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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 those to ask why? If they don't know, then perhaps you will have just suggested the next burning question that will become the object of new research. Any questions or ideas? If you do, send them too us at:

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Agricultural Lime

Final Reports

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

David Dunn and Gene Stevens
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Objective:
This study will investigate the possibility of using "quarter minus" materials as lime sources. A possible use will be evaluated, low pH sandy alluvial soils.

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

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

Procedure:
This study compares "quarter minus" material with traditional ag lime derived from the Delta Companies quarry located near Poplar Buff, MO The traditional ag lime from this source was found to contain 495 ENM per ton, while the quarter minus material was found to contain 284 ENM per ton. The details of this analysis are found in Table 1. Two low pH research areas were identified. One at the University of Missouri Marsh Farm where the soil type is a Tiptonville silt loam, here a corn/soybeans rotation was cultivated. The initial soil pH at this location was 5.2. The other research area is located at the University of Missouri Rhodes Farm; here in 2010 and 2011 cotton was cultivated. However, in 2012 drought conditions prevented the establishment of a cotton crop. Subsequently soybeans were cultivated. At this location the soil type is a Bosket

loamy sand and the initial soil pH was 5.4. Prior to planting in 2010 plots representing seven lime treatments were established at each location. The treatments used at each location are listed in Table 2. The corresponding amount of specified product was applied to each plot and incorporated with tillage prior to planting. All methods of N, P and K fertilization, weed & insect control and irrigation were the standard practices for Southeast Missouri. At the end of the season all plots were harvested and the yield measured. Soil samples were collected monthly from each plot during the growing season. These samples were analyzed for pH**.**

Project accomplishments:
Crop yields for 2010, 2011, and 2012 at both locations are presented in Table 3. For all years at both locations all lime treatments numerically increased crop yields relative to the untreated check. **Marsh Farm:** For all years in the study lime additions, traditional or ¼ minus, numerically increased yields. In 2011, when corn was cultivated, yields for the untreated check were statistically lower than treatments receiving either ag-lime or ¼ minus lime. Also in 2011 yields for treatments receiving less than more than 500 ENM (53% of the recommended rate) were also statistically equivalent. The treatment which received 1136 ENM as ¼ minus produced the greatest numerical yields two of the three years studied. **Rhodes Farm:** For all years in the study lime additions, traditional or ¼ minus, numerically increased yields. In 2012, when soybeans were cultivated, yields for the untreated check were statistically lower than treatments receiving either ag-lime or ¼ minus lime. This is in contrast to the two preceding years when cotton was cultivated. This could be due to the greater sensitivity to soil pH for soybeans relative to cotton. The treatment which received 1420 ENM as ¼ minus produced the greatest numerical yields all three years studied.

Relative yields for lime treatments are presented as Table 4. For both locations the three-year average relative yields indicate that when the recommended or greater rate of ENM for either product is applied relative yields of greater than 90% are captured. A comparison of % of the recommended ENM and % relative yields averaged over three years is presented as Figure 1. Here the slope of the yield curve is similar for each product. The yield data from this study indicates that ¼ minus materials are equivalent in producing yield increases to traditional ag-lime when applied on an equivalent ENM basis.

The season end, pH data for 2010, 2011, and 2012 is presented as Table 5. **2010:** The addition of any rate of lime as either traditional ag-lime or ¼ minus produced soil pH levels significantly greater than the untreated check. At both locations the ag-lime initially produced a greater pH change during the first year of the study than corresponding rates of ¼ minus material. However when the recommended ENM rate of either product was applied pH levels were raised into the desired range for row crop production (6.1+) by season's end in 2010. At the Rhodes Farm the first year pH increase was steeper for all treatments. This may be due to the lower buffering capacity offered by the Bosket loamy sand. This rapid pH rise during the first growing season was mirrored by a pH decline during the second. **2011:** At season's end in 2011 only the highest rates for each product produced pH levels at or above the 6.1 soil pH target at either location**.** **2012:** For both locations season end pH levels showed a decline to below optimum levels for all rates of traditional ag-lime. The ¼ minus treatments generally showed an increase of pH level for the season end 2012 sampling with several treatments increasing in pH to at or above target levels.. The data indicates that ¼ minus materials are equivalent in producing soil pH increases to traditional ag-lime when applied on an equivalent ENM basis. Further, the residual lime value contained in the greater than #8 contained in the ¼ minus material is continuing to neutralize soil acidity. It may be possible to postpone further lime applications for these treatments past the 3-year window covered by traditional ag-lime products.

Summary

- The ¼ minus lime material studied was found to be equivalent to traditional ag-lime for increasing soil pH and crop yields when compared on an ENM vrs. ENM basis.
- It takes approximately 2 tons of ¼ minus to equal 1 ton of traditional ag-lime in terms of ENM content.
- The portion of material greater than #8 contained in the ¼ minus continued to be effective at reducing soil acidity in the third year of this study.
- Transportation costs may be significant when comparing the economics of these two products.
- More study is needed to determine the long term impact of using ¼ minus materials as an ag-lime source.

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

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

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

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

Table 3. Crop yields for lime treatments 2010, 2011, and 2012.

Trt#	MU Marsh Farm: Soybeans (2010)/Corn (2011)/Soybean(2012)				MU Rhodes Farm: Cotton 2010 & 2011/Soybeans (2012)			
	Material	2010	2011	2012	Material	2010	2011	2012
		bu/a	bu/a	bu/a		lb/a	lb/a	bu/a
1	Check	24.7 b	131c	29.0 b	Check	854 b	821b	24.2c
2	Ag-lime (495 ENM)	30.0 ab	140b	31.6 ab	Ag-lime (495 ENM)	935 ab	850b	27.0b
3	Ag-lime (990 ENM)	31.5 ab	151a	33.3 ab	Ag-lime (990 ENM)	1010 a	993a	27.3b
4	Ag-lime (1485 ENM)	37.3 a	156a	34.7 a	¼ minus (568 ENM)	922 ab	892b	28.2ab
5	¼ minus (710 ENM)	32.0 ab	149a	32.1 ab	¼ minus (852 ENM)	992 a	877b	28.7ab
6	¼ minus (852 ENM)	36.8 a	155a	32.9 ab	¼ minus (1136 ENM)	968 a	983a	28.7ab
7	¼ minus (1136 ENM)	38.2 a	154a	35.4 a	¼ minus (1420 ENM)	1016 a	1018a	29.8a
lsd 0.05		5.9	8.1	3.1		77	66	1.4
CV %		12.0	3.7	6.3		5.4	4.9	3.3

Table 4. Relative yields for lime treatments 2010, 2011, and 2012.

Trt#	MU Marsh Farm: Soybeans (2010)/Corn (2011)/Soybean(2012)					MU Rhodes Farm: Cotton 2010 & 2011/Soybeans (2012)				
	Material	2010	2011	2012	3-year average	Material	2010	2011	2012	3-year average
1	Check	65	84	82	77	Check	84	81	81	82
2	Ag-lime (495 ENM)	79	90	89	86	Ag-lime (495 ENM)	92	83	91	89
3	Ag-lime (990 ENM)	83	97	94	91	Ag-lime (990 ENM)	99	98	92	96
4	Ag-lime (1485 ENM)	98	100	98	99	¼ minus (568 ENM)	91	88	95	91
5	¼ minus (710 ENM)	84	96	91	90	¼ minus (852 ENM)	98	86	96	93
6	¼ minus (852 ENM)	96	99	93	96	¼ minus (1136 ENM)	95	97	96	96
7	¼ minus (1136 ENM)	100	99	100	100	¼ minus (1420 ENM)	100	100	100	100

Table 5. Year-end soil pH for lime treatments 2010, 2011, and 2012.

Trt#	MU Marsh Farm: Soybeans (2010)/Corn (2011)/Soybean(2012)				MU Rhodes Farm: Cotton 2010 & 2011/Soybeans (2012)			
	Material	2010	2011	2012	Material	2010	2011	2012
1	Check	5.3	5.2	5.2	Check	5.4	5.4	5.3
2	Ag-lime (495 ENM)	6.1	6.1	5.9	Ag-lime (495 ENM)	6.3	5.8	5.7
3	Ag-lime (990 ENM)	6.1	6.1	6.0	Ag-lime (990 ENM)	6.6	6.1	6.0
4	Ag-lime (1485 ENM)	6.2	6.2	6.1	¼ minus (568 ENM)	6.2	5.7	5.9
5	¼ minus (710 ENM)	5.7	5.7	5.9	¼ minus (852 ENM)	6.2	5.8	6.0
6	¼ minus (852 ENM)	5.9	6.0	6.1	¼ minus (1136 ENM)	6.5	6.2	6.1
7	¼ minus (1136 ENM)	6.1	6.1	6.3	¼ minus (1420 ENM)	6.6	6.2	6.3

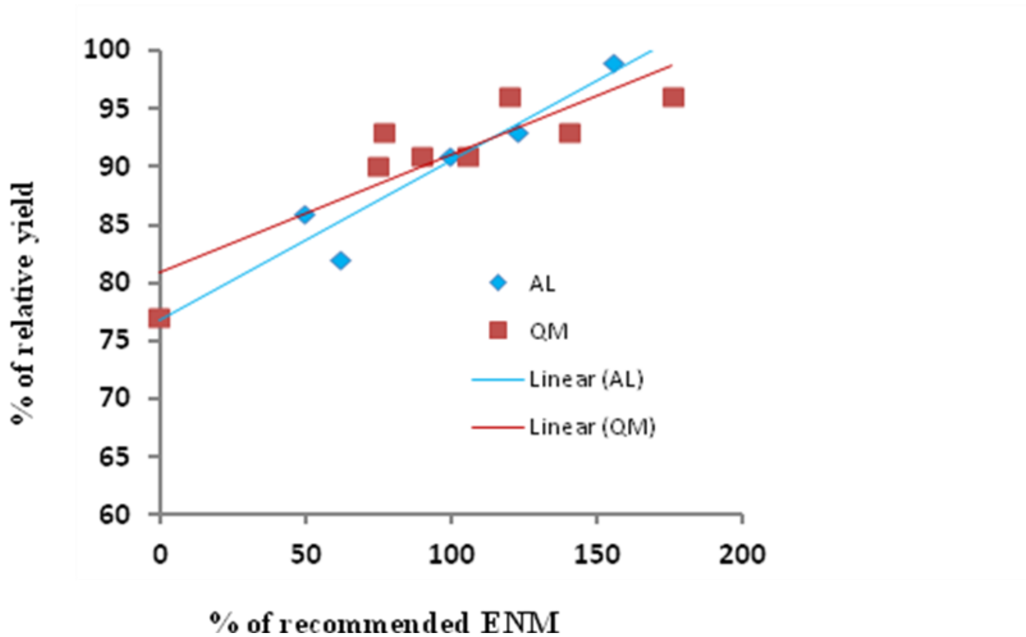

Figure 1. Relative yields for crops grown on low pH soils amended with differing amounts of traditional ag-lime (AL) and ¼ minus (QM) lime sources, MU Marsh Farm, Portageville, MO and MU Rhodes Farm, Clarkton, MO, 2010-2012.

Liming in a Rice/Soybean Rotation

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

Objective: The objective of this study is to determine the correct lime rates and application timings for a rice/soybean rotation.

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

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

Project accomplishments: Plots were established in 2010 for both rice and soybeans. The rice crop was successfully established, brought to harvest and yield measured. Protracted drought conditions in May through September of 2010 resulted in a failure to establish a consistent stand for the soybean crop. Consequently these plots had to be abandoned for 2010 and no yield measurement was possible. In both 2011 and 2012 favorable rainfall conditions returned. Both the rice and soybean crops were established brought to harvest and yield measured.

Crop yields for 2010, 2011 and 2012 are presented as Table 1 while relative yields are presented as Table 2. **Rice:** In all three years liming inconsistently affected rice yields with relative yields ranging from 93-100%. The untreated check consistently produced relative yields of 94% or greater. The 0.8 ton/a lime rate (1/2 of recommended rate) produced the numerically greatest rice yields each year. However, the numerical lowest yields for rice were obtained with the rate 1.2

ton/a in 2010, while the 1.6 ton rate produced the lowest yields in 2011. The 200 lb/a pel lime treatment applied annually produced yields which averaged 2 bu/a greater than the untreated check. With this treatment an average of 95% relative yield was obtained. In terms of relative yields lime or no lime did not adversely affect rice yields.

Soybeans: For the two years that a soybean yields was measure liming consistently increased yields. The untreated check only produced a 75% average relative yield for the two years. In 2011 the greatest soybean yields were obtained with the 1.2 ton/a rate of lime, while in 2012 the 1.6 ton/a rate produced the greatest numerical yields. The 200 lb/a pel lime treatment applied annually produced yields numerically greater that the untreated check but less than any of the lime treatments. With this treatment an average of 80% relative yield was obtained. In terms of relative yields liming consistently raised soybean yields.

Soil pH was measured for each plot at the beginning (May) and end (September) of each season. This data is presented in Tables 3a and 3b. For each year when the end of the season pH was averaged for all treatments higher pH levels were found for the plots on which rice was cultivated that year. This reflects the lime contribution of the flood waters applied supporting the rice crop.

Summary

- Rice yields were largely unaffected by liming. The untreated check produced an average of 94% relative yield.
- Soybean yields were strongly affected by liming. With no lime added only 75% of the relative yield was obtained.
- Given that MU lime recommendations cover a 3-year time period, for maximum economic impact lime should be applied before the soybean crop. This allows 2 of the 3 years to be in the crop that will benefit the most from lime.
- Lime rates should be determined by using soybeans as the crop to be grown in this rotation.

Table 1. Rice and soybean yields for lime treatments at Qulin, MO 2010, 2011, and 2012

Trt#	Lime Rate	2010		2011		2012	
		Rice	Beans	Rice	Beans	Rice	Beans
1	check	141	----	138	34	129	25
2	0.4 ton (200 ENM)	141	----	139	40	134	31
3	0.8 ton (400 ENM)	149	----	146	42	137	31
4	1.2 ton (600 ENM)	140	----	140	45	130	33
5	1.6 ton (800 ENM)	144	----	136	44	131	34
6	200 lb pel lime (60 ENM)	142	----	140	37	131	27

Table 2. Relative yields for crops with lime treatments at Qulin, MO 2010, 2011, and 2012.

