to evaluate how needs are changing. Summaries can be made on a county, regional, or statewide basis.

Objectives:

1. To summarize the soil test data for samples analyzed by MU soil testing labs from 1996 – 2006, by counties, soil region and cropping system.
2. To study the trend in soil test data for soil test pH, phosphorus, potassium over 10 years in Missouri soils.
3. Use of the soil test data summary in Extension Education Programs to enhance awareness and to improve nutrient and lime management practices amongst producers to optimize production.

Methodology:

The soil fertility summary consists of over 252,000 agronomic crop soil samples analyzed by the University of Missouri Soil Testing labs for the period of 1996-2006. The percentage of samples falling under low, medium, high, and very high levels for pH, P and K were calculated by county, soil region, and cropping option. The statewide trend in pH, P and K over the past decade was studied. Soil fertility data summary and statewide trends are presented in graphical and table format. Relationship between soil test P data and the mean total P in reservoirs in SW Missouri was calculated. The soil regions used in Missouri in summarizing the soil fertility status are presented in Fig. 1.

Soil Test Procedures and Rating:

pH: 1:1 (0.01 M CaCl₂)

Low: ≤ 5.3 ; Medium: 5.4 -6.0; High: ≥ 6.1

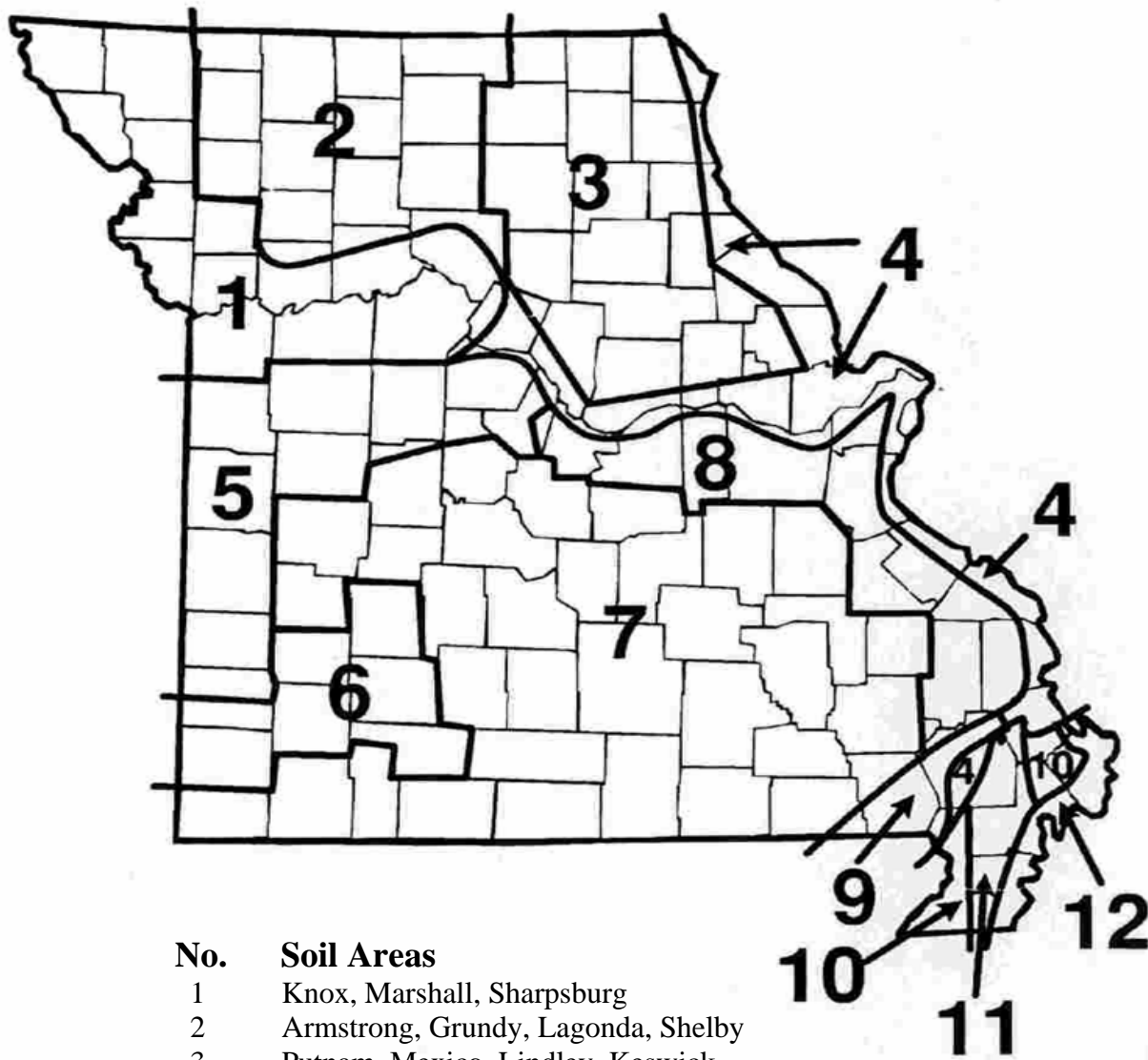
P: Bray 1 P mg/kg

Low: ≤ 11 ; Medium: 12 -22; High: 23-35; Very High: ≥ 36

K: Ammonium Acetate Extractable K mg/kg

Low: ≤ 55 ; Medium: 56 -110; High: 111-165; Very High: ≥ 166

Fig. 1: Missouri Soil Regions



| No. | Soil Areas |
|-----|-------------------------------------|
| 1 | Knox, Marshall, Sharpsburg |
| 2 | Armstrong, Grundy, Lagonda, Shelby |
| 3 | Putnam, Mexico, Lindley, Keswick |
| 4 | Menfro, Winfield, Wrengart |
| 5 | Barden, Hartwell, Parsons, Sampsel |
| 6 | Goss, Tonte, Crelton |
| 7 | Clarksville, Viration, Wilderness |
| 8 | Olred, Goss, Reuter, Union, Wrenger |
| 9 | Bosket, Calhoun, Tuckerman |
| 10 | Maden, Scotco |
| 11 | Sharkey |
| 12 | Commerce, Caruthersville |

Fig. 3: Dominant Soil pH levels by County in Missouri (1996-2006)

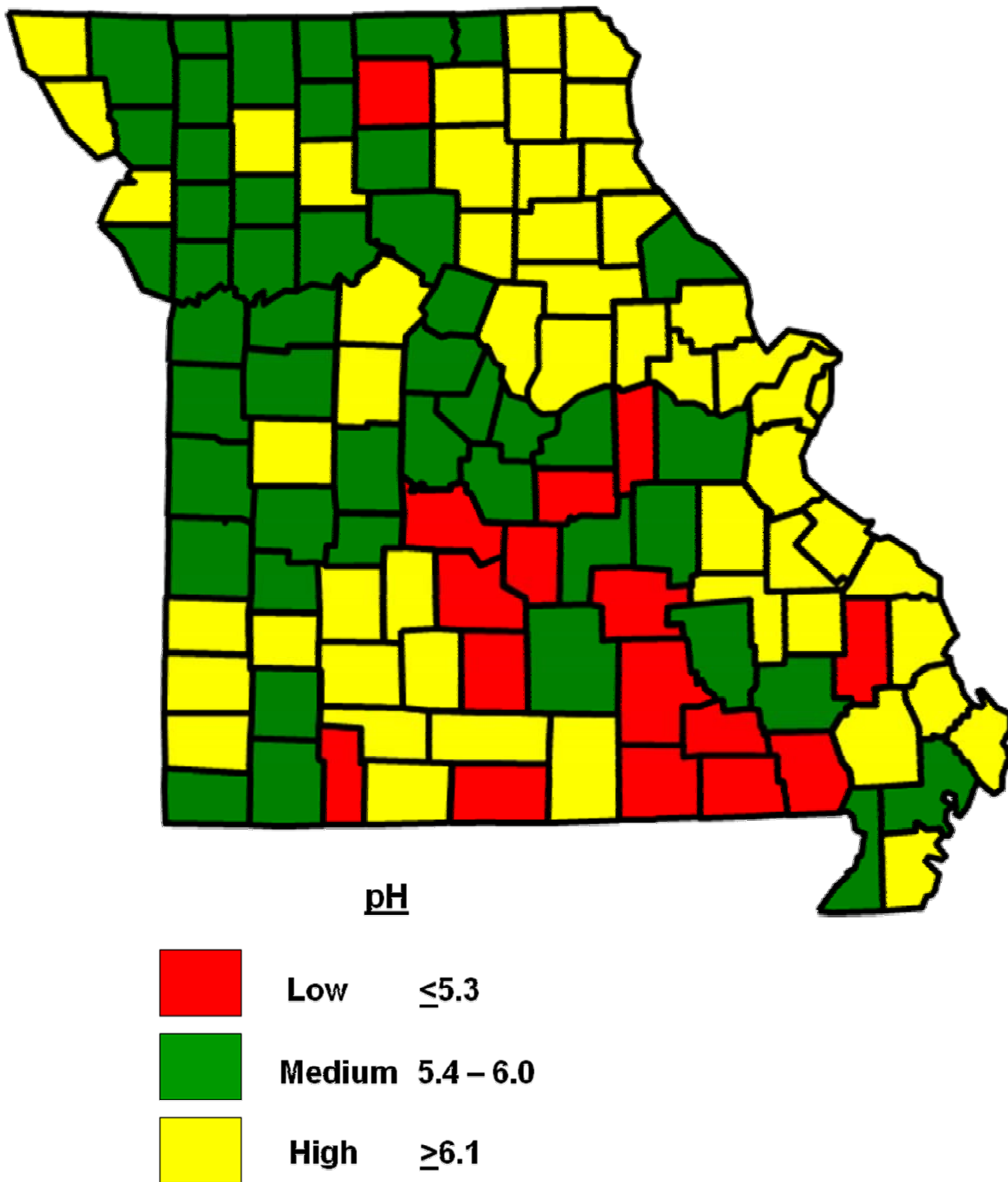


Fig. 4: Dominant Soil Test P levels by County in Missouri (1996-2006)