Trt#	Lime Rate	2010		2011		2012	
		Rice	Beans	Rice	Beans	Rice	Beans
1	check	95	----	95	76	94	74
2	0.4 ton (200 ENM)	95	----	95	89	98	91
3	0.8 ton (400 ENM)	100	----	100	93	100	91
4	1.2 ton (600 ENM)	94	----	96	100	95	97
5	1.6 ton (800 ENM)	97	----	93	98	96	100
6	200 lb pel lime (60 ENM)	95	----	96	82	96	79

Table 3a and 3b. Ph values measure in 3-year rice/soybean rotational experiment with lime additions at Qulin, MO 2010-2012.

Table 3a, Soil pH values for lime treatments for Rice-2010: Soybeans-2011: Rice-2012 (2 year rice, 1 year soybeans)							
Trt#	Lime Rate	5/1/10	9/30/10	5/1/11	9/30/11	5/1/12	9/30/12
		Rice		Soybeans		Rice	
1	check	5.6	5.8	5.6	5.4	5.5	5.6
2	0.4 ton (200 ENM)	5.6	6.0	6.0	5.9	5.7	5.7
3	0.8 ton (400 ENM)	5.5	6.1	6.2	6.2	5.9	5.8
4	1.2 ton (600 ENM)	5.6	6.1	6.3	6.3	6.0	5.9
5	1.6 ton (800 ENM)	5.6	6.2	6.4	6.4	6.1	6
6	200 lb pel lime (60 ENM)	5.5	5.9	5.7	5.9	5.7	5.6
Average of all treatments		5.6	6.0	6.0	6.0	5.8	5.8

Table 3b, Soil pH values for lime treatments for Soybeans-2010: Rice-2011: Soybeans-2012 (2 year soybeans, 1 year rice)							
Trt#	Lime Rate	5/1/10	9/30/10	5/1/11	9/30/11	5/1/12	9/30/12
		Soybeans		Rice		Soybeans	
1	check	5.6	5.4	5.5	5.7	5.6	5.4
2	0.4 ton (200 ENM)	5.6	5.8	5.9	6.1	5.9	5.7
3	0.8 ton (400 ENM)	5.5	5.9	6.1	6.2	5.9	5.8
4	1.2 ton (600 ENM)	5.5	6.1	6.2	6.2	6.0	5.9
5	1.6 ton (800 ENM)	5.6	6.3	6.3	6.4	6.2	5.9
6	200 lb pel lime (60 ENM)	5.6	5.8	5.7	5.8	5.6	5.5
Average of all treatments		5.6	5.9	6.0	6.1	5.9	5.7

Progress Reports

Benefits of Lime Placement on Grain Yield Response and Remediation of Acid Subsoils

Kelly Nelson, Peter Scharf and Peter Motavalli

Investigators:
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Objective and Relevance:

An extensive root system is essential for crop plants to tolerate short- and long-term periods of drought that often occur during the growing season in Missouri. Acid subsoils reduce root growth and grain yield. Stratification of pH values is common in claypan soils in Missouri. In soil survey publications, surface soil samples of claypan soils may have optimum pH values; however, the subsoil from 8 to 20 in. may decrease to pH values as low as 3.6, 4.5, and 4.5 for soils such as Putnam, Mexico, and Armstrong, respectively (Ferguson, 1995). In three-paired watershed research, seventy five soil samples from the Ap, AB, and Bt1 horizons had average pH values of 6.6 ($\pm$1.7), 6.3 ($\pm$0.6), and 4.9 ($\pm$1.2), respectively (Udawatta, unpublished). Drainage research plots had subsoil (8-18 in.) pH values from 4.7 to 5.2 (Nelson, unpublished) while other research indicated average subsoil pH values from 29 claypan soils at the 0-6 in., 6-12 in., 12-24 in., and 24-36 in. depths were 6.2, 6.0, 5.0, and 5.1 (Scharf, unpublished). Over 60% of the 29 fields had pH values less than 5 at the 12-24 in. depth. The lowest pH value at any site was 4.4. Acidic subsoils (at or below the 12 in. depth) may be a greater barrier to root growth than physical restrictions in many soils in Missouri.

Research on cotton (Adcock et al., 1999) and alfalfa (Rechcigl et al., 1991) has demonstrated the benefit of deep lime placement. Methods that incorporated lime increased corn grain yields greater than conventional liming techniques using surface applications (Farina and Channon, 1988). In this research, corn grain yields increased 20 bu/a in a dry year while in a wet year grain yield increased 6 bu/a (Farina and Channon, 1988). Low soil pH, 5 to 5.5, is an agronomic and environmental concern. Macronutrient and microbial activity is restricted and phytotoxic levels of exchangeable Al and Mn are common at low soil pH values. In addition, nitrification may be limited in an acidic environment. Nitrogen applications from ammonium-based N fertilizers acidify soils and require agriculture lime applications to neutralize the impact on soil pH. N sources may require 1.8 to 5.4 lb $CaCO_3$ to neutralize acidity depending on the N source. Anhydrous ammonia applications are commonly used throughout the region and may contribute to a decrease in subsoil pH while the surface soil pH is acceptable. A deep lime application may also reduce the impact of low soil pH on root growth and development.

Acid-subsoil amelioration has been studied with long-term impacts on soil pH levels (Toma et al., 1999; Farina et al., 2000b). Grain and forage yields increased 29 to 50% even 16 yr. after application (Toma et al., 1999) with increased returns (Farina et al., 2000a). Deep placement of dry lime at 1500 lbs/acre over two years increased soybean grain yields over 4 bu/a and increased profitability $94/acre compared to deep tillage only (Tupper et al. 1987). Farmers have utilized no-till and conventional tillage systems to attain specific production goals. Incorporation of lime may be necessary to realize an immediate (Toma et al. 1999) increase in grain yield. Deep placement of lime utilizing conservation-type knives could accomplish an immediate increase in grain yield, provide zone-tillage, increase subsoil pH, and maintain surface residue. Concerns regarding the practicality and economics of deep incorporation have been expressed; however, numerous producers continue to subsoil claypan soils. Previous MU research has evaluated pH management in the top 6 to 8 inches of soil; however, no research has evaluated deep lime applications or the impact on subsoil properties. This research initiates a long-term evaluation of the impact of addressing subsoil pH correction in no-till and reduced tillage cropping systems. *The objective of this research is to evaluate yield response of corn and soybean to lime placement and the impact on subsoil pH.* We will maintain the field that was established in 2012 and corn plots will rotate into soybean while soybean will rotate into corn. A second location was established for 2013 and treatments were applied in the fall of 2012 which is more typical of a deep tillage treatment.

Materials and Methods:

A field trial was established at the University of Missouri Greenley Research Center on a Putnam silt loam that has been in continuous no-till production for over 13 years with an acid subsoil in May 2012 (Table 1). A second research site was established in November 2012. A factorial arrangement of treatments included placement (no-till surface and conservation subsoiler deep placement), crop (corn and soybean), and lime rates (0, 1.5, and 3 tons/acre with 600 lbs effective neutralizing material/ton) to evaluate the response of corn or soybeans within a given year. Pelleted lime (Kelly's Limestone, Newark, MO) was derived from mined calcium carbonate and magnesium carbonate. A 2% lignosulfonate was utilized as the binding agent for pelletizing. The conservation subsoiler (Case IH 2500 ecolo-til) (Figure 1 left) had custom built shank (Figure 1 right) to deliver and distribute lime to 4 different levels in the soil profile, while delivery and metering was accomplished using a commercial Montag (Figure 1 left) dry fertilizer air delivery system. The selected rates of lime were based on an average subsoil recommendation (high rate), top 6 inches of soil recommendation (low rate), and a non-treated control. A site with a low surface pH was utilized in the experiment (Table 1).

Figure 1. Deep placement applicator with Montag dry fertilizer air delivery system (left) and custom built applicator shank (right).

Field management and crop protection chemical applications for corn and soybean are reported in Table 2. This research evaluated soil pH and neutralizable acidity at four depths (0-5, 6-10, 11-15, and 16-20 inches) similar to other research (Farina et al. 2000a, 2000b; Tupper et al., 1987), grain yield, and crop growth characteristics. These samples were collected in the fall of 2012. Soil samples are currently being processed through the University of Missouri Soil Testing Laboratory. Soil sampling depth corresponded to the different distribution drop tubes on the applicator shank.

Figure 2. Soil during application (left), after application at a field day demonstration (center), and an overhead overview after application (right).

The center two rows of corn were harvested for yield and converted to 15%, while the center 5 ft of the soybean plot was harvested and adjusted to 13% moisture prior to analysis. Grain samples were collected and are currently being analyzed for protein and oil (soybean), and starch, protein, oil (corn) using near-infrared spectroscopy (Foss Infratec 1241 Grain Analyzer, Eden Prairie, MN). All data were subjected to ANOVA and means separated using Fisher's protected LSD at $P = 0.1$.

Results:

The custom built shank effectively distributed lime throughout the soil profile (Figure 2). The modified shank caused more soil disturbance than normal and tillage following application was utilized to smooth the soil surface (Table 2) prior to planting. No tillage was used in the surface application only treatments. The site for 2013 was established and treatments were applied on Nov. 27, 2012. An extensive drought occurred in 2012. Precipitation during the 2012 growing was 7.3 inches below normal (Table 3).

Corn plants were 2 to 5 inches taller (July 5) in the deep placed treatments compared to no-till, which persisted until tasseling (August 2) (Table 4). Plant population at harvest was generally greater in the no-till surface applied treatments compared to the deep ripped/placement treatments. There was no treatment effect on soybean height or plant population.

In an extremely dry year, deep placement treatments increased corn yields 4 to 8 bu/acre (Figure 3). However, lime had no effect on yield in the corn crop after application. Deep placement treatments reduced soybean yield in the non-treated control and lime at 1.5 ton/acre (Figure 4). There was no effect of placement on soybean yield at the 3 ton/acre rate.

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Table 1. Initial soil characteristics at different depths in 2012.

Soil characteristics	0-5 inches	6-10 inches	11-15 inches	16-20 inches
pH	5.6 ± 0.2	5.6 ± 0.4	4.6 ± 0.2	4.6 ± 0.2
Neutralizable acidity (meq/100 g)	3.5 ± 2	2.9 ± 1	8.5 ± 1.6	6.8 ± 1.0
Organic matter (%)	2.7 ± 0.3	2.3 ± 0.1	2.3 ± 0.3	2.2 ± 0.2
Bray 1P (lb/acre)	15.5 ± 8.7	4.5 ± 1.3	3.5 ± 1.9	13.0 ± 4.0
Ca (lb/acre)	3950 ± 310	4640 ± 590	4690 ± 630	4450 ± 600
Mg (lb/acre)	441 ± 87	615 ± 169	875 ±123	889 ± 136
K (lb/acre)	159 ± 11	155 ± 25	202 ± 30	206 ± 14
CEC (meq/100 g)	15.4 ± 2.3	17.3 ± 3.2	24.2 ± 3.2	22.0 ± 2.3

Table 2. Field and management information at Novelty in 2012.

Management information	Corn	Soybean
Plot size (ft)	15 by 80	15 by 80
Hybrid or cultivar	DKC 63-25 VT3	AG3730 RR2
Planting date	30 May	30 May
Row spacing (inches)	30	7.5
Seeding rate (seeds/acre)	30,000	200,000
Harvest date		
Maintenance fertilizer	None	None
Urea and PCU	60 lbs N/acre and 130 lbs N/acre	
Lime	29 May	29 May
Tillage	Tilloll 2x 30 May Cultipacked 30 May in deep tilled treatments	Tilloll 2x 30 May Cultipacked 30 May in deep tilled treatments
Weed management		
Burndown	5 June, Verdict (5 oz/acre) + Roundup PowerMAX (32 oz/acre) + NIS (0.25% v/v) + UAN (1 qt/acre)	5 June, Verdict (5 oz/acre) + Roundup PowerMAX (32 oz/acre) + NIS (0.25% v/v) + UAN (1 qt/acre)
Postemergence	22 June, Roundup PowerMAX (32 oz/acre) + DAS (17 lbs/100 gal) + COC (1 qt/acre) + Callisto (3 oz/acre) + Atrazine (1 qt/acre)	22 June, Reflex (1.25 pt/acre) + Roundup PowerMAX (22 oz/acre) + DAS (17 lbs/100 gal) + NIS (0.25% v/v)
Insect management	NA	NA
Disease management	NA	NA

†Abbreviations: COC, crop oil concentrate; DAS, diammonium sulfate; NA, None applied; NIS, non-ionic surfactant; UAN, 32% urea ammonium nitrate.

Table 3. Monthly precipitation average (10-year) and during the 2012 growing season at Novelty.

Month	10-year average†	2012
	---------------- Inches ----------------	
Apr.	3.9	---
May	4.4	---‡
June	4.9	2.2
July	3.7	0.7
Aug.	4.8	3.0
Sep.	3.4	3.6
Total	25.1	9.5

†Averaged from 2000 to 2009.
‡Planted May 30, 2012

Table 4. Corn and soybean plant population and heights as affected by no-till surface or deep placed lime (non-treated = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre).

	Corn			Soybean	
	Height			Height	
Lime placement	July 5	August 2	Population	October 4	Population
	---- Inches ----		No./acre	Inches	No./acre
Surface non-treated	36	65	30,100	22	187,000
Surface 1.5 ton/acre	37	64	30,000	22	205,000
Surface 3 ton/acre	34	63	29,200	22	161,000
Deep placement non-treated	39	67	26,000	22	196,000
Deep placement 1.5 ton/acre	38	68	28,000	21	183,000
Deep placement 3 ton/acre	39	67	27,900	22	203,000
LSD (P = 0.1)	2	2	2,200	NS	NS

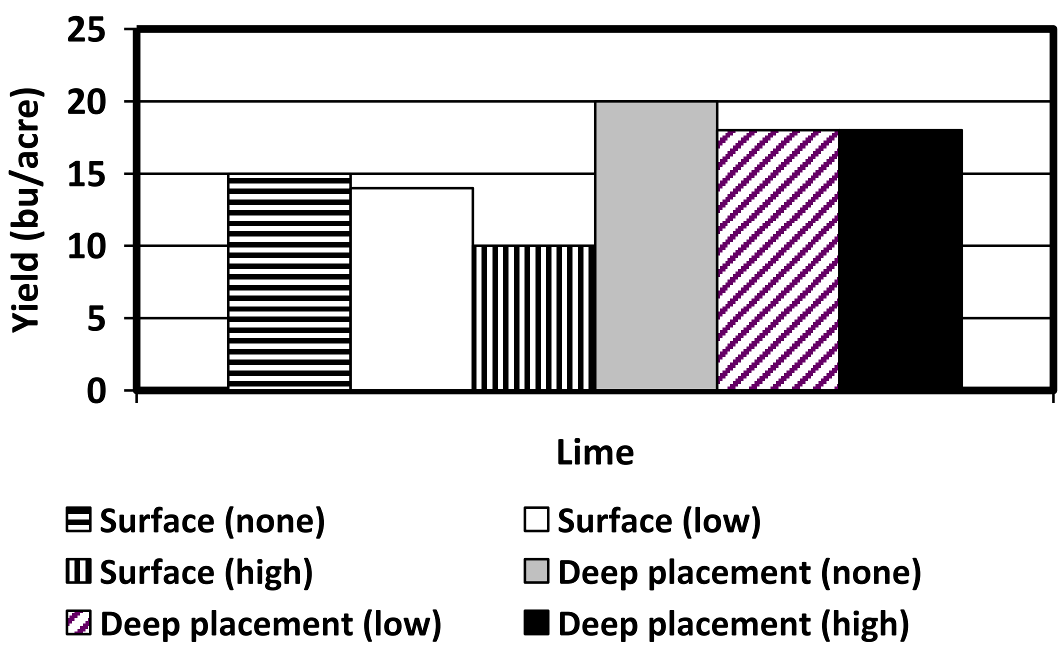

Figure 3. Corn grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre). LSD (P = 0.1) was 4 bu/acre.

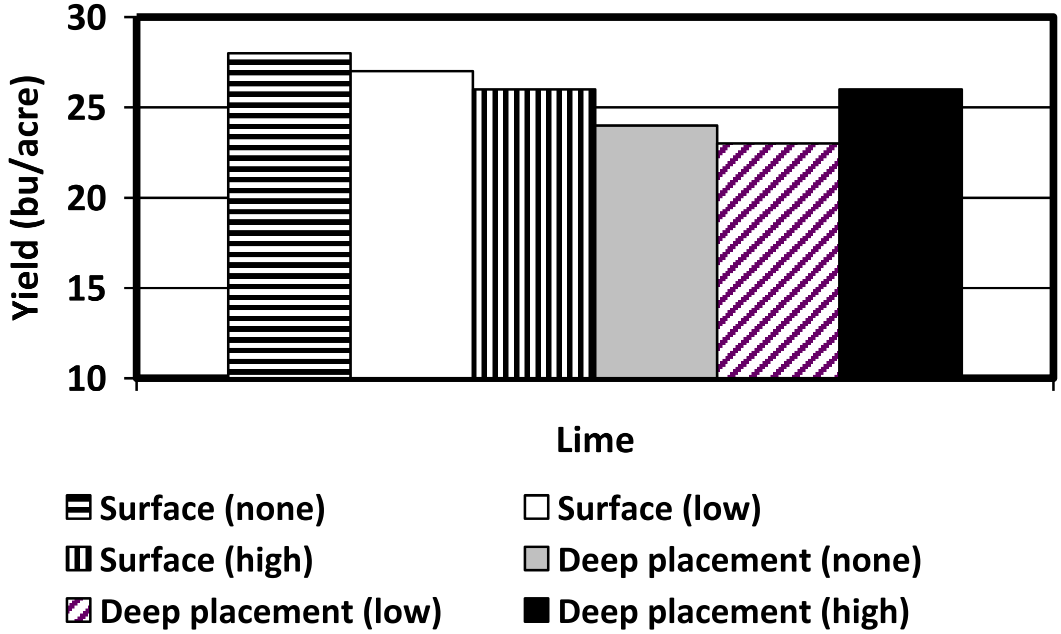

Figure 4. Soybean grain yield response to no-till surface or deep placed lime (none = 0 ton/acre, low = 1.5 ton/acre, and high 3.0 ton/acre). LSD (P = 0.1) was 2 bu/acre.

Timetable:

2013

February-April	Prepare equipment, sample soil, and apply lime treatments to an additional site
April-September	Manage plots and demonstrate at local field day
September	Harvest and resample soil
Oct-Dec	Analyze results
2014	Repeat 2013 procedures rotating corn to soybean and soybean to corn, complete results of the additional site.

Budget:

CATEGORIES	Year 2 (2013)	Year 3 (2014)	Total
A. Salaries Research Specialist or M.S. Graduate Research Assistant (50%)	$14,382	$14,670	$42,875
B. Fringe Benefits Fringe for graduate student	$2,474	$2,548	$7,424
TOTAL SALARIES AND FRINGE BENEFITS	$16,856	$17,218	$50,299
C. Travel			
Travel to field site	$0	$0	$0
To present research findings at National Meetings	$1,200	$1,200	$2,400
TOTAL TRAVEL COSTS	$1,200	$1,200	$2,400
D. Equipment	$0	$0	$0
TOTAL EQUIPMENT use and maintenance COSTS	$0	$0	$0
E. Other Direct Costs			
Soil analysis	$5,500	$5,500	$13,750
Grain analysis	$2,500	$2,500	$6,500
Publication cost	$750	$750	$1,500
Misc.	$3,500	$3,500	$10,500
TOTAL OTHER DIRECT COSTS	$12,250	$12,250	$32,250
TOTAL REQUEST	**$30,306**	**$30,668**	**$84,949**

Budget narrative:
Salaries and fringe benefits: Funds are requested for partial support of technical support or a M.S. student.
Presentations, publications, and documentation: This will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for presentation of results
Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, soil processing, and other field supplies and operations.

Project Title:

Liming to Reduce Ergovaline Concentration in Toxic Tall Fescue Pastures

Investigators:

Craig Roberts, Robert Kallenbach, and John Lory, University of Missouri

Nearly all pastures in Missouri include common tall fescue infected with a toxic fungus, called the "endophyte" because it grows inside the plant. The endophyte causes fescue toxicosis every year in Missouri. Fescue toxicosis is the most severe forage-livestock disorder in Missouri and costs the Missouri beef industry $160 million each year. The endophtye produces toxins that reduce calf gains by 40%, milk production by 30%, and pregnancy rate in spring-calving herds by up to 45%. The toxins have an even worse impact on dairy cattle and horses. The main endophyte toxin is ergovaline, although there are other toxins of interest.

In the 1980s, toxins were removed from pastures as the toxic grass was replaced with "endophyte-free" varieties. However, the endopyhte-free varieties died, being susceptible to drought, insects, pathogens, and overgrazing. Recently, pasture renovation has re-emerged, this time by replacing toxic tall fescue with varieties that contain nontoxic endophytes. These new, nontoxic varieties survive much better than endophyte-free varieties. Nevertheless, most fields will not be renovated, because renovation requires two sprays of glyphosate, a smother crop, and almost one year to complete. So farmers must continue to manage their toxic pastures.

Modern recommendations for tall fescue management involve "alkaloid management," which requires a set of practices that can reduce ergovaline ingestion in a toxic field. These practices include livestock rotation among fields, dilution of tall fescue in the pasture by interseeding legumes, feeding of supplements, and ammoniation of hay. The practices may also include liming, as good soil fertility encourages legume growth and therefore dilutes the toxicity in a pasture.

It may be that liming can reduce ergovaline inside the grass plant as well. Research has shown that endophyte toxins are unstable in alkaline environments. They are greatly reduced when hay is treated with ammonia. Also, they break down when an alkaline reagent is used on the extract in the laboratory. To date, no research has been published that explores the effect of lime on ergovaline concentrations.

Objective: To determine the effect of soil pH on ergovaline concentration in toxic tall fescue

Procedures

This research is being conducted on the Tom Roberts farm near Alton, MO. This farm was selected because it is primarily 'Kentucky-31' tall fescue established more than 20 years ago and is representative of most other farms in Missouri and surrounding states. On 14 October 2011 tillers from this field were tested for tall fescue endophyte using enzyme-linked immunosorbent assay (Hill, 2005); the results verified that the field was 95% infected with the endophyte. The field had been soil-sampled on 29 July 2011 and determined to have an average soil pH of 5.5.

Accomplishments for Year 1

In December 2011, 16 plots measuring 10 x 20 feet were marked with a two-foot buffer separating the replicates (Fig. 1 and 2). Treatments were randomly assigned as non-treated control or treated with limestone, and it was replicated 8 times. Also in December 2011 each plot was tested and limestone surface applied (Table 1.) The limestone used was from Doss and Harper, West Plains, MO with an effective neutralizing material (ENM) rating of 368; each plot received enough limestone to meet the ENM requirements from individual plot soil tests.

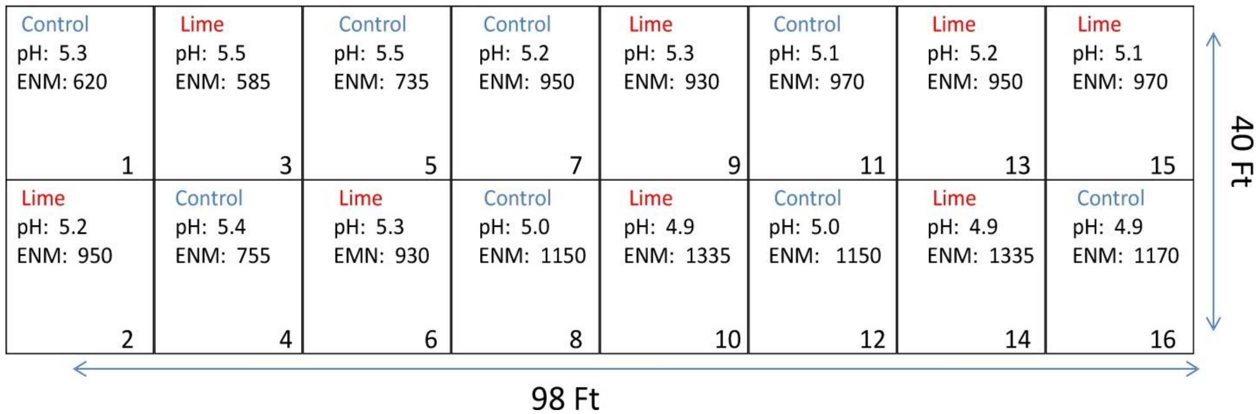

Figure 1. Plot layout of liming study located near Alton, MO with lime and pH data shown. The plots are 10 x 20 feet with 2-foot buffer strips (not shown).

Table 1. Soil test results for experimental site in Alton, MO. Dec 2011.

Lab No.	Sample I.D.	Treat-ment	pHs	N.A. meq/ 100g	O.M. %	Bray 1 P lb/a	Ca lb/a	Mg lb/a	K lb/a	CEC meq/ 100g
C1222709	1 0 - 1/2	Control	5.4	2.5	6.0	43	1486	371	284	8.1
C1222710	1 1/2 - 1		5.2	2.5	3.4	31	1227	290	300	7.2
C1222711	1 1 - 3		5.1	3.0	2.2	17	1324	282	297	7.9
C1222712	5 0 - 1/2	Control	5.4	3.0	6.2	110	1509	371	261	8.7
C1222713	5 1/2 - 1		5.4	3.0	3.4	133	1288	283	274	7.8
C1222714	5 1 - 3		5.4	3.0	2.3	145	1403	281	246	8.0
C1222721	11 0 - 1/2	Control	5.1	3.5	6.6	93	1335	345	274	8.6
C1222722	11 1/2 - 1		5.0	3.5	3.1	109	1055	241	279	7.5
C1222723	11 1 - 3		4.9	3.5	1.6	99	1129	233	260	7.6
C1222715	6 0 - 1/2	Lime	5.9	1.5	5.5	134	1459	402	265	7.2
C1222716	6 1/2 - 1		5.4	3.0	3.0	145	1398	316	276	8.2
C1222717	6 1 - 3		5.2	3.5	2.2	181	1523	281	317	8.9
C1222718	10 0 - 1/2	Lime	6.4	0.5	6.0	120	1571	499	244	6.8
C1222719	10 1/2 - 1		5.5	2.5	2.8	150	1186	355	309	7.3
C1222720	10 1 - 3		4.9	4.0	1.9	181	877	204	283	7.4
C1222724	14 0 - 1/2	Lime	6.3	1.0	6.2	104	1632	530	254	7.6
C1222725	14 1/2 - 1		5.4	3.0	2.8	137	1231	369	294	8.0
C1222726	14 1 - 3		4.8	4.0	1.8	139	1057	248	257	8.0

Figure 2. Plots for liming study established on the Tom Roberts farm near Alton, MO.

On 18 May 2012, plots were fertilized with nitrogen at the rate of 40 lb acre and with P and K to soil test. Annual grass weeds were controlled by spraying pendimethalin (Prowl H2O) at a rate of 4 pints acre-1 in early spring. Broadleaf weeds were controlled with picloram and 2,4-D (Grazon P+D) at a rate of 2 pints acre-1. During spray application a non-ionic surfactant was used.

Plant tillers were harvested on 4 May for the spring sampling and on 15 October for the fall sampling. The spring sampling date was chosen to harvest plants after "green-up" but before seedhead development. (Seedheads are highly concentrated with ergovaline and can temporarily skew the results.) The fall sampling date was chosen to harvest plants that greened up after summer dormancy but before the killing frost. Individual plant tillers were randomly selected, cut at soil level, and stored in a freezer immediately.

Sample analysis is scheduled for completion in 2013 (Table 2), but some of the analysis was completed in December 2012. Frozen samples were freeze-dried, ground to 1 mm, and analyzed for ergovaline by HPLC. The whole tillers have been analyzed; the tillers were cut into 2-inch segments, and those samples are currently in the laboratory.