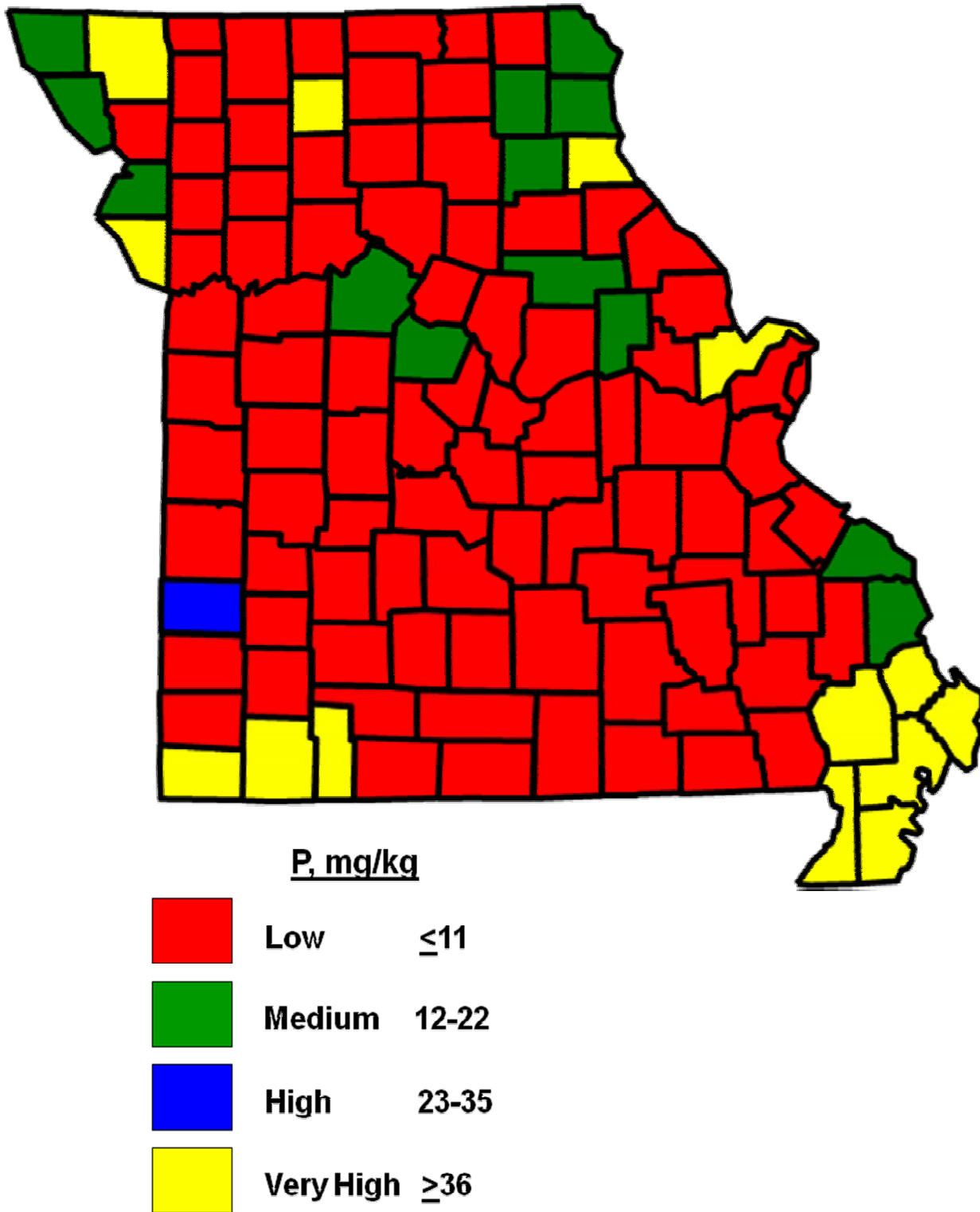
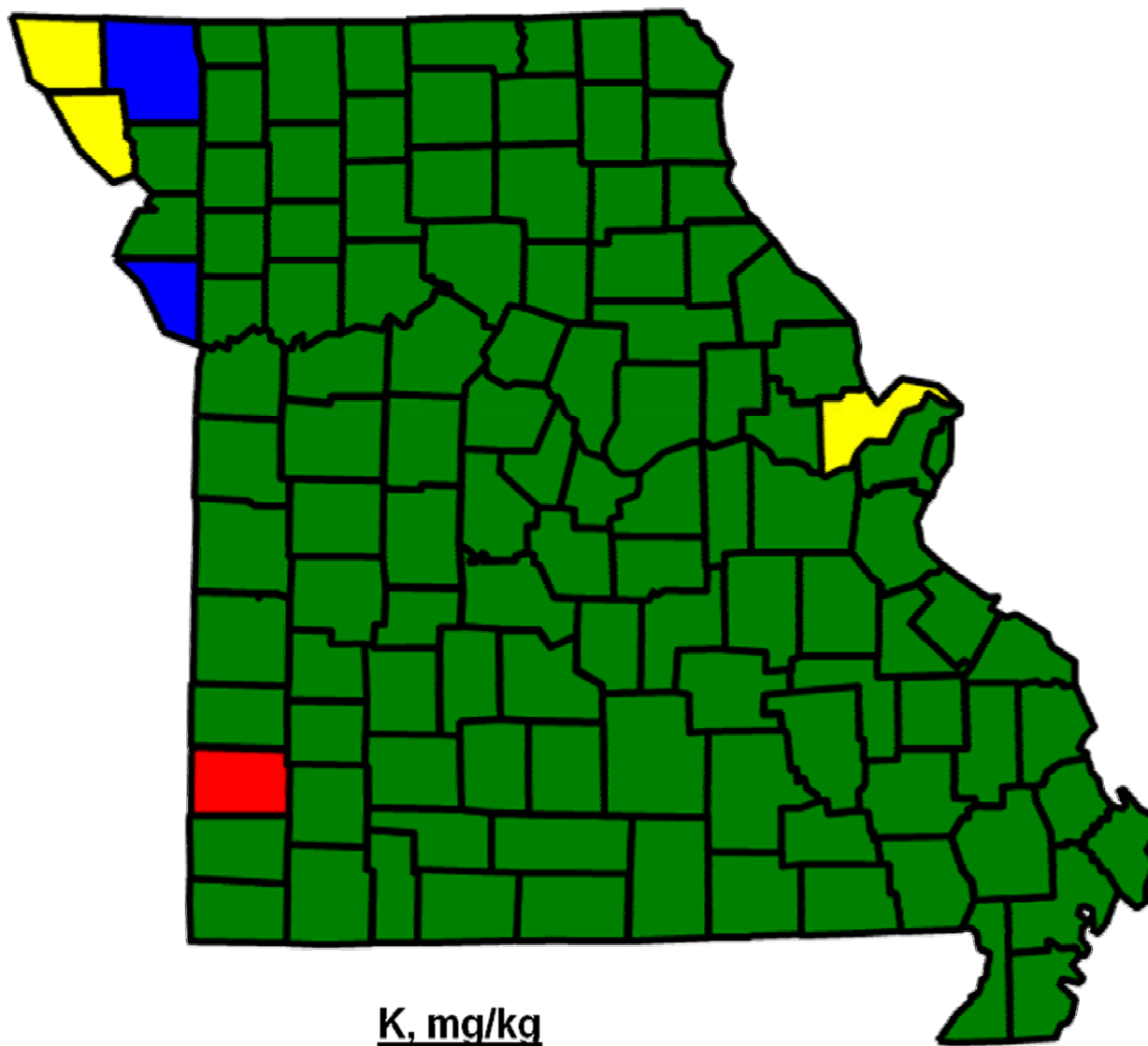






Fig. 5: Dominant Soil Test K levels by County in Missouri (1996-2006)



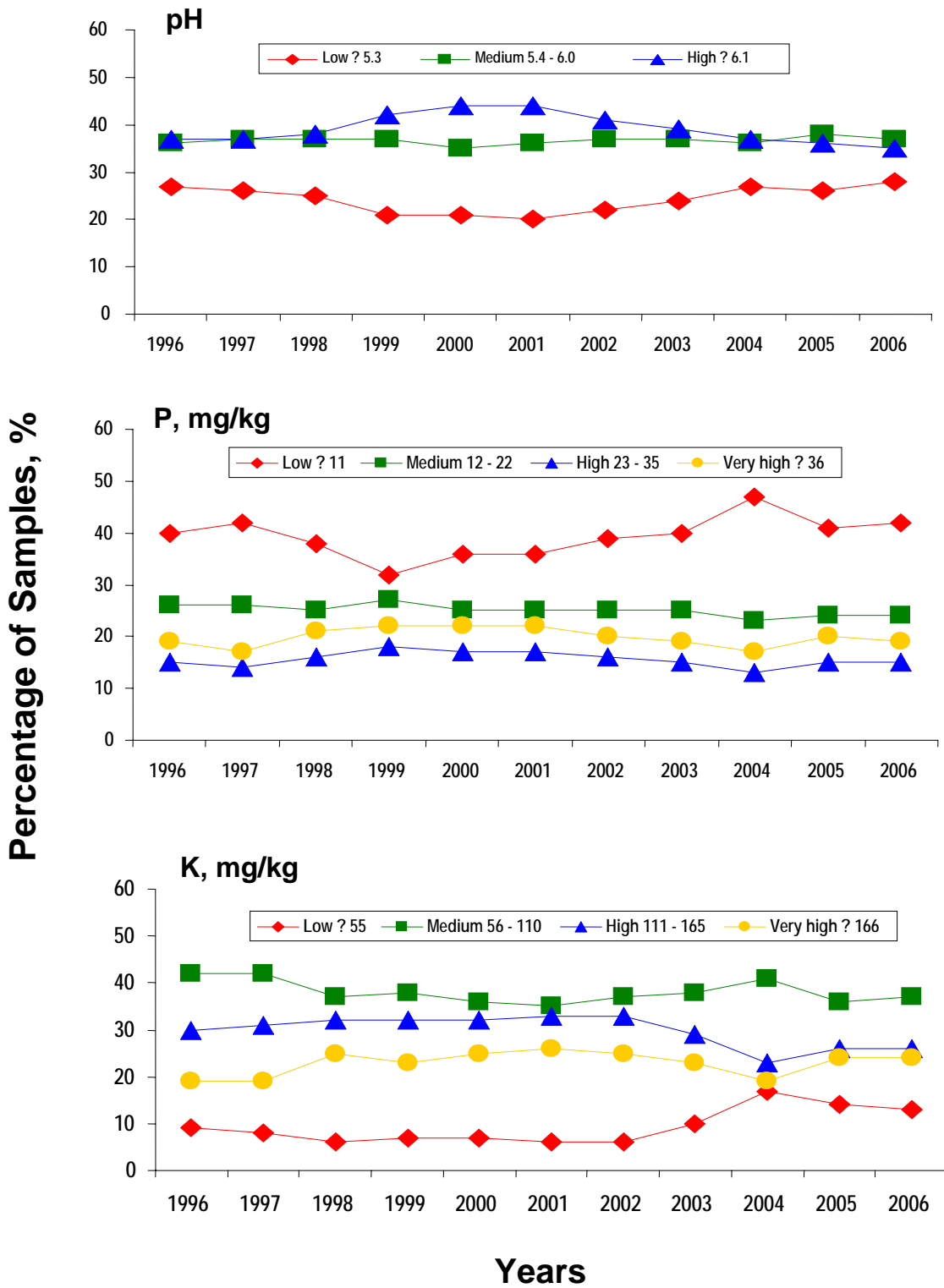
| <u>K, mg/kg</u> | |
|---|----------------------|
|  | Low ≤ 55 |
|  | Medium 56-110 |
|  | High 111-165 |
|  | Very High ≥ 166 |

The majority of the samples received from Missouri counties had pH greater than 5.4 (Fig. 3). About 24% of the soils tested indicated that lime should be applied for economically viable crop production ($\text{pH} \leq 5.3$; Fig. 3 and Fig. 6). Another 37% of the soils are likely to need lime ($\text{pH}=5.4-6.0$) to avoid profit loss.

The majority of counties in Missouri have low P ($\leq 11 \text{ mg/kg}$) soils (Fig. 4). This is also evident from the statewide trend data presented in Fig. 6. About 41% of the P tests ($\leq 11 \text{ mg P/kg}$) indicated that P fertilizer is essential to avoid profit loss by major crops. Another 25% of the P tests (12 - 22 mg P/kg) indicate P fertilizer is required for economic crop production.