Results from whole tillers show no difference in ergovaline between limed-treated plots and non-limed controls. This was expected for year 1; there has not been enough time to have seen a lime effect on soil pH in these plots, in part because of the drought of 2012. Preliminary results also show that spring tillers were less toxic than fall tillers. Thus far, the ergovaline concentrations in the spring are below 400 ppb and concentrations in the fall exceed 800 ppb. The complete data set for years 1 and 2 is on schedule for reporting in December 2013.

Objectives for Year 2

Objectives for the second year are seen below (Table 2). These objectives include plot maintenance for weed and pest control, harvesting tall fescue in April and October, then segmenting the plants. Objectives also include chemical analysis of all samples from the first two years, including all whole tillers and all tiller segments. Chemical analysis will be measurement of ergovaline. Lastly, the second year objectives involve presenting findings to date at extension meetings in the state.

Table 2. Timetable for research and extension activities.

Year	Activity
2012	Layout field plots and apply lime (January)
	Sample plots (April, October)
	Samples segmented and stored in freezer
2013	Sample plots (April, October)
	Samples segmented and stored in freezer
	Ergovaline analysis (including samples from 2012)
2013	Sample plots (April, October)
	Samples segmented and stored in freezer
	Research presented at conference
	Ergovaline analysis (samples from 2013)
	Manuscript prepared for journal; findings presented via Extension

Proposed Budget for Year 2

Item	Year 2
Research Technician (25%)	$12,187
Benefits	$3,900
Supplies	$2,600
Travel	$1,200
Ergovaline analysis	$13,568
Total	**33,455**

Justification: The salary and benefits for the **research technician** are based on 25% of a salary of $48,750 and 32% benefits. The research technician will be involved not only in the field and laboratory aspects of the experiment but also in extension presentations. **Supplies** are for all laboratory and field work, including fertilizer, sample bags, mower accessories, weigh boats, clippers, freeze drier oil, grinder parts, and similar supplies. **Travel** includes trips to the research site. **Ergovaline analysis** is based in a per sample charge of $53; samples from years 1 and 2 will be analyzed in year 2 (256 samples x $53 = $13,568).

Nitrogen Management

Progress Reports

Nitrogen Fertilizer Management of Temporarily Flooded Soils to Improve Corn Production and Reduce Environmental N Loss

Peter Motavalli, Kelly Nelson, Ranjith Udawatta

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Accomplishments for First Year:

Research was initiated in 2012 with the objectives of determining the effects of duration of flooding on corn (*Zea mays.* L.) growth and N use efficiency (NUE), assessing the use of different N sources including PCU and nitrification inhibitor and a post-flood rescue N fertilizer treatment, and evaluating the economic costs and benefits of using these fertilizer sources under different flooding conditions. The overall goal of this research is the development of an economically profitable N fertilizer strategy for both pre- and post-flood conditions that will increase corn production and decrease environmental N loss.

A field trial was established in 2012 at the University of Missouri Greenley Research Center in Northeast Missouri. The specific field was chosen because of its flat topography which would allow for a uniform ponding of water on the soil surface. Soil classification for the field is a Putnam silt loam (fine, smectitic, mesic Vertic Albaqualfs). Soil samples were collected in increments of 0-4, 4-8, and 8-12 inch depths before fertilizer application and incorporation and corn planting to characterize initial soil conditions (Table 1). Some differences in initial soil characteristics, especially soil pH_s and neutralizable acidity (NA) were observed among the three replicates in the field so an experimental design was implemented to account for this variation.

The field was separated into 15 by 100 foot plots of six 30-inch rows of DEKALB Corn Seed 62-97 planted at 30,000 seeds/acre on April 3rd. Nitrogen fertilizer treatments of a control (CO) and 150 lbs N/acre of urea (NCU), urea plus nitrapyrin nitrification inhibitor (NCU + NI) (N-Serve®, Dow AgroSciences, Indianapolis, Indiana), and polymer coated urea (PCU) (ESN®, Agrium, Inc., Calgary, Alberta). All fertilizer N treatments were incorporated immediately after application with a cultivator. The experimental design is a randomized split-split block with 3 replications.

Ponding of water occurred for durations of 0, 24, 48, and 72 hours at V6 corn growth stage on June 1st using temporary soil levees to surround each flooding block (Figure 1). Levees were knocked down to allow ponded water to escape after intended flooding duration had ceased. On June 21st, a rescue N fertilizer application of 75 lbs N $acre^{-1}$ of urea plus NBPT (N-(n-butyl) thiophosphoric triamide) urease inhibitor (NCU + UI) at 1 gal/ton was applied to half of each original fertilizer treatment (Agrotain®, Koch Agronomic Services, Wichita, Kansas). Following rescue application each 15 by 100 foot fertilizer treatment was split into two 15 by 50 foot plots, one being with the rescue application and the other without the rescue application. A rescue application of 75 lbs N acre^{-1} was applied as an estimate of an economical optimal N rate for yield response at corn growth stage V10 determined from SPAD 502 chlorophyll meter readings (Konica Minolta, Hong Kong) taken after flooding on June 12th (Scharf *et al*., 2006) (Table 2). These readings showed an increase in chlorophyll content with N fertilizer applicati0on compared to the control. At the 24 and 72 hour flooding, PCU had a higher chlorophyll content compared to urea (Table 2). This result suggests an effect of the fertilizer source on plant N content. No consistent effects of flooding duration were observed on plant chlorophyll content.

Corn grain harvest occurred on August 30th. Corn grain yields were harvested from the total row length of the two center rows from each N treatment. Figure 2 shows there were significant yield increases of 12 and 10.4 bu/acre among PCU and NCU + NI, respectively, versus the control where no N was applied for the 72 hour flooded plots. The rescue application of urea + UI had significant yield increases in all flooding durations compared to the control were no N was applied. Yield increases of 11 bu/acre occurred as a result of the rescue application with NCU fertilizer plots of 48 and 72 hour flooding durations. An increased yield of 10 bu/acre occurred with rescue N application in the NCU + NI treated plots at a 72 hour flooding duration. No significant yield increases we observed with a rescue N application in PCU treatments (Fig. 2).

Corn silage was collected from 20 foot of one row and total biomass dry weight, tissue N and N uptake were determined (Table 3 & 4). Silage yield increases occurred among PCU versus the control with no N fertilizer for 0, 24, and 72 hour flooding durations where no rescue N application was applied. There were no significant increases among PCU and the control where no N was applied in these flooding duration plots with the rescue application as a result of decreases in biomass. Plants in the 24 and 48 hour flooding plants had more N uptake with PCU and NCU + NI than where no N was applied. There was no significant difference between the amounts of N uptake with NCU in comparison with no N application.

All yields and N uptake results among the treatments were reduced during the 2012 research season because of the severe drought that occurred during the summer months (Fig. 3). The cumulative precipitation total from planting to harvest was 10.7 inches at the Greenley Research Station. The prior ten year average for this time period at Greenley Research Station was 27.5 inches. The drought reduced corn response to all N fertilizer treatments

Soil samples were collected from N fertilizer treatments before (May 30th) and after (June 11th) temporary flooding events (Table 5 and 6 A & B). These samples were taken from 0-4, 4-8, and 8-12 inch depths and analyzed for soil inorganic N (ammonium and nitrate-N). The PCU treatment generally maintained higher soil ammonium-N and nitrate-N concentrations among all the N treatments. There was a significant decrease in soil NO_3^- -N concentration from all plots treated with enhanced efficiency N fertilizers from 0 to 24 hours of soil saturation at a depth from 0-4 inches (Figure 4). The PCU treatment was the only N fertilizer treatment to continue significantly decreasing in soil NO_3^- -N concentration between 24 to 48 hours of soil saturation at a depth from 0-4 inches. No decrease in NH_4^+ concentration occurred as a result of saturated soils.

Soil surface effluxes of nitrous oxide and carbon dioxide gases were measured prior, during, and after soil saturation events to determine changes in gas loss from the soil under different flooding durations and enhanced efficiency N treatments (Figures 5 & 6). Gases were collected using small sealed chambers fitted with rubber septa for sample extraction using a syringe and placed into sealed vials. These gases were analyzed using gas chromatography and an automated sampler. The results show higher emissions of soil nitrous oxide under the saturated soil conditions versus when soils were not saturated (Fig. 5 A & B). The results also indicate that PCU had higher efflux of soil nitrous oxide at some times during the 72 hour saturation period compared to NCU and NCU + NI possibly due to the higher initial pre-flood soil nitrate-N in the PCU-treated plots compared to the other N fertilizer treatments (Table 5A).

Outreach and Training:

A M.S. graduate student in soil science and an undergraduate student majoring in soil science at the University of Missouri have been involved in working on this project as part of their training. Information about the research project was published in the 2012 Field Day Report for the Greenley Memorial Research Center and the first year research results will be presented to growers and agricultural professionals by the M.S. student at the 2013 Greenley Center Field Day in Northeast Missouri. He will also be presenting his results to the National Meetings of the American Society of Agronomy in 2013.

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 to assess changes in soil N and corn grain yield response due to different soil saturation durations among enhanced efficiency products with urea fertilizer.
2. To evaluate the ability of a rescue N application of Urea plus NBPT to increase grain yields following soil saturation durations at late corn growth stage of V10.
3. To calculate the cost-effectiveness of using enhanced efficiency products of polymer coated urea and the nitrification inhibitor nitrapyrin with urea under different durations of soil saturation.

The field study will be repeated for a second year to assess variation in climate on corn response to enhanced efficiency N fertilizers and rescue N application following soil saturation periods of 0, 24,48, and 72 hours. An economic analysis will be included using fluctuations in fertilizer and enhanced efficiency prices between the two years to determine whether use of enhanced efficiency products and a rescue application of N are cost effective after 0, 24,48, and 72 hours of soil saturation durations.

Table 1. Initial soil test for 2012 field study site at the Greenley Research Station by replicate and soil depth.

Replicate	**Depth**	**pH_s**	**NA**	**OM**	**Bray 1 P**	**Exch. Ca**	**Exch. Mg**	**Exch. K**	**CEC**	**B.D.**
	inches		meq/100 g	- % -	---------------	lbs/acre	----------------		meq/100 g	g/cm^3
1	0-4	6.4	1.0	2.8	53	5098	388	295	15.7	1.47
	4-8	6.5	1.0	2.2	22	5058	329	163	15.2	1.56
	8-12	5.5	3.5	1.6	9	4377	464	172	16.6	1.45
2	0-4	6.3	1.0	2.4	68	4403	315	383	13.8	1.38
	4-8	6.6	1.0	1.7	24	4938	343	185	15.0	1.32
	8-12	5.9	3.0	1.6	8	4477	455	182	16.3	1.46
3	0-4	5.6	3.0	3.0	53	4295	356	413	16.2	1.44
	4-8	5.9	2.1	2.1	16	4379	347	189	15.1	1.55
	8-12	5.0	1.9	1.9	6	4844	609	210	20.4	1.46

†Abbreviations: NA, Neutralizable Acidity; OM, Organic Matter; P, Bray-1 Phosphorus; Exch. Ca, Exchangeable Calcium; Exch Mg, Exchangeable Magnesium; Exch. K, Exchangeable Potassium; CEC, Cation Exchange Capacity; B.D, Bulk Density.

Figure 1. Ponding of water in a 72 hour flooding duration block on June 1st.

Table 2. Average SPAD chlorophyll readings on June 12th after flooding to determine an economically optimum N rate for rescue N application of urea plus urease inhibitor according to N treatments and temporary flooding durations.

N Fertilizer Treatment	Saturation Duration 0	24	48	72
	------------------------------- SPAD units -------------------------------			
Control	42.7	41.2	40.1	37.8
Urea	47.4	45.7	47.2	45.1
Urea + NI†	48.3	48.6	46.0	45.1
PCU‡	49.0	51.8	48.7	48.6
$LSD_{(0.05)}$ ††	--------------------------------- 3.2 ---------------------------------			

†Urea + nitrification inhibitor
‡Polymer coated Urea
††Fisher's protected least significant difference at $p<0.05$.

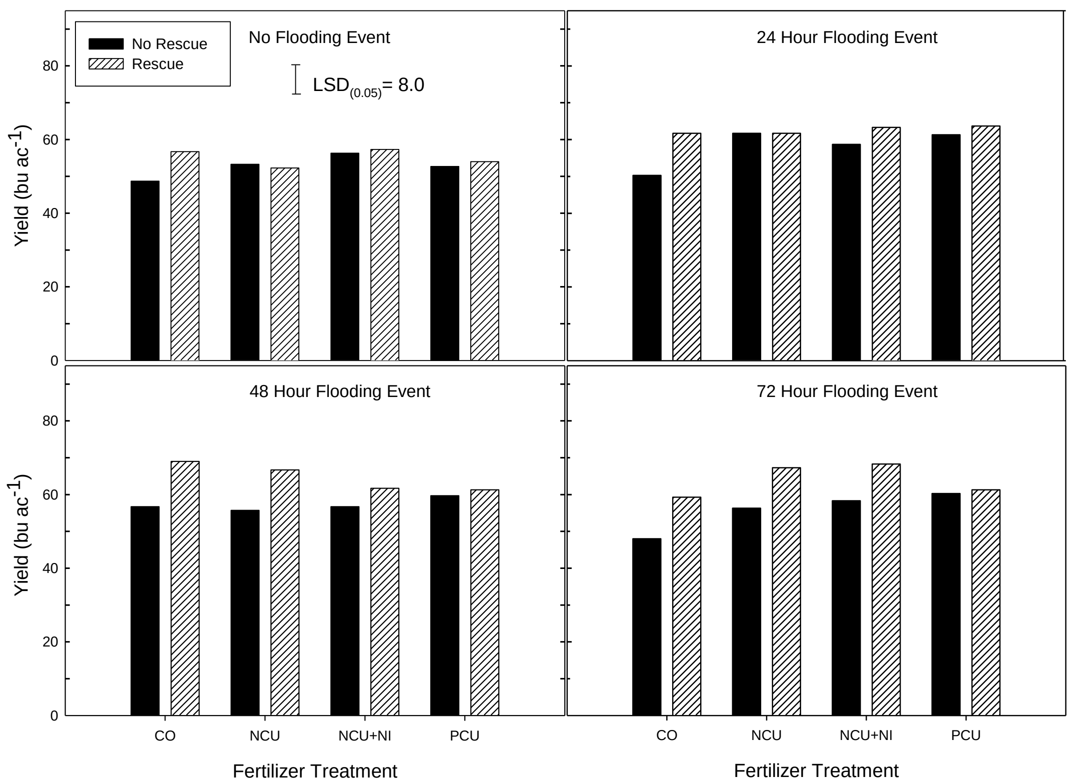

Figure 2. Average corn grain yield comparing no rescue N plus urease inhibitor with rescue N plus urease inhibitor for each N treatment and flooding duration. (†Abbreviations: CO, Control; NCU, Urea; NCU + NI, Urea + nitrification inhibitor; PCU, polymer coated urea; LSD, least significant difference at $p < .05$ between no rescue N plus urease inhibitor and with rescue N plus urease inhibitor.)

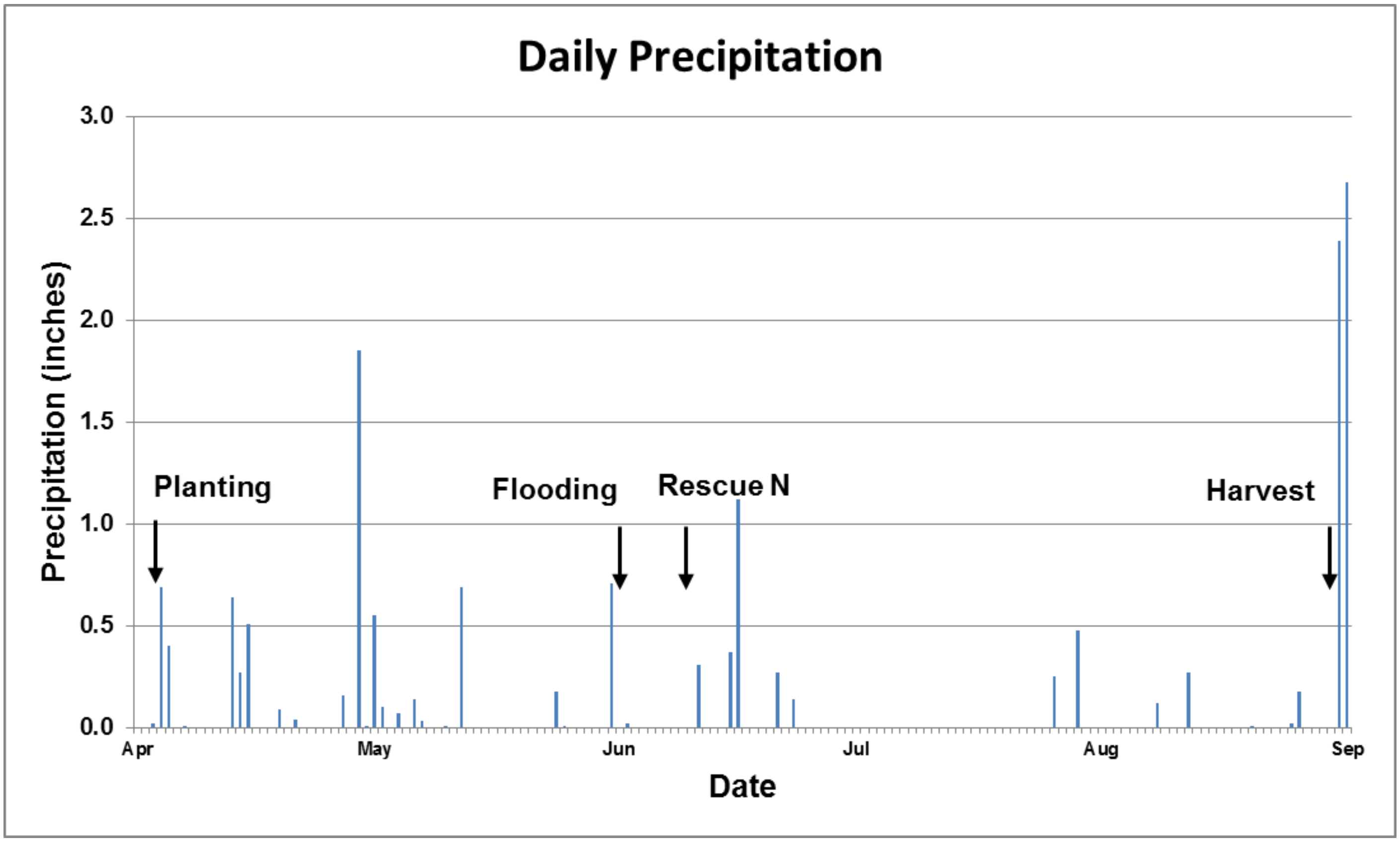

Figure 3. Daily precipitation values for the field research growing season from April 1st – August 28th, 2012 at the Greenley Research Station. Cumulative total for this time period was 10.7 inches. The prior ten year average from this time period at Greenley Research Station as 27.5 inches.

Table 3. Average corn silage yield with corresponding N treatments and temporary flooding durations with and without rescue N plus urease inhibitor application.

N Fertilizer Treatment	Saturation Duration			
	0	24	48	72
	------------------------ tons dry matter/acre -----------------------			
Without Rescue N				
Control	1.84	1.36	1.72	1.25
Urea	2.14	1.82	1.85	1.77
Urea + NI†	2.07	2.06	1.75	2.05
PCU‡	2.43	2.18	2.01	1.90
With Rescue N				
Control	1.98	1.60	1.83	1.49
Urea	1.67	1.94	1.97	2.01
Urea + NI†	1.59	1.97	1.89	1.90
PCU‡	1.81	2.02	2.52	1.84
$LSD_{(0.05)}$ ††	------------------------------------ 0.53 -------------------------			

†Urea + nitrification inhibitor

‡Polymer coated Urea

††Fisher's protected least significant difference at $p<0.05$.

Table 4. Average plant N uptake with corresponding N treatments and temporary flooding durations without and with rescue N plus urease inhibitor application.

N Fertilizer Treatment	Saturation Duration			
	0	24	48	72
	--------------------------- lbs N uptake/acre -----------------------			
Without Rescue N				
Control	24.0	16.4	19.5	15.3
Urea	28.3	19.1	26.5	24.9
Urea + NI†	33.2	28.2	21.5	23.9
PCU‡	34.6	29.8	29.1	23.2
With Rescue N				
Control	30.4	25.7	24.8	28.4
Urea	31.6	30.6	32.4	35.7
Urea + NI†	30.0	36.2	33.3	28.8
PCU‡	36.9	38.8	42.7	30.4
$LSD_{(0.05)}$ ††	-------------------------------------- 12.2 ---------------------------			

†Urea + nitrification inhibitor

‡Polymer coated Urea

††Fisher's protected least significant difference at $p<0.05$.

Table 5 A & B. Average pre-flood (May 30th) inorganic soil N for (A) nitrate-N and (B) ammonium-N with corresponding N treatments, temporary flooding durations and sampling depths.

A.

N Fertilizer Treatment	Depth	Saturation Duration 0	72
	inches	--------------- mg NO_3^--N/kg	-----------
Control	0-4	13.6	12.2
	4-8	5.4	4.5
	8-12	4.6	3.2
Urea	0-4	29.1	24.3
	4-8	7.5	7.6
	8-12	6.8	7.0
Urea + NI†	0-4	28.4	29.6
	4-8	5.8	6.4
	8-12	3.8	5.1
PCU‡	0-4	47.3	33.6
	4-8	11.5	6.1
	8-12	7.3	4.7
LSD $_{(0.05)}$ ††		--------------------- 9.5	-----------------

B.

N Fertilizer Treatment	Depth	Saturation Duration 0	72
	inches	-------------- mg NH_4^+-N/kg	-----------
Control	0-4	6.1	6.1
	4-8	6.5	5.7
	8-12	4.7	4.9
Urea	0-4	5.7	5.9
	4-8	5.5	5.2
	8-12	4.0	5.3
Urea + NI	0-4	7.1	6.2
	4-8	5.4	5.0
	8-12	4.9	4.4
PCU	0-4	10.4	8.1
	4-8	5.6	5.5
	8-12	4.9	4.5
LSD $_{(0.05)}$		------------------ 1.6	------------------

†Urea + nitrification inhibitor

‡Polymer coated Urea

††Fisher's protected least significant difference at $p<0.05$.

Table 6 A & B. Average post-flood (June 11th) inorganic soil N for (A) nitrate-N and (B) ammonium-N with corresponding N treatments, temporary flooding durations and sampling depths.

A. N Fertilizer Treatment	Depth	Saturation Duration 0	24	48	72
	inches	mg NO_3^--N/kg			
Control	0-4	13.5	6.2	2.3	4.8
	4-8	1.7	1.5	0.8	1.3
	8-12	1.7	1.6	0.9	1.7
Urea	0-4	32.5	12.4	13.9	10.9
	4-8	3.6	3.1	4.8	4.3
	8-12	3.2	3.6	3.6	3.3
Urea + NI†	0-4	33.3	19.6	10.2	15.2
	4-8	4.7	4.5	3.6	4.1
	8-12	3.4	3.8	4.2	3.8
PCU‡	0-4	49.0	29.2	13.2	16.8
	4-8	2.6	3.8	2.8	4.7
	8-12	2.4	3.4	3.0	3.9
LSD $_{(0.05)}$ ††		9.7			

B. N Fertilizer Treatment	Depth	Saturation Duration 0	24	48	72
	inches	mg NH_4^+-N/kg			
Control	0-4	6.4	6.7	6.3	7.0
	4-8	5.5	5.9	6.5	6.7
	8-12	5.7	7.3	7.3	5.6
Urea	0-4	8.0	6.2	8.5	7.3
	4-8	6.4	6.0	5.6	7.3
	8-12	5.4	5.7	5.8	5.5
Urea + NI	0-4	6.9	7.4	7.0	7.1
	4-8	6.0	6.6	6.0	8.8
	8-12	6.0	6.4	6.5	6.3
PCU	0-4	11.3	10.4	9.1	8.1
	4-8	6.6	6.1	5.6	7.4
	8-12	4.9	5.4	5.3	5.7
LSD $_{(0.05)}$		2.5			

†Urea + nitrification inhibitor

‡Polymer coated Urea

††Fisher's protected least significant difference at $p<0.05$.

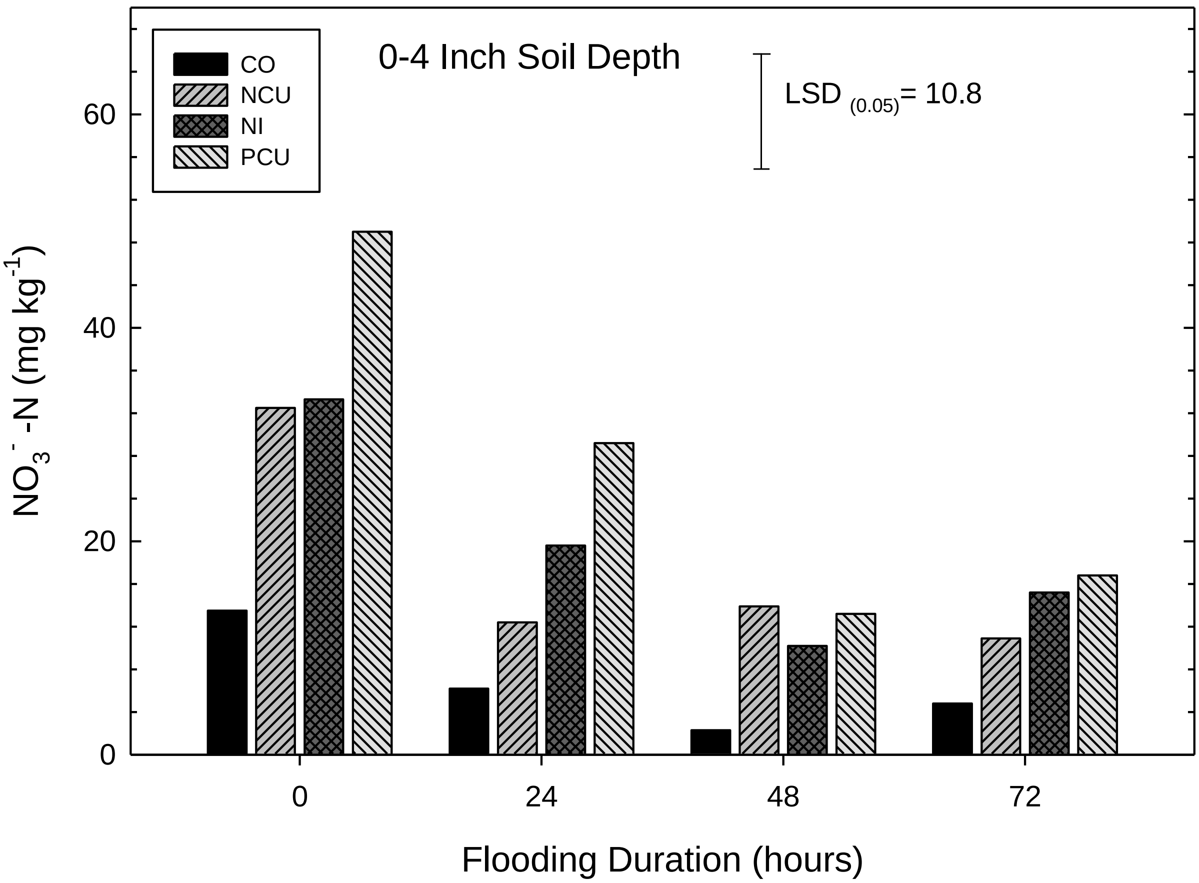

Figure 4. Average post-flood (June 11th) soil NO_3^- -N concentrations at a depth from 0-4 inches with respect to its N treatment and flooding duration. (†Abbreviations: CO, Control; NCU, Urea; NCU + NI, Urea + nitrification inhibitor; PCU, polymer coated urea; LSD, least significant difference at $p < 0.05$)