The majority of counties in Missouri have medium K (56-110 mg/kg) soils (Fig. 5). About 47% of the K tests (Low : $\leq 55 \text{ mg K/kg}$ + Medium: 56-110 mg K/kg) indicated that K fertilizer would be required to avoid profit loss by major crops (Fig. 6).

Fig. 6: Trends in soil pH, P and K in Missouri Soils (1996-2006)



| Table 1: Soil pHs Distribution by Soil Regions in Missouri (1996 - 2006) | | | | |
|---|-------------------|------------|---------------|-------------|
| Soil Region | Sample No. | Low | Medium | High |
| -----%----- | | | | |
| 1 | 13690 | 17 | 43 | 40 |
| 2 | 29631 | 23 | 41 | 35 |
| 3 | 26794 | 17 | 34 | 49 |
| 4 | 19632 | 17 | 31 | 52 |
| 5 | 23544 | 20 | 40 | 40 |
| 6 | 26501 | 22 | 36 | 42 |
| 7 | 59373 | 32 | 35 | 33 |
| 8 | 21260 | 28 | 34 | 38 |
| 9 | 8502 | 22 | 34 | 45 |
| 10 | 9893 | 16 | 34 | 50 |
| 11 | 12319 | 21 | 39 | 40 |
| 12 | 1521 | 16 | 29 | 55 |
| Statewide | 252660 | 24 | 36 | 40 |

| Table 2: Soil P Distribution by Soil Regions in Missouri (1996 – 2006) | | | | | |
|---|-------------------|------------|---------------|-------------|------------------|
| Soil Region | Sample No. | Low | Medium | High | Very High |
| -----%----- | | | | | |
| 1 | 11952 | 28 | 28 | 20 | 24 |
| 2 | 25961 | 41 | 24 | 16 | 19 |
| 3 | 23228 | 36 | 31 | 19 | 14 |
| 4 | 17607 | 19 | 26 | 26 | 19 |
| 5 | 20640 | 40 | 26 | 17 | 17 |
| 6 | 23295 | 39 | 23 | 14 | 24 |
| 7 | 51961 | 48 | 21 | 12 | 19 |
| 8 | 18816 | 48 | 22 | 15 | 15 |
| 9 | 7720 | 14 | 26 | 28 | 32 |
| 10 | 9233 | 6 | 18 | 27 | 49 |
| 11 | 11411 | 5 | 22 | 31 | 42 |
| 12 | 1411 | 5 | 26 | 31 | 38 |
| Statewide | 223235 | 35 | 24 | 18 | 23 |

| Soil Region | Sample No. | Low | Medium | High | Very High |
|------------------|---------------|-------------|-----------|-----------|-----------|
| | | -----%----- | | | |
| 1 | 13569 | 7 | 40 | 33 | 20 |
| 2 | 29246 | 16 | 53 | 21 | 10 |
| 3 | 26346 | 20 | 58 | 16 | 6 |
| 4 | 19380 | 15 | 49 | 21 | 15 |
| 5 | 23184 | 21 | 52 | 19 | 8 |
| 6 | 26084 | 25 | 44 | 19 | 12 |
| 7 | 58369 | 29 | 47 | 16 | 8 |
| 8 | 20883 | 27 | 53 | 14 | 6 |
| 9 | 8402 | 14 | 52 | 25 | 9 |
| 10 | 9804 | 6 | 38 | 32 | 24 |
| 11 | 12182 | 9 | 52 | 29 | 10 |
| 12 | 1509 | 7 | 34 | 33 | 26 |
| Statewide | 248958 | 20 | 50 | 20 | 10 |

Soil tests summarized by Missouri soil regions shows that the majority of samples from soil regions 5, 6, 7 & 8 (Ozarks and Ozarks border) had a higher percentage of soils falling under the low (≤ 5.1) to medium (5.2-6.0) pH ranges (Table 1). The majority of samples received from the same soil regions had a higher percentage of low P (≤ 11 mg/kg) soils (Table 2). The soils in the Ozarks and Ozarks boarder region are highly weathered, highly acidic and are inherently low in soil P. The soil test summary of P by soil region reflects a similar pattern. On the other hand, soil regions 10, 11 & 12 (Bootheel) had a higher percentage of soils testing high in pH (≥ 6.1) and P (≥ 23 mg/kg). As observed in soil test distribution by county (Fig 5), the majority of the samples from all soil regions had medium soil K levels (56 – 110 mg/kg; Table 3).

| Cropping Option | Sample No. | Low | Medium | High |
|---------------------|---------------|-------------|-----------|-----------|
| | | -----%----- | | |
| Corn | 53801 | 15 | 36 | 49 |
| Soybeans | 33699 | 17 | 37 | 46 |
| Wheat | 9875 | 19 | 36 | 45 |
| Cool Season Grasses | 65359 | 27 | 37 | 36 |
| Warm Season Grasses | 13167 | 28 | 37 | 35 |
| Clover-Grass | 44050 | 31 | 36 | 33 |
| Alfalfa-Grass | 13460 | 21 | 32 | 47 |
| Cotton | 6096 | 27 | 38 | 35 |
| Statewide | 249762 | 24 | 36 | 40 |

| Table 5: Soil P Distribution by Cropping System in Missouri (1996 – 2006) | | | | | |
|--|-------------------|-------------|---------------|-------------|------------------|
| Cropping Option | Sample No. | Low | Medium | High | Very High |
| | | -----%----- | | | |
| Corn | 48159 | 14 | 29 | 28 | 28 |
| Soybeans | 29892 | 20 | 29 | 25 | 26 |
| Wheat | 8874 | 18 | 27 | 25 | 30 |
| Cool Season Grasses | 57287 | 49 | 21 | 12 | 18 |
| Warm Season Grasses | 11569 | 50 | 21 | 11 | 17 |
| Clover-Grass | 38379 | 55 | 20 | 11 | 15 |
| Alfalfa-Grass | 11746 | 39 | 25 | 15 | 21 |
| Cotton | 5796 | 1 | 13 | 24 | 61 |
| Statewide | 220581 | 36 | 24 | 18 | 22 |

| Table 6: Soil K Distribution by Cropping System in Missouri (1996 – 2006) | | | | | |
|--|-------------------|-------------|---------------|-------------|------------------|
| Cropping Option | Sample No. | Low | Medium | High | Very High |
| | | -----%----- | | | |
| Corn | 53162 | 12 | 53 | 24 | 11 |
| Soybeans | 33255 | 14 | 52 | 22 | 12 |
| Wheat | 9749 | 16 | 52 | 21 | 11 |
| Cool Season Grasses | 64325 | 26 | 46 | 18 | 10 |
| Warm Season Grasses | 12963 | 24 | 49 | 18 | 9 |
| Clover-Grass | 43340 | 27 | 48 | 16 | 9 |
| Alfalfa-Grass | 13222 | 23 | 51 | 18 | 8 |
| Cotton | 6036 | 5 | 41 | 40 | 14 |
| Statewide | 246108 | 20 | 50 | 20 | 10 |

The soil test summary by cropping options (Tables 4 -6) shows that a higher percentage of the soils tested for corn, soybean, wheat, and alfalfa had high pH (≥ 6.1). Alternatively, the soils tested for cool and warm season grass pasture/hay had a higher percentage of soils testing in low (≤ 5.1) to medium (5.2-6.0) levels of pH (Table 4). A similar trend is observed with soil test P for cropping options (Table 5). Irrespective of the crop options, the majority of samples received by soil testing labs had medium soil test K levels (56-110 mg/kg; Table 6).

Summary:

The soil test summary provides invaluable information regarding soil fertility status at the county, soil region and state levels. A higher percentage of adequately fertilized soils occur in the intensively cropped Bootheel region. Conversely, the highest percentage of low fertility soils occur in the highly weathered Ozarks region. Soil test data summary by cropping options clearly indicates that corn, soybean, and wheat fields are better managed than the forage crops. We are in the process of publishing a detailed peer reviewed report on “Soil Fertility Summary Status for Missouri Soils 1996-2006”. This publication will have details of soil test distribution by counties, soil regions, and crop options for all the regular fertility tests analyzed by MU soil testing labs. It is beyond the scope of this report to have all that information included.

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Nutrient Removal Values for Major Agronomic Crops in Missouri Report for 2006-2007

Manjula V. Nathan and Yichang Sun, and David Dunn

Introduction:

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

Objective:

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

Current Status:

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

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

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

The N, P and K nutrient removal values for grain crops in Missouri for 2006 and 2007 were different for both years, and didn't match with the nutrient values provided by the National Beef and Dairy Research Council (Table 5). The values used by the Beef and Dairy Research Councils are from a national database and do not truly represent the Missouri conditions. The discrepancy between the two years of grain nutrient survey data and proposed values from National Beef and Dairy Research Council strongly suggests the need for additional years of data collection for grain nutrient removal values for major agronomic crops in Missouri to come up with the

most appropriate values and truly representative grain nutrient removal values to refine MU fertilizer recommendations.

Table 6 provides the forage analysis results from the 2006 samples which were analyzed in early 2007, thus was not included in the 2006 grant report.

Need for Future Research:

The success or failure of soil test recommendations are evidenced by crop yields and ability to maintain critical soil test levels of P & K. Fertilizer recommendations for P & K are largely dependent on crop removal. Crop nutrient removal values vary with weather conditions, yields, management and soil type. Multiple years of data are needed to develop appropriate and realistic nutrient removal values for growing conditions in Missouri. Paul Tracy, MFA Inc (personal communication, 2006) has indicated that the average soil test values from the same fields have been testing progressively lower in P with time. As these fields have been fertilized as to soil test recommendations this indicates that more P is being removed than supplied. The soil test summary from 1996-2006 clearly indicates majority (41%) of the soils tested by University of Missouri soil testing labs are low in phosphorus and 25% had medium levels of soil test P (Nathan et al., 2007). The soil fertility summary report for North America by Fixen, et al., (2005) showed the similar trends in soil test P levels in Missouri. Adequate phosphorus is critical for maximum crop yields. By reducing the crop removal values from 0.46 lbs P₂O₅ to 0.32 lbs P₂O₅/bu for corn we will be under recommending P fertilizer. With time this will deplete the soil P levels in Missouri and end up with significant yield losses to the producers. Additional grain nutrient removal data from Missouri is needed before making any changes in the nutrient removal values for agronomic crops. Other states use the data collected from their states to establish appropriate values for nutrient removal that represent the growing conditions in their state.

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

| Crop | Yield Unit | N removal | | | P ₂ O ₅ removal | | | K ₂ O removal | | |
|-----------------------|------------|-----------|-------|-------|---------------------------------------|--------|--------|--------------------------|--------|--------|
| | | Current | NRC | IPNI | Current | NRC | IPNI | Current | NRC | IPNI |
| Barley | bushel | 0.96 | 0.87 | 1.1 | 0.38 | 0.33 | 0.4 | 0.24 | 0.29 | 0.35 |
| Corn Grain | bushel | 0.9 | 0.74 | 0.75 | 0.45 | 0.32 | 0.44 | 0.30 | 0.25 | 0.29 |
| Corn Silage | ton | 9.0 | 9.9 | 8.3 | 3.6 | 4.1 | 3.6 | 9.0 | 10 | 8.3 |
| Oats | bushel | 0.64 | 0.6 | 0.8 | 0.26 | 0.26 | 0.25 | 0.19 | 0.17 | 0.2 |
| Rice | pound | 0.013 | - | - | 0.0065 | - | - | 0.004 | - | - |
| Sorghum grain | pound | 0.014 | 0.018 | 0.015 | 0.0093 | 0.0067 | 0.0075 | 0.006 | 0.0047 | 0.0038 |
| Sorghum silage | ton | 13.0 | 10 | - | 4.6 | 3.5 | - | 10 | 15 | - |
| Soybean | bushel | - | 3.4 | 4.0 | 0.84 | 0.80 | 0.80 | 1.44 | 1.30 | 1.40 |
| Wheat | bushel | 1.26 | 1.18 | 1.5 | 0.60 | 0.50 | 0.5 | 0.30 | 0.30 | 0.35 |
| Alfalfa-grass hay | ton | - | 54 | 50 | 10.0 | 11 | 14 | 45 | 53 | 54 |
| Bermuda grass hay | ton | 50 | 30 | 41 | 9.0 | 11 | 11 | 34 | 40 | 45 |
| Clover-grass hay | ton | - | 55 | 45 | 8.2 | 13 | 14 | 38 | 57 | 54 |
| Cool season grass hay | ton | 40 | 38 | 34 | 9.0 | 12 | 16 | 34 | 47 | 47 |
| Lespedeza-grass hay | ton | - | - | - | 8.8 | - | - | 20 | - | - |
| Sudan grass hay | ton | 40 | 27 | 36 | 6.9 | 8 | 14 | 19 | 52 | 52 |
| Warm season grass hay | ton | - | - | - | 2.0 | - | - | 14.6 | - | - |
| | | | | | | | | | | |

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

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

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

| Crops | | Nutrient Removal Values lbs/bu | | | | | |
|----------|----------------|--------------------------------|---------------|-------------------------------|---------------|------------------|---------------|
| | | N | | P ₂ O ₅ | | K ₂ O | |
| | | 2006 | 2007 | 2006 | 2007 | 2006 | 2007 |
| Corn | Mean | 0.678 | 0.705 | 0.479 | 0.334 | 0.343 | 0.270 |
| | STD | 0.099 | 0.105 | 0.081 | 0.038 | 0.049 | 0.047 |
| | N | 141 | 214 | 141 | 214 | 141 | 214 |
| | Min | 0.511 | 0.458 | 0.279 | 0.227 | 0.208 | 0.133 |
| | Max | 1.007 | 0.994 | 0.695 | 0.435 | 0.477 | 0.421 |
| | Mean ± 2.5 STD | 0.431 - 0.926 | 0.444 - 0.967 | 0.278 - 0.681 | 0.239 - 0.428 | 0.221 - 0.465 | 0.151 - 0.388 |
| Soybeans | Mean | 2.546 | 3.017 | 0.526 | 0.739 | 1.005 | 1.177 |
| | STD | 0.260 | 0.206 | 0.041 | 0.060 | 0.090 | 0.154 |
| | N | 87 | 83 | 87 | 83 | 87 | 83 |
| | Min | 1.826 | 2.558 | 0.422 | 0.574 | 0.764 | 0.789 |
| | Max | 3.289 | 3.353 | 0.653 | 0.883 | 1.228 | 1.876 |
| | Mean ± 2.5 STD | 1.896 - 3.197 | 2.502 - 3.531 | 0.424 - 0.627 | 0.589 - 0.889 | 0.780 - 1.230 | 0.792 - 1.563 |
| Wheat | Mean | 0.948 | 1.151 | 0.397 | 0.501 | 0.292 | 0.348 |
| | STD | 0.168 | 0.160 | 0.052 | 0.044 | 0.049 | 0.077 |
| | N | 52 | 71 | 52 | 71 | 52 | 71 |
| | Min | 0.716 | 0.953 | 0.289 | 0.414 | 0.192 | 0.243 |
| | Max | 1.473 | 1.686 | 0.536 | 0.643 | 0.404 | 0.576 |
| | Mean ± 2.5 STD | 0.528 - 1.369 | 0.751 - 1.551 | 0.267 - 0.527 | 0.392 - 0.610 | 0.170 - 0.414 | 0.156 - 0.540 |
| Sorghum | Mean | 0.828 | 0.741 | 0.901 | 0.339 | 0.559 | 0.293 |
| | STD | 0.083 | 0.081 | 0.093 | 0.032 | 0.062 | 0.052 |
| | N | 17 | 19 | 17 | 19 | 17 | 19 |
| | Min | 0.716 | 0.610 | 0.697 | 0.278 | 0.428 | 0.217 |
| | Max | 1.055 | 0.899 | 1.050 | 0.419 | 0.649 | 0.410 |
| | Mean ± 2.5 STD | 0.619 - 1.036 | 0.538 - 0.944 | 0.669 - 1.133 | 0.259 - 0.419 | 0.403 - 0.714 | 0.163 - 0.423 |

Table 4: Survey Report of the Grain Nutrient Removal Values for Major Agronomic Crops in Missouri – Year 2007

| CORN | N | P | K | Nutrient | Removal | Values |
|---------------|----------|----------|----------|-----------------|--|------------------------------|
| County | % | % | % | lbs N/bu | lbs P₂O₅/bu | lbs K₂O/bu |
| Audrain | 1.449 | 0.317 | 0.670 | 0.686 | 0.341 | 0.382 |
| Audrain | 1.516 | 0.303 | 0.738 | 0.717 | 0.326 | 0.421 |
| Audrain | 1.485 | 0.306 | 0.712 | 0.703 | 0.329 | 0.406 |
| Barton | 1.383 | 0.304 | 0.506 | 0.655 | 0.327 | 0.288 |
| Barton | 1.390 | 0.318 | 0.469 | 0.658 | 0.342 | 0.267 |
| Barton | 1.404 | 0.299 | 0.346 | 0.664 | 0.322 | 0.198 |
| Boone | 1.195 | 0.307 | 0.402 | 0.566 | 0.331 | 0.229 |
| Chariton | 1.247 | 0.298 | 0.549 | 0.590 | 0.321 | 0.313 |
| Chariton | 1.269 | 0.291 | 0.527 | 0.601 | 0.313 | 0.301 |
| Chariton | 1.376 | 0.296 | 0.541 | 0.651 | 0.318 | 0.308 |
| Clark | 1.464 | 0.314 | 0.710 | 0.693 | 0.338 | 0.405 |
| Clay | 1.419 | 0.287 | 0.461 | 0.672 | 0.309 | 0.263 |
| Clay | 1.367 | 0.263 | 0.470 | 0.647 | 0.283 | 0.268 |
| DeKalb | 1.447 | 0.295 | 0.340 | 0.685 | 0.317 | 0.194 |
| Dunklin | 1.108 | 0.270 | 0.529 | 0.524 | 0.290 | 0.302 |
| Dunklin | 1.404 | 0.309 | 0.482 | 0.664 | 0.332 | 0.275 |
| Dunklin | 1.615 | 0.358 | 0.494 | 0.764 | 0.384 | 0.282 |
| Dunklin | 1.931 | 0.325 | 0.537 | 0.914 | 0.350 | 0.306 |
| Dunklin | 1.568 | 0.281 | 0.496 | 0.742 | 0.302 | 0.283 |
| Dunklin | 1.640 | 0.309 | 0.514 | 0.776 | 0.332 | 0.293 |
| Dunklin | 1.459 | 0.345 | 0.516 | 0.690 | 0.371 | 0.294 |
| Dunklin | 1.245 | 0.281 | 0.530 | 0.589 | 0.302 | 0.302 |
| Dunklin | 1.771 | 0.391 | 0.569 | 0.838 | 0.421 | 0.325 |
| Dunklin | 1.408 | 0.213 | 0.523 | 0.666 | 0.230 | 0.298 |
| Dunklin | 1.647 | 0.304 | 0.502 | 0.779 | 0.327 | 0.286 |
| Dunklin | 1.585 | 0.345 | 0.503 | 0.750 | 0.371 | 0.287 |
| Dunklin | 1.751 | 0.308 | 0.435 | 0.828 | 0.331 | 0.248 |
| Dunklin | 1.642 | 0.339 | 0.516 | 0.777 | 0.365 | 0.294 |
| Dunklin | 1.800 | 0.340 | 0.519 | 0.852 | 0.366 | 0.296 |
| Dunklin | 1.474 | 0.295 | 0.503 | 0.698 | 0.317 | 0.287 |
| Dunklin | 1.572 | 0.303 | 0.502 | 0.744 | 0.326 | 0.286 |
| Dunklin | 1.262 | 0.290 | 0.509 | 0.597 | 0.311 | 0.290 |
| Grundy | 1.529 | 0.367 | 0.355 | 0.724 | 0.395 | 0.202 |
| Grundy | 1.400 | 0.321 | 0.368 | 0.663 | 0.345 | 0.210 |
| Howard | 1.482 | 0.305 | 0.484 | 0.701 | 0.328 | 0.276 |
| Howard | 1.475 | 0.286 | 0.509 | 0.698 | 0.308 | 0.290 |
| Howard | 1.398 | 0.292 | 0.530 | 0.662 | 0.314 | 0.302 |
| Jackson | 1.599 | 0.287 | 0.464 | 0.757 | 0.309 | 0.264 |
| Lafayette | 1.337 | 0.290 | 0.677 | 0.633 | 0.312 | 0.386 |
| Lafayette | 1.323 | 0.296 | 0.645 | 0.626 | 0.318 | 0.368 |
| Lafayette | 1.336 | 0.293 | 0.669 | 0.632 | 0.316 | 0.381 |
| Lewis | 1.478 | 0.283 | 0.663 | 0.700 | 0.305 | 0.378 |
| Lewis | 1.359 | 0.308 | 0.390 | 0.643 | 0.332 | 0.223 |
| Mississippi | 1.432 | 0.274 | 0.460 | 0.678 | 0.294 | 0.262 |
| Mississippi | 1.605 | 0.333 | 0.462 | 0.760 | 0.358 | 0.263 |
| Mississippi | 1.490 | 0.307 | 0.507 | 0.705 | 0.330 | 0.289 |