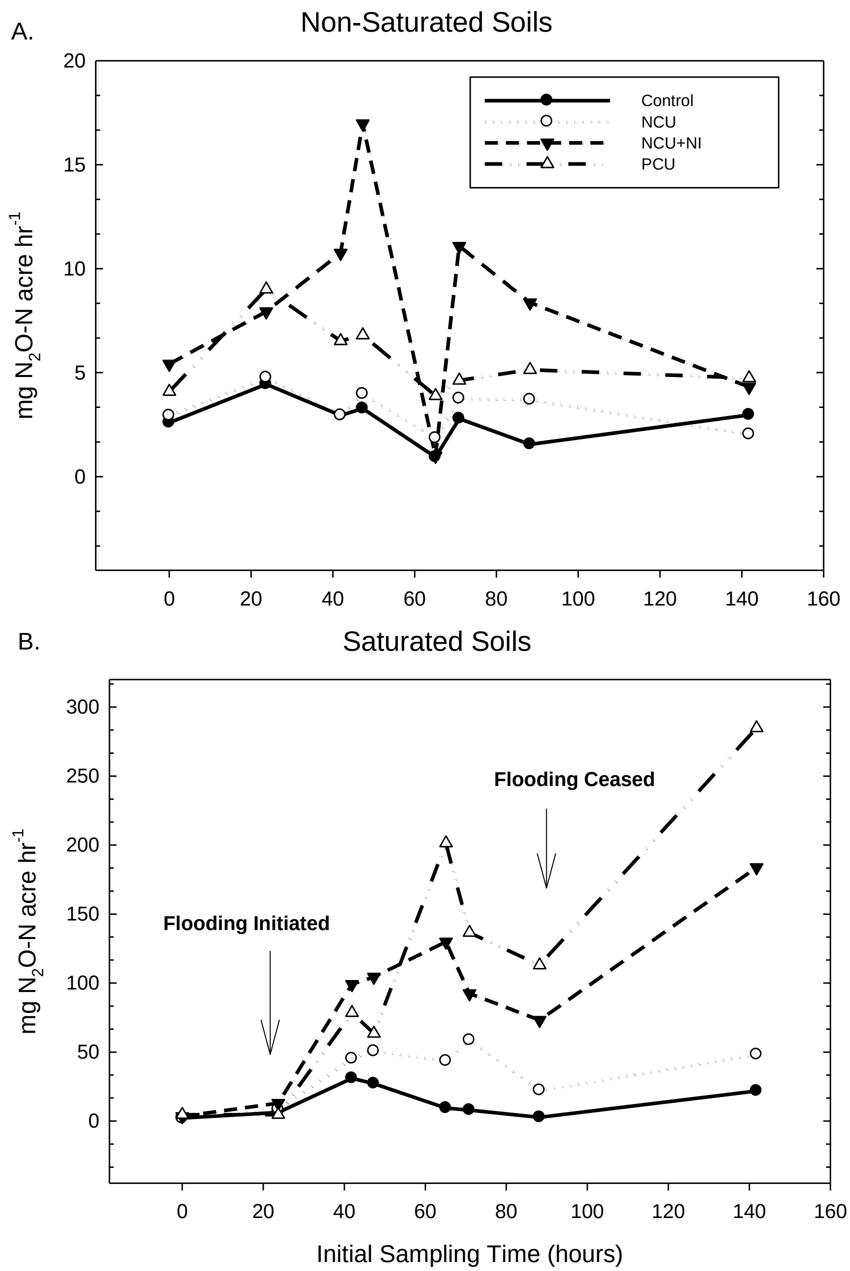

Figure 5 A & B. Average soil nitrous oxide emissions between (A) non-saturated and (B) saturated soils before, during, and after flooding event. Each point is the initial sample time with respect to the cumulative elapsed time from when the sampling period began. (†Abbreviations: CO, Control; NCU, Urea; NCU + NI, Urea + nitrification inhibitor; PCU, polymer coated urea). Note scale change between both figures.

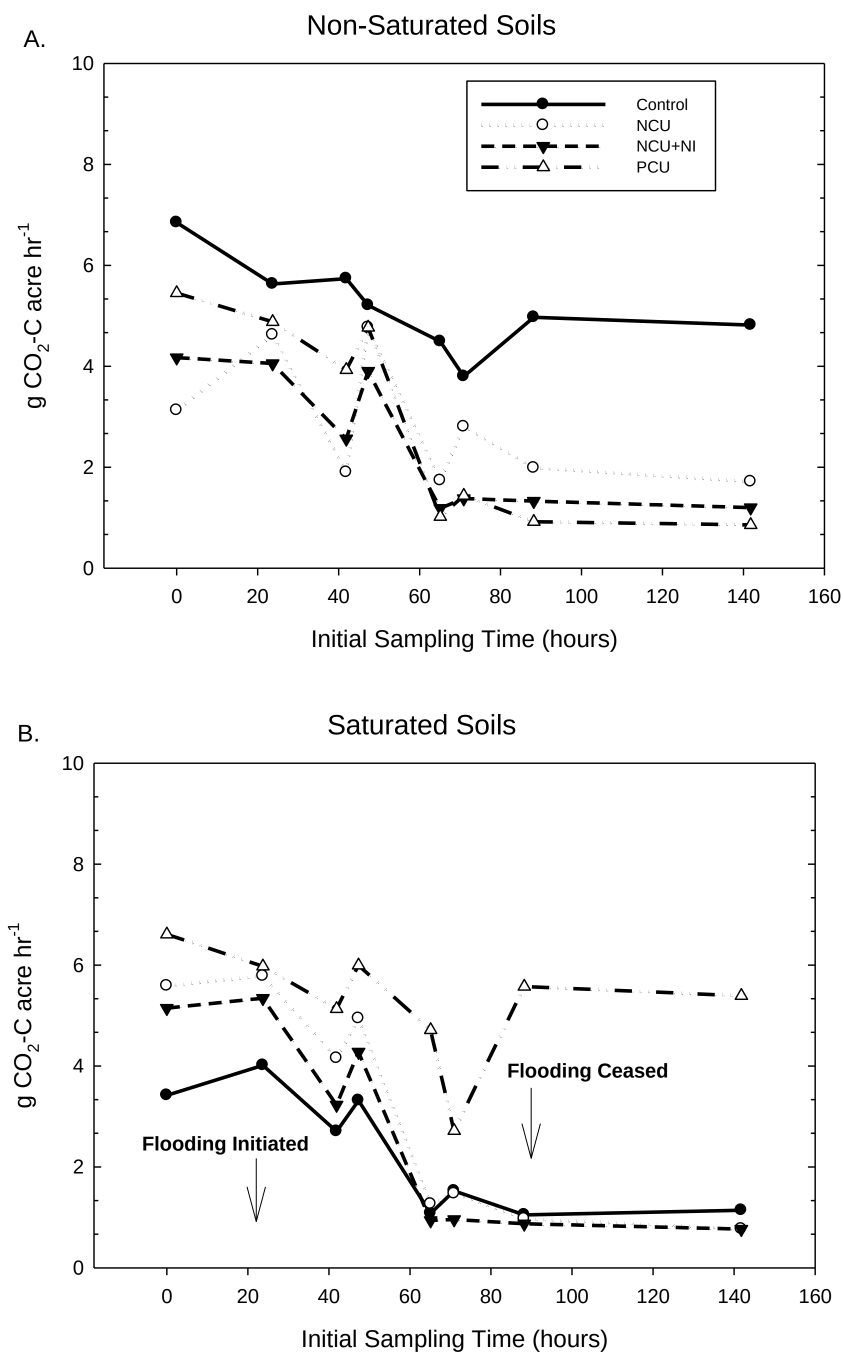

Figure 6 A & B. Average carbon dioxide emissions between (A) non-saturated and (B) saturated soils before, during, and after flooding event. Each point is the initial sample time with respect to the cumulative elapsed time from when the sampling period began. (†Abbreviations: CO, Control; NCU, Urea; NCU + NI, Urea + nitrification inhibitor; PCU, polymer coated urea).

Proposed Budget for Years Two and Three:

CATEGORIES	YEAR TWO	YEAR THREE
A. Salaries M.S. or Ph.D. Graduate Research Assistant (50%)	$17,228	$17,745
B. Fringe Benefits Fringe for graduate student	$2,474	$2,548
TOTAL SALARIES AND FRINGE BENEFITS	$19,702	$20,293
C. Travel		
Travel to field site	$672	$672
Travel to professional meeting	$1,000	$1,000
TOTAL TRAVEL COSTS	$1,672	$1,672
D. Equipment	$0	$0
TOTAL EQUIPMENT COSTS	$0	$0
E. Other Direct Costs		
Laboratory reagents and supplies	$2,000	$2,000
Field supplies	$2,000	$2,000
Soil analysis	$500	$500
Publications/Documentation	$500	$500
TOTAL OTHER DIRECT COSTS	$5,000	$5,000
TOTAL REQUEST	$26,374	$26,965

Justification:

Salaries and Fringe Benefits: Funds are requested for support of a graduate research assistant (50% time) based on set rates at the University of Missouri. Fringe benefits for the graduate student cover the cost of health insurance.

Travel: Covers cost of travel to Greenley Farm and to farm site at a rate of 48 ¢/mile. In the second year, $1,000 and in the third year $1,000 are requested to cover cost of travel and board for one researcher to attend a professional conference for presentation of results.

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

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

Soil Analysis: Covers cost of drying, grinding and analysis of soil samples at the University of Missouri Soil and Plant Testing Laboratory.

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

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

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

Investigators:

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Objective and Relevance:

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

Soil and water conservation systems for productivity and environmental protection are key components of this enhanced efficiency N fertilizer and managed drainage project. In order for rural communities to remain competitive in a rapidly changing agricultural environment, technology that integrates current best management practices must also maintain a highly productive, safe, and efficient food supply. Water conservation, reduced fertilizer loss, increased nutrient use efficiency, and reduced sediment loss while improving crop production combined with managed drainage that is based on solid research is a win-win situation for farmers, consumers, and the environment. It is expected that there will be a reduction in NO_3-N loading of up to 75% (Zucker and Brown, 1998; Frankenberger et al., 2006; Drury et al., 2009) and an additive effect of the enhanced efficiency fertilizer on reducing N loss in the crop production system and increasing corn grain yield. The hypothesis of this research is that managed drainage and enhanced efficiency fertilizer (polymer-coated urea) will synergistically increase corn yields and reduce NO_3-N loss.

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

<u>Preliminary results from July 2010 through Oct. 2012:</u>

Research was initiated in July 2010 in a Putnam silt loam (Greenley site) and Wabash silty-clay (Bee Ridge site). Water samples and flow were collected and monitored from the drainage systems at both sites year around using automated collection systems and flow monitoring equipment. Water samples were analyzed for nitrate-N, ortho-phosphate, and sediment concentration. Water flowing out of subsurface drainage systems was typically restricted over the period of Oct. through Apr. with MSD, while conventional subsurface drainage systems (CSD) had unrestricted water flow over the same period of time.

Supplemental data including ammonia volatilization, nitrous oxide gas loss, and soil nitrogen concentration were also collected at the Greenley site which allows us to better understand how subsurface drainage systems and enhanced efficiency nitrogen fertilizer impacted corn production, nitrogen loss, and fertilizer use efficiency. However, some of this supplemental data is currently being analyzed at this time and were not presented in this report.

Putnam silt loam (Greenley site)

Corn grain yields averaged over the 2010-12 season at the Greenley site (Putnam silt loam) were generally low (<80 bu/acre) for all treatment combinations, which may have been a function of a wet springs followed by dry summer conditions (Table 1). Without subsurface drainage (NSD), PCU significantly ($P \leq 0.1$) increased yields by 16 bu/acre compared to non-coated urea (NCU). Although not statistically significant, when NCU was applied, the addition of CSD and MSD increased yields on average by 10.8 bu/acre compared to NSD treatments. When PCU was applied, grain yields were similar among drainage systems (CSD, MSD, and NSD). Although not statistically significant, yields increased 3% with MSD compared to CSD when averaged over N sources and years (2010-12).

Ammonia (NH_3) volatilization loss was up to 7.4 lbs N/acre greater with NCU compared to PCU (Table 1). Averaged over the 2010-12 growing season, annual loss from the NCU/CSD treatment was 13.4 lbs-N/acre which was significantly ($P \leq 0.1$) greater than all other treatments. Non-coated urea with NSD had the second largest annual loss (9.2 lbs-N/acre) but was only significantly greater than the PCU/MSD treatment (5.3 lbs-N/acre). When averaged over the drainage systems, NCU had 41% greater annual volatilization loss compared to PCU. During the 2011 growing season, the amount of N loss as nitrous oxide (N_2O) gas was typically greater with NCU compared to PCU, and ranged from 10.4 to 2.4 lbs-N/acre with NCU/MSD and PCU/CSD treatments, respectively (data not presented).

Analysis of subsurface drainage data collected from July 2010 through Oct. 2012 found that MSD significantly ($P \leq 0.1$) reduced the total amount of water drained by 42% compared to CSD (Table 1). MSD reduced total nitrate (NO_3) and ortho-phosphate loss 54 and 77% compared to CSD, respectively. However, differences in the average flow weighted mean of nitrate-N over this period among treatments were not statistically significant.

Wabash silty-clay (Bee Ridge site)

The corn crop at the Bee Ridge site (Wabash silty-clay) was lost in 2010 due to a severe flooding event which occurred in July. This may contribute to carryover N that is common in the Missouri and Mississippi River bottoms. Excluding 2010, there were no significant differences ($P \leq 0.1$) in yield among the treatments.

Analysis of subsurface drainage data collected from July 2010 through Oct. 2012 found that MSD significantly ($P \leq 0.1$) reduced the total amount of water drained by 46% compared to CSD

(Table 2). MSD had a 20 and 61% reduction in the total nitrate (NO_3) and ortho-phosphate loss, respectively, compared to CSD. However, there was no difference in the average N flow weighted mean among treatments.