| | | | | | | |
|-------------|-------|-------|-------|-------|-------|-------|
| Mississippi | 1.792 | 0.392 | 0.484 | 0.848 | 0.422 | 0.276 |
| Mississippi | 1.304 | 0.226 | 0.371 | 0.617 | 0.243 | 0.212 |
| Mississippi | 1.593 | 0.281 | 0.523 | 0.754 | 0.302 | 0.298 |
| Mississippi | 1.678 | 0.249 | 0.428 | 0.794 | 0.268 | 0.244 |
| Mississippi | 1.521 | 0.284 | 0.519 | 0.720 | 0.306 | 0.296 |
| Mississippi | 1.491 | 0.251 | 0.433 | 0.705 | 0.270 | 0.247 |
| Mississippi | 1.732 | 0.287 | 0.587 | 0.819 | 0.309 | 0.335 |
| Mississippi | 1.429 | 0.305 | 0.510 | 0.676 | 0.328 | 0.291 |
| Mississippi | 1.620 | 0.226 | 0.550 | 0.767 | 0.243 | 0.314 |
| Mississippi | 2.027 | 0.314 | 0.449 | 0.959 | 0.338 | 0.256 |
| Mississippi | 1.231 | 0.324 | 0.529 | 0.583 | 0.349 | 0.302 |
| Mississippi | 1.168 | 0.286 | 0.574 | 0.553 | 0.308 | 0.327 |
| Mississippi | 1.272 | 0.323 | 0.460 | 0.602 | 0.347 | 0.262 |
| Mississippi | 1.866 | 0.404 | 0.460 | 0.883 | 0.435 | 0.262 |
| Mississippi | 1.861 | 0.341 | 0.412 | 0.880 | 0.366 | 0.235 |
| Mississippi | 1.574 | 0.326 | 0.408 | 0.745 | 0.351 | 0.233 |
| Mississippi | 1.673 | 0.290 | 0.371 | 0.792 | 0.312 | 0.212 |
| Mississippi | 1.192 | 0.322 | 0.474 | 0.564 | 0.346 | 0.270 |
| Mississippi | 1.666 | 0.340 | 0.491 | 0.788 | 0.366 | 0.280 |
| Mississippi | 1.556 | 0.305 | 0.436 | 0.736 | 0.328 | 0.249 |
| Mississippi | 1.200 | 0.324 | 0.572 | 0.568 | 0.348 | 0.326 |
| Mississippi | 1.744 | 0.327 | 0.642 | 0.825 | 0.352 | 0.366 |
| Mississippi | 1.333 | 0.291 | 0.619 | 0.631 | 0.313 | 0.353 |
| Mississippi | 1.440 | 0.277 | 0.476 | 0.681 | 0.298 | 0.272 |
| Mississippi | 1.338 | 0.240 | 0.470 | 0.633 | 0.259 | 0.268 |
| Mississippi | 1.374 | 0.300 | 0.297 | 0.650 | 0.322 | 0.169 |
| New Madrid | 1.622 | 0.266 | 0.499 | 0.767 | 0.287 | 0.285 |
| New Madrid | 1.670 | 0.308 | 0.540 | 0.790 | 0.332 | 0.308 |
| New Madrid | 1.610 | 0.325 | 0.560 | 0.762 | 0.350 | 0.319 |
| New Madrid | 1.693 | 0.312 | 0.517 | 0.801 | 0.336 | 0.295 |
| New Madrid | 1.280 | 0.289 | 0.433 | 0.605 | 0.311 | 0.247 |
| New Madrid | 1.492 | 0.259 | 0.526 | 0.706 | 0.279 | 0.300 |
| New Madrid | 1.833 | 0.304 | 0.489 | 0.867 | 0.327 | 0.279 |
| New Madrid | 1.834 | 0.371 | 0.519 | 0.868 | 0.399 | 0.296 |
| New Madrid | 1.534 | 0.374 | 0.503 | 0.726 | 0.402 | 0.287 |
| New Madrid | 1.823 | 0.308 | 0.515 | 0.862 | 0.331 | 0.294 |
| New Madrid | 1.926 | 0.357 | 0.548 | 0.911 | 0.384 | 0.312 |
| New Madrid | 1.773 | 0.332 | 0.513 | 0.839 | 0.357 | 0.292 |
| New Madrid | 1.037 | 0.308 | 0.568 | 0.491 | 0.332 | 0.324 |
| New Madrid | 1.069 | 0.235 | 0.498 | 0.506 | 0.253 | 0.284 |
| New Madrid | 1.309 | 0.304 | 0.472 | 0.619 | 0.327 | 0.269 |
| New Madrid | 1.633 | 0.307 | 0.537 | 0.773 | 0.331 | 0.306 |
| New Madrid | 1.179 | 0.283 | 0.559 | 0.558 | 0.304 | 0.319 |
| New Madrid | 1.650 | 0.315 | 0.529 | 0.781 | 0.339 | 0.301 |
| New Madrid | 1.471 | 0.289 | 0.504 | 0.696 | 0.311 | 0.287 |
| New Madrid | 1.418 | 0.251 | 0.466 | 0.671 | 0.270 | 0.266 |
| New Madrid | 1.769 | 0.374 | 0.487 | 0.837 | 0.403 | 0.277 |
| New Madrid | 1.434 | 0.304 | 0.547 | 0.679 | 0.327 | 0.312 |
| New Madrid | 1.340 | 0.279 | 0.495 | 0.634 | 0.300 | 0.282 |
| New Madrid | 1.626 | 0.324 | 0.542 | 0.769 | 0.348 | 0.309 |
| New Madrid | 1.896 | 0.354 | 0.468 | 0.897 | 0.380 | 0.267 |

| | | | | | | |
|------------|-------|-------|-------|-------|-------|-------|
| New Madrid | 1.612 | 0.297 | 0.523 | 0.763 | 0.320 | 0.298 |
| New Madrid | 1.625 | 0.351 | 0.554 | 0.769 | 0.377 | 0.316 |
| New Madrid | 1.430 | 0.351 | 0.455 | 0.677 | 0.378 | 0.259 |
| New Madrid | 1.325 | 0.328 | 0.447 | 0.627 | 0.352 | 0.255 |
| New Madrid | 1.837 | 0.323 | 0.513 | 0.869 | 0.347 | 0.292 |
| New Madrid | 1.279 | 0.339 | 0.523 | 0.605 | 0.365 | 0.298 |
| New Madrid | 1.681 | 0.334 | 0.493 | 0.796 | 0.359 | 0.281 |
| New Madrid | 1.386 | 0.290 | 0.507 | 0.656 | 0.312 | 0.289 |
| New Madrid | 1.620 | 0.298 | 0.504 | 0.766 | 0.321 | 0.287 |
| New Madrid | 1.613 | 0.318 | 0.461 | 0.763 | 0.341 | 0.263 |
| New Madrid | 1.691 | 0.359 | 0.507 | 0.800 | 0.386 | 0.289 |
| New Madrid | 1.059 | 0.367 | 0.566 | 0.501 | 0.395 | 0.322 |
| New Madrid | 1.302 | 0.281 | 0.443 | 0.616 | 0.302 | 0.252 |
| New Madrid | 1.807 | 0.359 | 0.476 | 0.855 | 0.386 | 0.272 |
| New Madrid | 1.352 | 0.343 | 0.557 | 0.640 | 0.369 | 0.317 |
| New Madrid | 1.759 | 0.355 | 0.469 | 0.832 | 0.382 | 0.267 |
| New Madrid | 1.049 | 0.301 | 0.554 | 0.496 | 0.323 | 0.316 |
| New Madrid | 1.328 | 0.303 | 0.386 | 0.628 | 0.325 | 0.220 |
| New Madrid | 1.645 | 0.343 | 0.304 | 0.778 | 0.369 | 0.173 |
| New Madrid | 1.453 | 0.305 | 0.377 | 0.687 | 0.328 | 0.215 |
| New Madrid | 2.026 | 0.363 | 0.402 | 0.959 | 0.390 | 0.229 |
| New Madrid | 1.392 | 0.323 | 0.442 | 0.659 | 0.347 | 0.252 |
| New Madrid | 1.312 | 0.283 | 0.359 | 0.621 | 0.305 | 0.205 |
| New Madrid | 1.600 | 0.317 | 0.422 | 0.757 | 0.341 | 0.241 |
| New Madrid | 1.132 | 0.276 | 0.507 | 0.536 | 0.297 | 0.289 |
| New Madrid | 1.814 | 0.350 | 0.501 | 0.858 | 0.376 | 0.286 |
| New Madrid | 1.856 | 0.358 | 0.480 | 0.878 | 0.385 | 0.273 |
| New Madrid | 1.547 | 0.316 | 0.468 | 0.732 | 0.340 | 0.267 |
| New Madrid | 1.391 | 0.291 | 0.494 | 0.658 | 0.313 | 0.282 |
| New Madrid | 1.596 | 0.349 | 0.489 | 0.755 | 0.375 | 0.279 |
| New Madrid | 1.094 | 0.339 | 0.600 | 0.518 | 0.364 | 0.342 |
| New Madrid | 1.730 | 0.343 | 0.485 | 0.819 | 0.369 | 0.276 |
| New Madrid | 2.097 | 0.304 | 0.409 | 0.992 | 0.327 | 0.233 |
| New Madrid | 1.023 | 0.314 | 0.537 | 0.484 | 0.338 | 0.306 |
| New Madrid | 1.195 | 0.285 | 0.460 | 0.565 | 0.307 | 0.262 |
| New Madrid | 1.323 | 0.299 | 0.408 | 0.626 | 0.322 | 0.233 |
| Nodaway | 1.555 | 0.345 | 0.396 | 0.736 | 0.371 | 0.226 |
| Nodaway | 1.564 | 0.337 | 0.401 | 0.740 | 0.362 | 0.228 |
| NW MO | 1.447 | 0.282 | 0.341 | 0.685 | 0.303 | 0.194 |
| NW MO | 1.470 | 0.287 | 0.360 | 0.695 | 0.308 | 0.205 |
| NW MO | 1.366 | 0.267 | 0.345 | 0.646 | 0.287 | 0.196 |
| NW MO | 1.249 | 0.249 | 0.352 | 0.591 | 0.268 | 0.201 |
| Pemiscot | 1.093 | 0.300 | 0.465 | 0.517 | 0.322 | 0.265 |
| Pemiscot | 1.921 | 0.351 | 0.513 | 0.909 | 0.377 | 0.292 |
| Pemiscot | 1.652 | 0.349 | 0.441 | 0.782 | 0.375 | 0.251 |
| Pemiscot | 1.608 | 0.379 | 0.480 | 0.761 | 0.408 | 0.273 |
| Pemiscot | 1.351 | 0.296 | 0.412 | 0.639 | 0.319 | 0.235 |
| Pemiscot | 1.672 | 0.298 | 0.426 | 0.791 | 0.320 | 0.243 |
| Pemiscot | 1.360 | 0.289 | 0.400 | 0.644 | 0.310 | 0.228 |
| Pemiscot | 1.706 | 0.345 | 0.504 | 0.807 | 0.371 | 0.287 |
| Pemiscot | 1.389 | 0.323 | 0.484 | 0.657 | 0.347 | 0.276 |

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|----------|-------|-------|-------|-------|-------|-------|
| Pemiscot | 1.747 | 0.342 | 0.436 | 0.827 | 0.368 | 0.248 |
| Pemiscot | 1.636 | 0.356 | 0.442 | 0.774 | 0.383 | 0.252 |
| Pemiscot | 1.677 | 0.384 | 0.435 | 0.794 | 0.413 | 0.248 |
| Pemiscot | 1.287 | 0.279 | 0.429 | 0.609 | 0.300 | 0.245 |
| Pemiscot | 1.232 | 0.340 | 0.494 | 0.583 | 0.366 | 0.282 |
| Pemiscot | 1.602 | 0.347 | 0.451 | 0.758 | 0.373 | 0.257 |
| Pemiscot | 1.630 | 0.343 | 0.421 | 0.772 | 0.368 | 0.240 |
| Pemiscot | 1.030 | 0.344 | 0.511 | 0.488 | 0.370 | 0.291 |
| Pemiscot | 1.204 | 0.297 | 0.488 | 0.570 | 0.319 | 0.278 |
| Pemiscot | 1.452 | 0.334 | 0.463 | 0.687 | 0.359 | 0.264 |
| Pemiscot | 1.289 | 0.340 | 0.484 | 0.610 | 0.366 | 0.276 |
| Pemiscot | 1.567 | 0.356 | 0.450 | 0.742 | 0.383 | 0.257 |
| Pemiscot | 1.380 | 0.355 | 0.507 | 0.653 | 0.381 | 0.289 |
| Pemiscot | 1.657 | 0.341 | 0.443 | 0.784 | 0.367 | 0.252 |
| Pemiscot | 1.475 | 0.312 | 0.392 | 0.698 | 0.335 | 0.224 |
| Pemiscot | 1.121 | 0.302 | 0.509 | 0.531 | 0.325 | 0.290 |
| Pemiscot | 1.460 | 0.289 | 0.500 | 0.691 | 0.311 | 0.285 |
| Pemiscot | 1.416 | 0.319 | 0.456 | 0.670 | 0.343 | 0.260 |
| Pemiscot | 1.543 | 0.286 | 0.439 | 0.730 | 0.308 | 0.250 |
| Pemiscot | 1.297 | 0.220 | 0.400 | 0.614 | 0.237 | 0.228 |
| Pemiscot | 1.650 | 0.349 | 0.390 | 0.781 | 0.375 | 0.223 |
| Pemiscot | 1.346 | 0.364 | 0.437 | 0.637 | 0.391 | 0.249 |
| Pemiscot | 1.561 | 0.352 | 0.466 | 0.739 | 0.379 | 0.266 |
| Pemiscot | 1.478 | 0.297 | 0.503 | 0.700 | 0.319 | 0.287 |
| Ray | 1.399 | 0.261 | 0.565 | 0.662 | 0.281 | 0.322 |
| Ray | 1.443 | 0.286 | 0.553 | 0.683 | 0.307 | 0.315 |
| Ray | 1.405 | 0.304 | 0.580 | 0.665 | 0.327 | 0.330 |
| Ray | 1.425 | 0.299 | 0.340 | 0.675 | 0.321 | 0.194 |
| Scott | 1.731 | 0.303 | 0.583 | 0.819 | 0.326 | 0.333 |
| Scott | 1.626 | 0.338 | 0.517 | 0.769 | 0.363 | 0.295 |
| Scott | 1.558 | 0.335 | 0.476 | 0.737 | 0.361 | 0.271 |
| Scott | 1.462 | 0.338 | 0.520 | 0.692 | 0.363 | 0.296 |
| Scott | 1.259 | 0.335 | 0.500 | 0.596 | 0.360 | 0.285 |
| Scott | 0.968 | 0.323 | 0.615 | 0.458 | 0.347 | 0.351 |
| Scott | 1.457 | 0.327 | 0.560 | 0.690 | 0.352 | 0.319 |
| Scott | 1.567 | 0.286 | 0.458 | 0.741 | 0.308 | 0.261 |
| Scott | 1.532 | 0.282 | 0.457 | 0.725 | 0.304 | 0.261 |
| Scott | 1.161 | 0.287 | 0.446 | 0.550 | 0.308 | 0.254 |
| Scott | 1.716 | 0.304 | 0.441 | 0.812 | 0.327 | 0.252 |
| Scott | 1.130 | 0.211 | 0.384 | 0.535 | 0.227 | 0.219 |
| Scott | 1.458 | 0.284 | 0.367 | 0.690 | 0.306 | 0.209 |
| Scott | 1.602 | 0.314 | 0.328 | 0.758 | 0.337 | 0.187 |
| Scott | 1.594 | 0.302 | 0.422 | 0.754 | 0.325 | 0.241 |
| Scott | 1.751 | 0.352 | 0.415 | 0.828 | 0.379 | 0.237 |
| Scott | 1.798 | 0.312 | 0.439 | 0.851 | 0.336 | 0.250 |
| Scott | 1.314 | 0.324 | 0.468 | 0.622 | 0.349 | 0.267 |
| Scott | 2.100 | 0.379 | 0.301 | 0.994 | 0.408 | 0.172 |
| Scott | 1.474 | 0.378 | 0.360 | 0.698 | 0.406 | 0.205 |
| Scott | 2.049 | 0.362 | 0.489 | 0.969 | 0.389 | 0.279 |
| Scott | 1.354 | 0.272 | 0.521 | 0.641 | 0.293 | 0.297 |
| Scott | 1.429 | 0.302 | 0.475 | 0.676 | 0.325 | 0.271 |

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|-----------------------|----------------------|----------------------|----------------------|----------------------|--|------------------------------|
| Scott | 1.421 | 0.256 | 0.354 | 0.672 | 0.275 | 0.202 |
| Scott | 1.419 | 0.299 | 0.364 | 0.671 | 0.322 | 0.207 |
| Scott | 1.472 | 0.273 | 0.402 | 0.697 | 0.294 | 0.229 |
| Scott | 1.582 | 0.276 | 0.409 | 0.749 | 0.297 | 0.233 |
| Scott | 1.588 | 0.290 | 0.321 | 0.752 | 0.312 | 0.183 |
| Scott | 1.519 | 0.299 | 0.283 | 0.719 | 0.321 | 0.162 |
| Scott | 1.401 | 0.317 | 0.277 | 0.663 | 0.340 | 0.158 |
| Scott | 1.479 | 0.259 | 0.234 | 0.700 | 0.279 | 0.133 |
| Scott | 1.421 | 0.248 | 0.286 | 0.672 | 0.267 | 0.163 |
| Scott | 1.444 | 0.306 | 0.372 | 0.683 | 0.329 | 0.212 |
| Stoddard | 1.384 | 0.271 | 0.400 | 0.655 | 0.292 | 0.228 |
| Stoddard | 1.286 | 0.272 | 0.337 | 0.608 | 0.292 | 0.192 |
| Stoddard | 1.245 | 0.289 | 0.320 | 0.589 | 0.311 | 0.182 |
| Stoddard | 1.260 | 0.275 | 0.360 | 0.596 | 0.296 | 0.205 |
| Stoddard | 1.105 | 0.277 | 0.431 | 0.523 | 0.298 | 0.246 |
| Mean | 1.491 | 0.310 | 0.473 | 0.705 | 0.334 | 0.270 |
| STD | 0.221 | 0.035 | 0.083 | 0.105 | 0.038 | 0.047 |
| N | 214 | 214 | 214 | 214 | 214 | 214 |
| Min | 0.968 | 0.211 | 0.234 | 0.458 | 0.227 | 0.133 |
| Max | 2.100 | 0.404 | 0.738 | 0.994 | 0.435 | 0.421 |
| Mean ± 2.5 STD | 0.939 - 2.043 | 0.223 - 0.398 | 0.265 - 0.681 | 0.444 - 0.967 | 0.239 - 0.428 | 0.151 - 0.388 |
| Soybean | N | P | K | Nutrient | Removal | Values |
| County | % | % | % | lbs N/bu | lbs P₂O₅/bu | lbs K₂O/bu |
| Atchison | 6.209 | 0.717 | 1.861 | 3.241 | 0.851 | 1.171 |
| Atchison | 5.942 | 0.658 | 1.983 | 3.102 | 0.781 | 1.247 |
| Audrain | 5.765 | 0.562 | 2.982 | 3.009 | 0.667 | 1.876 |
| Audrain | 5.851 | 0.579 | 2.869 | 3.054 | 0.687 | 1.804 |
| Audrain | 5.730 | 0.611 | 2.787 | 2.991 | 0.725 | 1.753 |
| Barton | 5.287 | 0.552 | 1.596 | 2.760 | 0.654 | 1.004 |
| Bates | 5.766 | 0.499 | 1.993 | 3.010 | 0.592 | 1.253 |
| Bates | 6.167 | 0.547 | 1.802 | 3.219 | 0.649 | 1.134 |
| Bates | 6.132 | 0.549 | 1.814 | 3.201 | 0.652 | 1.141 |
| Benton | 6.352 | 0.601 | 1.970 | 3.316 | 0.713 | 1.239 |
| Boone | 5.351 | 0.650 | 1.924 | 2.793 | 0.771 | 1.210 |
| Cass | 5.967 | 0.533 | 1.952 | 3.115 | 0.633 | 1.228 |
| Cass | 6.301 | 0.653 | 1.941 | 3.289 | 0.775 | 1.221 |
| Clay | 5.671 | 0.658 | 1.894 | 2.960 | 0.780 | 1.191 |
| Clay | 5.653 | 0.558 | 1.959 | 2.951 | 0.662 | 1.232 |
| Clinton | 6.075 | 0.557 | 1.939 | 3.171 | 0.661 | 1.219 |
| Clinton | 6.152 | 0.593 | 1.854 | 3.211 | 0.703 | 1.166 |
| Clinton | 6.030 | 0.637 | 1.888 | 3.147 | 0.755 | 1.187 |
| Davies | 5.983 | 0.646 | 1.891 | 3.123 | 0.767 | 1.189 |
| Davies | 6.194 | 0.591 | 1.858 | 3.233 | 0.702 | 1.169 |
| Gentry | 5.856 | 0.635 | 1.736 | 3.057 | 0.754 | 1.092 |
| Gentry | 5.306 | 0.646 | 1.254 | 2.770 | 0.766 | 0.789 |
| Grundy | 6.148 | 0.647 | 1.886 | 3.209 | 0.768 | 1.186 |
| Harrison | 5.796 | 0.668 | 1.857 | 3.025 | 0.792 | 1.168 |
| Harrison | 5.976 | 0.629 | 1.914 | 3.119 | 0.747 | 1.204 |
| Henry | 6.032 | 0.647 | 1.834 | 3.149 | 0.768 | 1.154 |
| Henry | 5.267 | 0.648 | 1.832 | 2.750 | 0.768 | 1.152 |
| Holt | 5.860 | 0.615 | 1.889 | 3.059 | 0.729 | 1.188 |
| Holt | 5.961 | 0.585 | 1.863 | 3.111 | 0.695 | 1.172 |