<u>Procedures for Final Study Year:</u>

- The final year of the corn trials will continue to be conducted on Putnam silt loam (Greenley) and Wabash silty-clay (Bee Ridge) soil types.
    - Greenley site (Putnam silt loam). Two subsurface drain tiles were installed on 20 ft centers with a water level control structure in four of the six plots. Treatments include drainage only, managed drainage, and a non-drained control in a factorial arrangement with an enhanced efficiency fertilizer (polymer-coated urea) or non-coated urea. A plastic barrier was installed between the non-drained controls, drainage only, and managed drainage treatments. A levee plow used to construct rice levees was used to separate plots and prevent surface water movement between treatments.
    - Bee Ridge site (Wabash silty clay). Subsurface drain tiles were installed on 20 ft centers with four water level control structures installed per replication. There is a 40 ft spacing between treatments since the soil permeability is very slow. Fertilizer treatments are similar to the Greenley site.
- Plant Nutrient Uptake, Silage and Grain Yields. Plant samples will be harvested from a transect perpendicular to the tile lines to determine total N uptake. Whole-plant tissue samples will be collected from each treatment at physiological maturity, ground in a portable chopper, and a 1-kg subsample will be collected for determination of silage moisture content and total N. Silage yields will be determined on a dry weight basis. Grain yield will be determined using a yield monitor and plot weights at the Greenley site. Grain yield will be determined using a yield monitor from between the tiles at the Bee Ridge site. The combine will be able to quantify yield from a 20 ft harvest width in a single pass. Grain samples will be collected to determine N removal.
- Tile Flow Measurements. A pressure transducer, data logger, and minisat are being used to document water flow at each water level control structure to determine total N loading throughout the year. Calibrations for a V-weir installed in drainage systems have been determined (Norm Fausey, personal communication). Water level control structures were installed in the drainage only treatment with a V-notched weir as the bottom board in the control structure which is being used to determine tile water flow.
- Water and Soil Sampling for nitrate-N, orthophosphate-P, and total suspended solids. Flow proportional samples of subsurface drainage water for NO_3-N are being collected with individual auto samplers at each water level control structure. Auto samplers are being utilized to capture grab samples to determine concentrations during the winter periods. The minisat are being used to identify water flow events during the winter months and obtain grab samples. Deep soil samples (3 ft. depth; 2 in diameter) will be collected at both locations using a Giddings probe to determine soil N and organic C concentration in a transect perpendicular to the tile lines to determine residual N in the soil and indicate carbon sequestration differences among treatments.
- Nitrous Oxide and Ammonia Gas Efflux Measurements. The Greenley site is being utilized to monitor gaseous N fertilizer loss over the growing season Nitrous oxide and ammonia flux data will be collected multiple times a week over a four month period following nitrogen application.

- Nitrogen Use Efficiency. The collection of nitrogen loss, plant nitrogen uptake, and soil nitrogen concentration data at the Greenley site will be used to determine the impact of managed subsurface drainage and enhanced efficiency nitrogen fertilizer on nitrogen use efficiency.

Timetable:

2013

Jan.-Dec.	Monitor for water flows and nitrate-N concentration
April	Corn planting for the 2013 trials. Monitor for nitrous oxide and ammonia efflux.
September	Harvest tissue and grain samples for N uptake
Nov.-Dec.	Soil sample for nitrate and ammonium
December	Submission of final report

Proposed Budget:

CATEGORIES	Year 2013	Total
A. Salaries		
Ph.D. student	$17,397	$17,397
B. Fringe Benefits	$2,454	$2,454
Fringe for graduate student		
TOTAL SALARIES AND FRINGE BENEFITS	$19,851	$19,851
C. Travel		
Travel to field site	$0	$0
To present research findings at National Meetings	$1,000	$1,000
TOTAL TRAVEL COSTS	$1,000	$1,000
D. Equipment	$0	$0
TOTAL EQUIPMENT use and maintenance COSTS	$0	$0
E. Other Direct Costs		
Soil analysis	$840	$840
Grain analysis	$900	$900
Tissue analysis	$1,000	$1,000
Water analysis	$5,900	$5,900
Field supplies	$2,000	$2,000
Publication cost	$0	$0
TOTAL OTHER DIRECT COSTS	$10,640	$10,640
TOTAL REQUEST	**$31,491**	**$31,491**

Budget narrative:
Salaries and fringe benefits: Funds are requested for partial support of a Ph.D. student.
Presentations, publications, and documentation: This will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for presentation of results
Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, and other field supplies and operations.

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Table 1. Yield, subsurface drainage, and gaseous N loss data from 2010-12 on a Putnam silt loam soil in continuous corn production.

				Subsurface drainage				Gaseous N loss
			Yield[‡]	**Water drained**	**NO_3 loss**	**N flow weighted mean**	**Ortho-P loss**	**NH_3**
Year(s)[†]	**Drainage**	**N fertilizer**	**(Bu/acre)**	**(1000 L/acre)**	**(Lbs-N/acre)**	**(ppm)**	**(Lbs-P/acre)**	**(Lbs-N/acre)**
2010	NSD	NTC	41.1b	--------	--------	--------	--------	2.8d
2010	NSD	NCU	102.0a	--------	--------	--------	--------	15.0b
2010	NSD	PCU	107.1a	--------	--------	--------	--------	8.7bcd
2010	CSD	NCU	109.5a	1232a	20.8a	7.7a	0.10a	26.3a
2010	CSD	PCU	103.1a	1183a	20.3a	7.8a	0.28a	4.6bcd
2010	MSD	NCU	112.7a	1015a	16.8a	7.3a	0.10a	14.2bc
2010	MSD	PCU	106.4a	1015a	13.3a	6.1a	0.08a	3.7cd
2011	NSD	NTC	13.5c	--------	--------	--------	--------	4.2a
2011	NSD	NCU	43.5b	--------	--------	--------	--------	4.5a
2011	NSD	PCU	80.7a	--------	--------	--------	--------	4.0a
2011	CSD	NCU	61.1ab	1654a	30.2ab	8.8ab	0.70a	5.8a
2011	CSD	PCU	66.5a	1521a	33.2a	10.0a	0.57a	4.6a
2011	MSD	NCU	61.3ab	737b	15.4bc	9.5ab	0.10a	4.6a
2011	MSD	PCU	63.1ab	650b	4.9c	3.5b	0.12a	4.2a
2012	NSD	NTC	12.2d	--------	--------	--------	--------	10.1a
2012	NSD	NCU	44.8c	--------	--------	--------	--------	8.0bc
2012	NSD	PCU	51.0b	--------	--------	--------	--------	9.0ab
2012	CSD	NCU	49.9b	159ab	2.6b	7.4a	0.04ab	8.2bc
2012	CSD	PCU	51.1b	256a	5.0a	8.9a	0.11a	8.6bc
2012	MSD	NCU	55.3a	48b	0.7bc	11.7a	0.01b	7.6c
2012	MSD	PCU	55.4a	5b	0.1c	4.8a	0.00b	7.9bc
			Average	Total	Total	Average	Total	Average
2010-12	NSD	NTC	22.3c	--------	-------	--------	--------	5.7bc
2010-12	NSD	NCU	63.5b	--------	-------	--------	--------	9.2b
2010-12	NSD	PCU	79.6a	--------	-------	--------	--------	7.2bc
2010-12	CSD	NCU	73.5ab	3044a	53.6ab	8.0a	0.84a	13.4a
2010-12	CSD	PCU	73.6ab	2960a	58.4a	8.9a	0.96a	6.0bc
2010-12	MSD	NCU	76.4ab	1800b	32.9bc	9.5a	0.21a	8.8bc
2010-12	MSD	PCU	75.0ab	1670b	18.2c	4.8a	0.20a	5.3c

[†] **Annual values were calculated over the period of July 6 through Dec. 31 in 2010 and Jan 1 through Oct. 15 in 2012.**

[‡] **Letters following yields, water drained, N flow weighted mean, NO_3, ortho-P, and NH_3 loss (by year) denote Fisher's Least Sign. Diff. (P = 0.1).**

Table 2. Yield and subsurface drainage data from 2010-12 on a Wabash silty-clay soil in continuous corn production.

				Subsurface drainage			
Year(s)[†]	**Drainage**	**N fertilizer**	**Yield[§] (Bu/acre)**	**Water drained (1000 L/acre)**	**NO_3 loss (Lbs-N/acre)**	**N Flow weighted mean (ppm)**	**Ortho-P loss (Lbs-P/acre)**
2010[‡]	NSD	NCU	0	--------	--------	--------	--------
2010	NSD	PCU	0	--------	--------	--------	--------
2010	CSD	NCU	0	1598a	8.1a	2.7a	0.03a
2010	CSD	PCU	0	1457a	7.1a	2.3a	0.03a
2010	MSD	NCU	0	946b	13.3a	7.4a	0.03a
2010	MSD	PCU	0	970b	9.5a	5.3a	0.03a
2011	NSD	NCU	204.6a	--------	--------	--------	--------
2011	NSD	PCU	198.5a	--------	--------	--------	--------
2011	CSD	NCU	192.0a	2997a	51.2a	8.1b	0.26ab
2011	CSD	PCU	200.7a	3011a	46.1b	7.3b	0.32a
2011	MSD	NCU	194.2a	1746b	35.2c	10.0ab	0.13bc
2011	MSD	PCU	193.6a	1727b	49.7ab	14.0a	0.12c
2012	NSD	NCU	92.2a	--------	--------	--------	--------
2012	NSD	PCU	90.5a	--------	--------	--------	--------
2012	CSD	NCU	102.5a	2099a	20.9a	5.8a	0.08b
2012	CSD	PCU	100.0a	1988a	12.8a	3.7a	0.12a
2012	MSD	NCU	101.4a	895b	4.3a	3.6a	0.03c
2012	MSD	PCU	100.1a	850b	5.4a	3.5a	0.03c
			Average[¶]	Total	Total	Average	Total
2010-12	NSD	NCU	148.4a	--------	--------	--------	--------
2010-12	NSD	PCU	144.5a	--------	--------	--------	--------
2010-12	CSD	NCU	147.3a	6693a	80.2a	5.5ab	0.34a
2010-12	CSD	PCU	150.3a	6456a	66.0a	4.4b	0.45a
2010-12	MSD	NCU	147.8a	3586b	64.6a	7.0ab	0.16b
2010-12	MSD	PCU	146.8a	3548b	52.8a	7.6a	0.15b

[†] Annual values were calculated over the period of July 6 through Dec. 31 in 2010 and Jan. 1 through Oct. 15 in 2012.
[‡] Corn crop in 2010 was lost due to severe flooding event.
[§] Letters following yields, water drained, NO_3 loss, N flow weighted mean, ortho-P loss (by year) denote Fisher's Least Significant Difference (P = 0.1).
[¶] Corn yield data was averaged over the 2011 and 2012 season.

Phosphorus Management

<u>Final Report</u>

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

Xi Xiong and John Haguewood

Objectives:

1) Determine surface phosphorus runoff from different fertility programs applied to lawns with low (<40 lbs P_2O_5/acre) and high (>60 lbs P_2O_5/acre) soil phosphorus.
2) Evaluate the quality of turfgrass in response to phosphorus treatments applied to soils with different concentrations of available phosphorus.
3) Visually demonstrate to home owners through permanent demonstration plots the differences in turfgrass quality and phosphorus runoff potential of different fertilization scenarios as related to soil test values.

Current status/importance of research area:

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

Procedures:

Design - Twelve plots were established on a laser leveled 4% slope measuring 5 ft by 20 ft with a two foot buffer between each plot. Initial soil phosphorus levels were determined through soil test and plots were assigned to ‘high’ (>60 lbs P/acre) and ‘low’ <40 lbs P/acre) soil phosphorus designations. The differences in soil P were further magnified through triple super phosphate (46% of P_2O_5) fertilization to develop a substantial difference in soil phosphorus levels for the four corresponding treatments with three replications. The treatments are a homeowner scenario with high soil P (treatment 1), a soil test scenario with high soil P (treatment 2), a soil test scenario with low soil P (treatment 3), and a restricted scenario with low soil P (treatment 4)

(Table 1). Once the soil phosphorus level had been adjusted, treatments were applied. Starting in the fall of 2011, a single phosphorus application in the amount of 50 lbs P/acre was applied to treatment 1 (homeowner scenario with high soil P), and treatment 3 (soil test scenario with low soil P). Treatment 2 (soil test scenario with high soil P) did not receive any phosphorus treatment as based on soil test (no additional P were needed). Similarly, no phosphorus treatments were applied to treatment 4 as it is designated as a low soil P, and a restricted use scenario. After the fall phosphorus application, simulated rainfalls (4 inches) were applied twice in the fall at 0 day after treatment (DAT) and 5 DAT to induce runoff. The reason 0 day when rainfall was applied was to simulate the extreme condition when homeowners ignored the weather condition and applied the phosphorus fertilizer at the same day when significant rainfall occurs. We also simulated the second rainfall event at 5 DAT to evaluate if residue phosphorus exits. Since we had an unusually dry year, 4 inches of rainfall was necessary to induce runoff from treatment area. **In 2012**, P treatments were applied May 24th and October 12th. In the spring, a single phosphorus applications in the amount of 50 lbs P/acre was applied to treatment 1 (homeowner scenario with high soil P), and treatment 3 (soil test scenario with low soil P). One of the three plots receiving treatment 2 (soil test scenario with high soil P) was applied with 25 lbs P/acre to meet the needs indicated by the soil test. No phosphorus was applied for treatment 4 as it is designated as low soil P with a restricted use scenario. In the fall, P was applied at 50 lbs P/acre for treatment 1(homeowner scenario), treatment 3 (soil test scenario with low soil P) only needed 0, 1 and 5 lbs P/acre for the three replications, respectively. Treatments 2 (soil test scenario with high soil P) and 4 (restricted use scenario) received no P applications in fall 2012. Nitrogen fertilizer in the form of granular urea (46-0-0) was applied at 1 lb N/1000ft^2 as a normal maintenance practice in both years in spring and fall. Due to extremely dry conditions in 2011 and 2012, only one natural rainfall event (May 2012) resulted with water runoff, and simulated rainfalls were conducted to gather additional data in spring and fall 2012.