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|------------|-------|-------|-------|-------|-------|-------|
| Holt | 5.980 | 0.598 | 1.913 | 3.122 | 0.710 | 1.203 |
| Johnson | 6.043 | 0.585 | 1.722 | 3.154 | 0.694 | 1.083 |
| Lafayette | 5.625 | 0.568 | 1.963 | 2.936 | 0.673 | 1.235 |
| Lafayette | 5.522 | 0.579 | 1.906 | 2.882 | 0.687 | 1.198 |
| Lafayette | 6.005 | 0.623 | 1.913 | 3.135 | 0.739 | 1.203 |
| Linn | 6.029 | 0.605 | 1.857 | 3.147 | 0.717 | 1.168 |
| Livingston | 6.176 | 0.680 | 1.944 | 3.224 | 0.807 | 1.223 |
| Livingston | 6.192 | 0.679 | 1.928 | 3.232 | 0.806 | 1.212 |
| Livingston | 6.423 | 0.701 | 1.930 | 3.353 | 0.832 | 1.214 |
| Macon | 5.229 | 0.587 | 1.580 | 2.730 | 0.697 | 0.994 |
| New Madrid | 5.900 | 0.710 | 1.904 | 3.080 | 0.843 | 1.198 |
| New Madrid | 6.230 | 0.649 | 1.549 | 3.252 | 0.770 | 0.974 |
| New Madrid | 5.985 | 0.617 | 1.811 | 3.124 | 0.732 | 1.139 |
| New Madrid | 6.136 | 0.667 | 1.713 | 3.203 | 0.791 | 1.077 |
| New Madrid | 6.008 | 0.654 | 1.839 | 3.136 | 0.775 | 1.157 |
| New Madrid | 5.802 | 0.698 | 1.737 | 3.028 | 0.828 | 1.093 |
| New Madrid | 5.995 | 0.687 | 1.884 | 3.129 | 0.815 | 1.185 |
| New Madrid | 6.111 | 0.684 | 1.810 | 3.190 | 0.811 | 1.138 |
| New Madrid | 5.326 | 0.639 | 1.746 | 2.780 | 0.758 | 1.098 |
| New Madrid | 6.041 | 0.694 | 2.083 | 3.154 | 0.823 | 1.310 |
| New Madrid | 5.116 | 0.609 | 1.741 | 2.671 | 0.723 | 1.095 |
| New Madrid | 5.179 | 0.596 | 1.511 | 2.704 | 0.707 | 0.950 |
| Nodaway | 6.255 | 0.601 | 1.981 | 3.265 | 0.713 | 1.246 |
| Nodaway | 6.081 | 0.642 | 1.999 | 3.174 | 0.761 | 1.258 |
| Nodaway | 5.746 | 0.562 | 1.908 | 2.999 | 0.666 | 1.200 |
| Nodaway | 5.954 | 0.603 | 1.885 | 3.108 | 0.715 | 1.186 |
| Nodaway | 6.040 | 0.600 | 1.897 | 3.153 | 0.712 | 1.193 |
| Nodaway | 6.212 | 0.627 | 1.671 | 3.243 | 0.744 | 1.051 |
| Nodaway | 6.028 | 0.678 | 1.773 | 3.147 | 0.804 | 1.115 |
| Pemiscot | 5.926 | 0.613 | 2.133 | 3.093 | 0.728 | 1.341 |
| Pemiscot | 5.286 | 0.604 | 1.865 | 2.760 | 0.717 | 1.173 |
| Pemiscot | 6.019 | 0.646 | 1.874 | 3.142 | 0.766 | 1.179 |
| Pemiscot | 6.013 | 0.673 | 1.927 | 3.139 | 0.798 | 1.212 |
| Pemiscot | 6.045 | 0.668 | 1.887 | 3.155 | 0.792 | 1.187 |
| Pemiscot | 6.082 | 0.625 | 1.987 | 3.175 | 0.741 | 1.250 |
| Pemiscot | 5.915 | 0.695 | 1.959 | 3.087 | 0.824 | 1.232 |
| Pemiscot | 4.901 | 0.639 | 1.676 | 2.558 | 0.758 | 1.054 |
| Pemiscot | 5.103 | 0.672 | 1.494 | 2.664 | 0.797 | 0.940 |
| Pemiscot | 5.255 | 0.602 | 1.606 | 2.743 | 0.714 | 1.010 |
| Pemiscot | 5.272 | 0.662 | 1.716 | 2.752 | 0.785 | 1.079 |
| Pemiscot | 5.114 | 0.599 | 1.619 | 2.670 | 0.711 | 1.018 |
| Pemiscot | 5.063 | 0.588 | 1.770 | 2.643 | 0.698 | 1.113 |
| Pike | 5.251 | 0.612 | 1.794 | 2.741 | 0.726 | 1.128 |
| Platte | 5.998 | 0.644 | 2.041 | 3.131 | 0.764 | 1.284 |
| Platte | 5.993 | 0.613 | 1.747 | 3.128 | 0.727 | 1.098 |
| Platte | 6.026 | 0.631 | 2.019 | 3.145 | 0.749 | 1.270 |
| Ray | 5.896 | 0.570 | 1.736 | 3.078 | 0.676 | 1.092 |
| Scott | 5.312 | 0.580 | 1.820 | 2.773 | 0.688 | 1.145 |
| Scott | 5.168 | 0.524 | 1.674 | 2.698 | 0.621 | 1.053 |
| Scott | 5.204 | 0.629 | 1.836 | 2.716 | 0.746 | 1.155 |
| Scott | 5.028 | 0.484 | 1.789 | 2.624 | 0.574 | 1.125 |
| Scott | 5.135 | 0.693 | 1.886 | 2.680 | 0.823 | 1.186 |
| Vernon | 5.306 | 0.605 | 2.053 | 2.770 | 0.718 | 1.291 |
| Vernon | 5.202 | 0.744 | 1.535 | 2.715 | 0.883 | 0.965 |

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| Mean | 5.779 | 0.623 | 1.872 | 3.017 | 0.739 | 1.177 |
| STD | 0.394 | 0.050 | 0.245 | 0.206 | 0.060 | 0.154 |
| N | 83 | 83 | 83 | 83 | 83 | 83 |
| Min | 4.901 | 0.484 | 1.254 | 2.558 | 0.574 | 0.789 |
| Max | 6.423 | 0.744 | 2.982 | 3.353 | 0.883 | 1.876 |
| Mean ± 2.5 STD | 4.794 - 6.764 | 0.497 - 0.729 | 1.259 - 2.485 | 2.502 - 3.531 | 0.589 - 0.889 | 0.792 - 1.563 |
| Wheat | N | P | K | Nutrient | Removal | Values |
| County | % | % | % | lbs N/bu | Lbs P₂O₅/bu | lbs K₂O/bu |
| Audrain | 1.846 | 0.392 | 0.872 | 0.958 | 0.463 | 0.545 |
| Barton | 2.148 | 0.439 | 0.575 | 1.115 | 0.518 | 0.359 |
| Barton | 2.306 | 0.463 | 0.613 | 1.197 | 0.546 | 0.383 |
| Barton | 2.314 | 0.545 | 0.586 | 1.201 | 0.643 | 0.366 |
| Barton | 2.309 | 0.451 | 0.500 | 1.198 | 0.532 | 0.312 |
| Bates | 2.308 | 0.485 | 0.551 | 1.198 | 0.572 | 0.345 |
| Bates | 2.200 | 0.452 | 0.585 | 1.142 | 0.533 | 0.366 |
| Bates | 2.173 | 0.433 | 0.556 | 1.128 | 0.511 | 0.348 |
| Boone | 2.312 | 0.446 | 0.539 | 1.200 | 0.527 | 0.337 |
| Cape Girardeau | 2.347 | 0.388 | 0.578 | 1.218 | 0.457 | 0.362 |
| Cape Girardeau | 2.811 | 0.461 | 0.617 | 1.459 | 0.543 | 0.386 |
| Cape Girardeau | 3.248 | 0.502 | 0.691 | 1.686 | 0.592 | 0.432 |
| Cape Girardeau | 3.213 | 0.437 | 0.735 | 1.668 | 0.515 | 0.459 |
| Carroll | 2.104 | 0.446 | 0.678 | 1.092 | 0.526 | 0.424 |
| Carroll | 1.944 | 0.419 | 0.662 | 1.009 | 0.494 | 0.414 |
| Cass | 2.139 | 0.449 | 0.572 | 1.110 | 0.530 | 0.358 |
| Chariton | 1.881 | 0.369 | 0.512 | 0.976 | 0.435 | 0.320 |
| Chariton | 2.102 | 0.409 | 0.643 | 1.091 | 0.482 | 0.402 |
| Chariton | 2.013 | 0.389 | 0.661 | 1.045 | 0.459 | 0.413 |
| Clay | 2.352 | 0.469 | 0.641 | 1.221 | 0.553 | 0.401 |
| Grundy | 2.101 | 0.390 | 0.609 | 1.091 | 0.460 | 0.381 |
| Howard | 2.050 | 0.408 | 0.696 | 1.064 | 0.481 | 0.435 |
| Howard | 1.968 | 0.398 | 0.548 | 1.021 | 0.470 | 0.343 |
| Jackson | 2.096 | 0.431 | 0.530 | 1.088 | 0.509 | 0.332 |
| Jackson | 2.134 | 0.381 | 0.539 | 1.108 | 0.450 | 0.337 |
| Lewis | 1.856 | 0.374 | 0.808 | 0.963 | 0.441 | 0.505 |
| Lewis | 1.872 | 0.391 | 0.729 | 0.972 | 0.462 | 0.456 |
| Livingston | 1.997 | 0.370 | 0.573 | 1.036 | 0.436 | 0.358 |
| Mississippi | 1.978 | 0.432 | 0.545 | 1.027 | 0.510 | 0.341 |
| Montgomery | 1.954 | 0.393 | 0.857 | 1.014 | 0.464 | 0.536 |
| New Madrid | 2.230 | 0.443 | 0.580 | 1.158 | 0.523 | 0.363 |
| Pemiscot | 2.248 | 0.418 | 0.561 | 1.167 | 0.493 | 0.351 |
| Pemiscot | 2.286 | 0.418 | 0.554 | 1.187 | 0.493 | 0.347 |
| Pike | 2.020 | 0.392 | 0.922 | 1.048 | 0.463 | 0.576 |
| Randolph | 2.034 | 0.385 | 0.564 | 1.056 | 0.454 | 0.353 |
| Randolph | 2.061 | 0.392 | 0.613 | 1.070 | 0.462 | 0.383 |
| Randolph | 2.006 | 0.376 | 0.804 | 1.041 | 0.444 | 0.503 |
| Ray | 2.218 | 0.426 | 0.725 | 1.151 | 0.503 | 0.453 |
| Ray | 1.983 | 0.386 | 0.610 | 1.029 | 0.455 | 0.381 |
| Ray | 1.997 | 0.384 | 0.615 | 1.037 | 0.454 | 0.385 |
| Scott | 2.374 | 0.491 | 0.653 | 1.232 | 0.580 | 0.408 |
| Boone | 2.538 | 0.439 | 0.479 | 1.317 | 0.518 | 0.299 |
| Boone | 2.865 | 0.485 | 0.544 | 1.487 | 0.572 | 0.340 |
| Boone | 2.500 | 0.446 | 0.484 | 1.298 | 0.526 | 0.302 |
| Boone | 2.342 | 0.433 | 0.440 | 1.215 | 0.510 | 0.275 |

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|-----------------------|----------------------|----------------------|----------------------|----------------------|--|------------------------------|
| Boone | 2.604 | 0.477 | 0.437 | 1.351 | 0.562 | 0.273 |
| Boone | 2.534 | 0.432 | 0.412 | 1.315 | 0.510 | 0.258 |
| Boone | 2.852 | 0.432 | 0.561 | 1.480 | 0.509 | 0.351 |
| Boone | 2.476 | 0.457 | 0.462 | 1.285 | 0.539 | 0.289 |
| Boone | 2.503 | 0.447 | 0.420 | 1.299 | 0.528 | 0.262 |
| Boone | 2.532 | 0.432 | 0.503 | 1.314 | 0.510 | 0.314 |
| Boone | 2.567 | 0.456 | 0.512 | 1.332 | 0.538 | 0.320 |
| Boone | 2.280 | 0.422 | 0.472 | 1.183 | 0.498 | 0.295 |
| Boone | 2.602 | 0.432 | 0.472 | 1.350 | 0.509 | 0.295 |
| Boone | 2.504 | 0.460 | 0.489 | 1.299 | 0.542 | 0.306 |
| Boone | 2.495 | 0.425 | 0.454 | 1.295 | 0.501 | 0.284 |
| Knox | 2.030 | 0.436 | 0.426 | 1.053 | 0.514 | 0.266 |
| Knox | 2.126 | 0.401 | 0.475 | 1.104 | 0.473 | 0.297 |
| Knox | 1.870 | 0.370 | 0.412 | 0.971 | 0.437 | 0.257 |
| Knox | 1.959 | 0.438 | 0.461 | 1.017 | 0.517 | 0.288 |
| Knox | 2.026 | 0.443 | 0.411 | 1.051 | 0.523 | 0.257 |
| Knox | 2.013 | 0.372 | 0.409 | 1.045 | 0.439 | 0.256 |
| Knox | 1.930 | 0.415 | 0.452 | 1.002 | 0.490 | 0.283 |
| Knox | 1.926 | 0.412 | 0.420 | 1.000 | 0.486 | 0.262 |
| Knox | 2.231 | 0.487 | 0.394 | 1.158 | 0.574 | 0.246 |
| Knox | 1.965 | 0.404 | 0.422 | 1.020 | 0.476 | 0.264 |
| Knox | 2.075 | 0.419 | 0.413 | 1.077 | 0.494 | 0.258 |
| Knox | 1.836 | 0.351 | 0.450 | 0.953 | 0.414 | 0.282 |
| Knox | 1.939 | 0.439 | 0.422 | 1.006 | 0.518 | 0.264 |
| Knox | 1.940 | 0.408 | 0.430 | 1.007 | 0.482 | 0.269 |
| Knox | 1.880 | 0.381 | 0.389 | 0.976 | 0.450 | 0.243 |
| Mean | 2.218 | 0.425 | 0.557 | 1.151 | 0.501 | 0.348 |
| STD | 0.308 | 0.037 | 0.123 | 0.160 | 0.044 | 0.077 |
| N | 71 | 71 | 71 | 71 | 71 | 71 |
| Min | 1.836 | 0.351 | 0.389 | 0.953 | 0.414 | 0.243 |
| Max | 3.248 | 0.545 | 0.922 | 1.686 | 0.643 | 0.576 |
| Mean ± 2.5 STD | 1.448 - 2.988 | 0.333 - 0.517 | 0.250 - 0.863 | 0.751 - 1.551 | 0.392 - 0.610 | 0.156 - 0.540 |
| <u>Sorghum</u> | N | P | K | Nutrient | Removal | Values |
| County | % | % | % | lbs N/bu | Lbs P₂O₅/bu | lbs K₂O/bu |
| Audrain | 1.600 | 0.308 | 0.633 | 0.780 | 0.341 | 0.371 |
| Livingston | 1.359 | 0.251 | 0.369 | 0.662 | 0.278 | 0.217 |
| Livingston | 1.354 | 0.275 | 0.371 | 0.660 | 0.305 | 0.218 |
| New Madrid | 1.487 | 0.283 | 0.497 | 0.725 | 0.314 | 0.292 |
| New Madrid | 1.571 | 0.297 | 0.486 | 0.765 | 0.329 | 0.285 |
| New Madrid | 1.846 | 0.378 | 0.377 | 0.899 | 0.419 | 0.221 |
| New Madrid | 1.410 | 0.361 | 0.604 | 0.687 | 0.399 | 0.355 |
| New Madrid | 1.495 | 0.304 | 0.447 | 0.728 | 0.337 | 0.263 |
| Pemiscot | 1.525 | 0.283 | 0.475 | 0.743 | 0.313 | 0.279 |
| Pemiscot | 1.469 | 0.298 | 0.449 | 0.716 | 0.330 | 0.263 |
| Pemiscot | 1.340 | 0.295 | 0.413 | 0.653 | 0.327 | 0.242 |
| Pike | 1.700 | 0.297 | 0.699 | 0.828 | 0.329 | 0.410 |
| Scott | 1.737 | 0.329 | 0.571 | 0.846 | 0.364 | 0.335 |
| Scott | 1.580 | 0.318 | 0.524 | 0.770 | 0.352 | 0.308 |
| Scott | 1.252 | 0.288 | 0.511 | 0.610 | 0.319 | 0.300 |
| Scott | 1.834 | 0.306 | 0.480 | 0.894 | 0.339 | 0.281 |
| Scott | 1.475 | 0.305 | 0.541 | 0.719 | 0.337 | 0.318 |
| Scott | 1.358 | 0.327 | 0.550 | 0.662 | 0.362 | 0.323 |
| Scott | 1.516 | 0.310 | 0.482 | 0.739 | 0.343 | 0.283 |

| | | | | | | |
|-----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Mean | 1.522 | 0.306 | 0.499 | 0.741 | 0.339 | 0.293 |
| STD | 0.167 | 0.029 | 0.089 | 0.081 | 0.032 | 0.052 |
| N | 19 | 19 | 19 | 19 | 19 | 19 |
| Min | 1.252 | 0.251 | 0.369 | 0.610 | 0.278 | 0.217 |
| Max | 1.846 | 0.378 | 0.699 | 0.899 | 0.419 | 0.410 |
| Mean ± 2.5 STD | 1.105 - 1.938 | 0.234 - 0.378 | 0.277 - 0.720 | 0.538 - 0.944 | 0.259 - 0.419 | 0.163 - 0.423 |

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

| Crop | Yield Unit | N removal | | | | | P ₂ O ₅ removal | | | | | K ₂ O removal | | | | |
|---------|------------|-----------|-------|-----------|-------|-------|---------------------------------------|--------|-----------|-------|--------|--------------------------|--------|-----------|--------|--------|
| | | Current | NRC | MO Values | | IPNI | Current | NRC | MO Values | | IPNI | Current | NRC | MO Values | | IPNI |
| | | | | 2006 | 2007 | | | | 2006 | 2007 | | | | 2006 | 2007 | |
| Corn | bushel | 0.9 | 0.74 | 0.68 | 0.71 | 0.75 | 0.45 | 0.32 | 0.48 | 0.33 | 0.44 | 0.3 | 0.25 | 0.34 | 0.27 | 0.29 |
| Sorghum | pound | 0.014 | 0.018 | 0.014 | 0.012 | 0.015 | 0.0093 | 0.0067 | 0.015 | 0.006 | 0.0075 | 0.006 | 0.0047 | 0.0093 | 0.0048 | 0.0038 |
| Soybean | bushel | - | 3.4 | 2.55 | 3.02 | 4 | 0.84 | 0.8 | 0.53 | 0.74 | 0.8 | 1.44 | 1.3 | 1.01 | 1.18 | 1.4 |
| Wheat | bushel | 1.26 | 1.18 | 0.95 | 1.15 | 1.5 | 0.6 | 0.5 | 0.4 | 0.5 | 0.5 | 0.3 | 0.3 | 0.29 | 0.35 | 0.35 |

Table 6: Survey Report of the Forage Nutrient Percentages for Major Grass in Missouri – Year 2006

| <u>Species</u> | <u>N</u> % | <u>P</u> % | <u>K</u> % |
|--------------------|---------------|---------------|---------------|
| Alfalfa | 4.467 | 0.394 | 1.740 |
| Alfalfa | 3.210 | 0.313 | 1.910 |
| Alfalfa | 4.194 | 0.243 | 1.334 |
| Alfalfa | 6.146 | 0.494 | 1.981 |
| Alfalfa | 4.141 | 0.367 | 1.764 |
| Alfalfa | 3.955 | 0.381 | 1.699 |
| Alfalfa | 3.590 | 0.339 | 1.484 |
| Alfalfa | 4.097 | 0.388 | 1.604 |
| Alfalfa | 4.491 | 0.443 | 3.058 |
| Alfalfa | 3.511 | 0.333 | 2.738 |
| Alfalfa | 3.549 | 0.351 | 2.863 |
| Alfalfa | 3.259 | 0.325 | 2.668 |
| Alfalfa | 3.622 | 0.367 | 2.865 |
| Alfalfa | 3.866 | 0.363 | 2.486 |
| Alfalfa | 3.181 | 0.341 | 2.546 |
| Alfalfa | 3.267 | 0.323 | 2.255 |
| Alfalfa | 3.135 | 0.298 | 2.446 |
| Alfalfa | 3.420 | 0.329 | 2.150 |
| Ann. Ryegrass | 3.257 | 0.361 | 3.465 |
| Ann. Ryegrass | 2.666 | 0.403 | 3.594 |
| Ann. Ryegrass | 1.705 | 0.346 | 2.438 |
| Ann. Ryegrass | 1.854 | 0.386 | 2.408 |
| Ann. Ryegrass | 3.437 | 0.302 | 2.570 |
| Ann. Ryegrass | 3.004 | 0.369 | 2.940 |
| Ann. Ryegrass | 1.980 | 0.502 | 1.985 |
| Ann. Ryegrass | 1.609 | 0.389 | 1.624 |
| Bermuda | 1.100 | 0.248 | 0.875 |
| Caucasian Bluestem | 1.708 | 0.357 | 2.193 |
| Caucasian Bluestem | 1.907 | 0.371 | 2.012 |
| Caucasian Bluestem | 1.553 | 0.184 | 1.691 |
| Caucasian Bluestem | 1.449 | 0.169 | 1.908 |
| Caucasian Bluestem | 1.772 | 0.196 | 1.184 |
| Caucasian Bluestem | 1.965 | 0.228 | 1.587 |
| Caucasian Bluestem | 1.854 | 0.230 | 1.970 |
| Caucasian Bluestem | 1.450 | 0.158 | 1.292 |
| Caucasian Bluestem | 1.403 | 0.156 | 1.149 |
| Early Cut Fescue | 1.549 | 0.229 | 1.399 |
| Late Cut Fescue | 1.356 | 0.157 | 1.711 |
| Lespedeza | 1.799 | 0.270 | 1.886 |
| Lespedeza | 1.155 | 0.374 | 2.581 |
| Orchard Grass | 1.545 | 0.217 | 1.737 |
| Red Clover | 2.506 | 0.219 | 1.390 |
| Red Clover | 3.497 | 0.282 | 1.953 |
| Red Clover | 1.741 | 0.429 | 3.535 |
| Red Clover | 1.875 | 0.450 | 1.983 |
| Sorg/Sudan | 0.954 | 0.129 | 0.958 |
| Sorg/Sudan | 1.538 | 0.211 | 1.240 |
| Sorg/Sudan | 2.667 | 0.383 | 2.555 |
| Sorg/Sudan | 2.314 | 0.314 | 2.176 |

| | | | |
|-----------------------|------------------|----------------------|----------------------|
| Sorg/Sudan | 1.307 | 0.305 | 1.347 |
| Spring Alfalfa | 2.930 | 0.419 | 2.563 |
| Spring Fescue | 1.685 | 0.274 | 1.578 |
| Spring Wheat | 1.550 | 0.254 | 1.837 |
| Tall Fescue | 1.904 | 0.232 | 2.220 |
| Tall Fescue | 1.748 | 0.232 | 2.031 |
| Tall Fescue | 1.699 | 0.240 | 1.801 |
| Tall Fescue | 1.565 | 0.252 | 1.169 |
| Tall Fescue | 1.167 | 0.221 | 1.917 |
| Tall Fescue | 1.632 | 0.398 | 2.133 |
| Tall Fescue Spring N | 1.138 | 0.252 | 1.777 |
| Tall Fescue Spring N | 1.549 | 0.517 | 2.397 |
| Tall Fescue Spring N | 1.474 | 0.514 | 2.213 |
| Mean | 2.429 | 0.315 | 2.041 |
| STD | 1.116 | 0.095 | 0.612 |
| N | 62 | 62 | 62 |
| Min | 0.954 | 0.129 | 0.875 |
| Max | 6.146 | 0.517 | 3.594 |
| Mean ± 2.5 STD | 0 - 5.219 | 0.078 - 0.553 | 0.511 - 3.571 |

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