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

Treatment	Phosphorus fertilization	Soil available phosphorus
1.Common homeowner scenario	150 lbs P_2O_5/acre	High (>60 lbs P_2O_5/acre)
2. Soil test recommendation	None (as recommended by soil test)	High (>60 lbs P_2O_5/acre)
3. Soil test recommendation	50-150 lbs P_2O_5/acre (as recommended by soil test)	Low (<40 lbs P_2O_5/acre)
4. Restricted use scenario	None	Low (<40 lbs P_2O_5/acre)

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

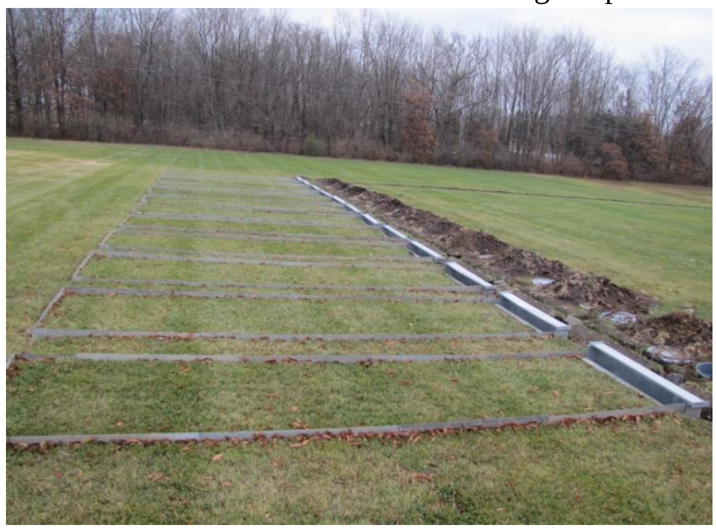


Figure 1. Field Plots constructed.

Measurements – Runoff water is collected from natural or simulated rainfall (Figure 2) events. Total volume is determined and a representative one liter sample is collected and sent to the MU Soil and Plant Testing Laboratory for determination of total phosphorus, dissolved phosphorus, and percent sediments. Plant tissue samples and soil samples are also taken and analyzed by the Soil and Plant Testing Laboratory for total plant and soil nutrients including phosphorus. Weekly measurements (when weather condition permits) include chlorophyll index (Field Scout CM1000), NDVI (GreenSeeker®), and overall turf quality on a 1-9 scale.

Figure 2. Rainfall simulator. Simulated rainfall in precisely applied to plots using a custom irrigation system. Plots are evenly irrigated using 8 small irrigation heads. Volume is measured using an in-line digital flow meter.

Results:

Soil P level: Prior to the treatment in 2011, there was no statistical difference in soil phosphorous concentrations between plots. After adjusting the soil P level, plots that receiving treatments 1 and 2 had high level of P (>35 lb/A) and were classified as high soil P (Figure 3 A, blue bars). Plots that receiving treatments 3 and 4 had relatively low P level (<25 lb/A) and were categorized as low soil P (Figure 3A, blue bars). This indicates that we have established treatments within our intended parameters. After P treatment, plots received P fertilizer resulted in high (>80 lb/A) soil P compared to plots without additional P fertilizer (Figure 3A, red bars). Similar trend was found in 2012 spring (Figure 3B) and fall (Figure 3C) that soil P levels corresponded to the initial P level and the additional P fertilizers applied. It is interesting to note that **following a typical homeowner scenario (treatment 1), soil P has risen from 40 to over 100 lb/A after just three applications** (Figure 3A and C), indicating how rapid the accumulation of P can happen after repeated applications.

Runoff water P in 2011 and 2012: Following 2011 fall treatment, plots received P fertilizer (treatments 1 and 3) resulted in significantly higher levels P as both total P and dissolved P in runoff water collected at the same day of treatment (Day 0) (Figure 4). Total P was 6.94-fold higher for treatment 1 compared to treatment 2 in runoff water occurred in the plots (Table 2). This suggests that for soils with high P levels, high rainfall shortly after application of P fertilizer results in a significant loss of P applied. Similarly, high rainfall shortly after application of P fertilizer on soils with low P levels also results in a significant loss of P (7.04-fold) compared to treatment 4, which did not receive only P fertilizer (Table 2). We also found that P application applied on soil with high P level (treatment 1) resulted in significantly higher total runoff P loss than applied to plots with low soil P level (treatment 3). **This result indicates that accumulated higher soil P level will likely increase the chance of P loss in runoff water.** These same trends were also found for P dissolved in water (Table 2). In examining the sediment P levels, we observed that some differences were noted among treatments, but this was not significant. When rainfall event was simulated at 5 DAT, more total P loss was found in plots with high soil P level and received P fertilizer treatment (treatment 1), compared to other plots regardless of P level and/or P fertilizer treatment (Figure 4A). When amount of runoff water collected taken into consideration, however, the numerical differences in total, dissolved, and sediment P were not statistically significant (Table 2). At 5 DAT, levels of total P and dissolved P were quantitatively similar at plots with high or low soil P levels. These data indicate that a majority of the potential P lost with high rainfall events will occur with the first event.

In 2012, simulated rainfalls were made 2 weeks after P fertilizer treatment (WAT) in spring and 4 WAT in fall. Similar trend were found in spring and fall P loss in runoff water (Figure 5 & 6). In spring, higher amount of total P was found in runoff water from plots received additional P fertilizers (treatment 1 & 3), regardless of soil P levels (Figure 5). Plots received treatment 4 resulted in significant less total P loss in runoff water as expected. Compared to total P in runoff water, less than 0.5 mg/L of dissolved P were found in runoff water, regardless of the treatments. In fall 2012, after 4 weeks of P fertilizer application, the runoff water P analysis found no differences of either total or dissolved P. However, we did found a trend that plots received treatment 1 resulted in numerically higher P loss in runoff water, compared to other treatments

(Figure 6). This result indicates that rainfall event at 4 weeks after P fertilizer treatment does not induce significant P loss in runoff compared to plots received no P fertilizers. **Collectively, our results suggest that the potential of P loss in runoff water is amplified when rainfall event occurs shortly after P fertilization (within days).** When amount of runoff water collected taken into consideration, we found a similar trend that higher amount of P loss occurred in plots with higher soil P level and received additional P fertilizers (treatment 1), although the difference was not significant (Table 3). Compared to 2011 results where simulated rainfall occurred within days of P fertilization (Table 2), the amount of P loss in runoff reduced significantly when rainfall events occurred at 2 weeks or later after P fertilization (Talbe 3). **These results suggest that proper timing of P fertilization, for example within weeks of major rainfall rather than days, could reduce the total amount of P loss in runoff water up to 85%.**

Tissue sample mineral concentrations: No difference in N and K concentrations were found in tall fescue tissue samples collected in 2010 and 2011 (Talbe 4). For P concentrations, however, we found that plots established on high soil P and received additional P fertilizers resulted in the highest amount of tissue P concentration in both 2010 and 2011 (0.36% and 0.41%, respectively). Plots that established on high soil P but practiced soil test-based P management (treatment 2) resulted in the second highest P concentration in the tissue samples in both years. The lowest tissue P concentrations were found in plots established on lower soil P areas, regardless of the P fertilizer additions. However, regardless the statistic difference in tissue P levels, all tall fescue samples collected from the plot area resulted in adequate amount of P concentration for turfgrass standard, which is between 0.3% and 0.5% by dry weight. **These results indicate that tall fescue plants maintained adequate amount of P concentration, regardless of the soil P levels and/or P fertilizer additions.**

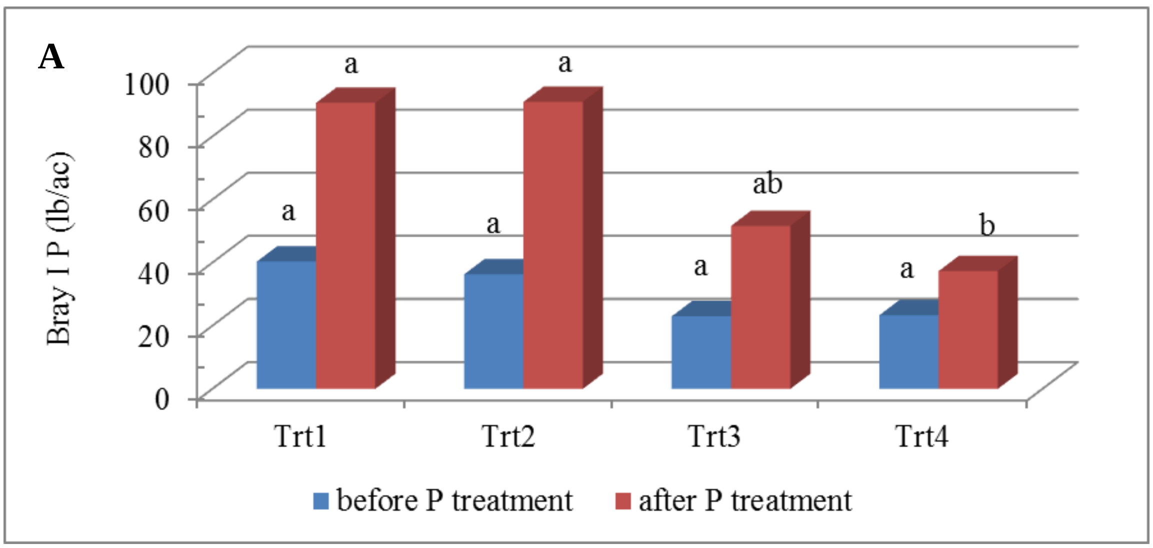
Turf performance: In 2011, evaluation of turf performance over a 25 day period following application of P and high rainfall were similar for the four treatments (Table 5). Among all the variables of turf health and performance, only NDVI measured at 10 DAT showed differences between treatments. Higher NDVI values would correlate with better turf color and coverage, but differences between treatments could not be associated with P levels. In 2012, over a year of data was recorded and no significant differences in turf quality or NDVI (table 6) were observed. **Our data indicate that the relative P levels in the soil and/or additions of P fertilizer have no influence on turf performance.**

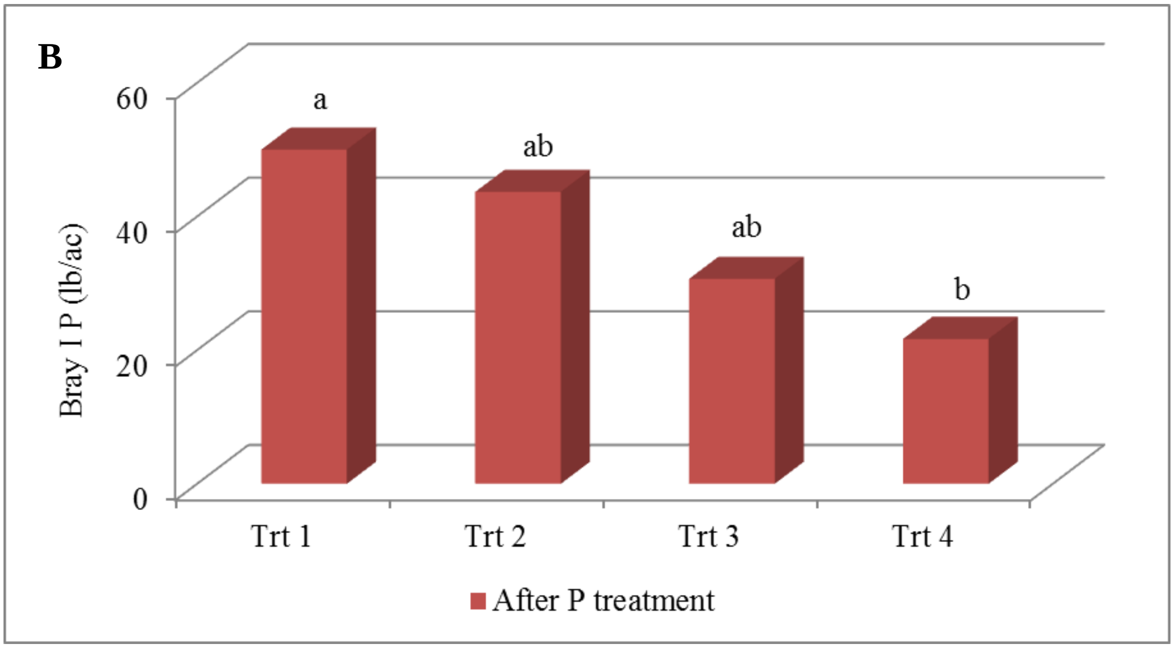
Natural rainfall amounts: In the two-year experimental period, we experienced extremely dry seasons and historically low rainfalls (Figure 7A and B) and high temperatures during the summer months. As a result, we had little opportunity to collect runoff water from natural rainfall events, and majority of the data collected were from simulated rainfalls. We also experienced very low soil moisture level that more than 4 inches of water were necessary to induce runoff from the plots.

Conclusion

- Applying a complete fertilizer (such as 12-12-12) annually will increase the soil P level within a couple of years.
- High levels of soil P (>60 lb/A) will increase the chance of P loss in runoff compared to soil with low P levels (<40 lb/A).
- Applying P fertilizer within days of a major rainfall increases the chance of P loss in runoff water up to 85%.
- Turfgrass plants, such as tall fescue, requires limited amount of P (0.3~0.5% by dry weight) to sustain the normal function and maintain acceptable turf performance. Addition of P fertilizer does not improve the turf quality and performance.
- Homeowners and lawn-care professionals are suggested to apply P only when soil/tissue test indicates a need, or try to avoid major rainfalls (that cause runoff) within days of fertilization that contains P (Figure 8).

Figure 3. Soil phosphorus (P) concentration (lb/ac) measured by Bray I P before and after P fertilizer treatments during the fall 2011 (A), spring 2012 (B) and fall 2012 (C). Soil samples were randomly taken from 8-10 different locations within each plot and mixed for analysis. Blue bars represent samples taken before P treatment, and red bars represent samples taken after P treatment. Bars labeled by different letters before or after P treatment are not significantly different using Fisher's Protected LSD (*P*=0.05).





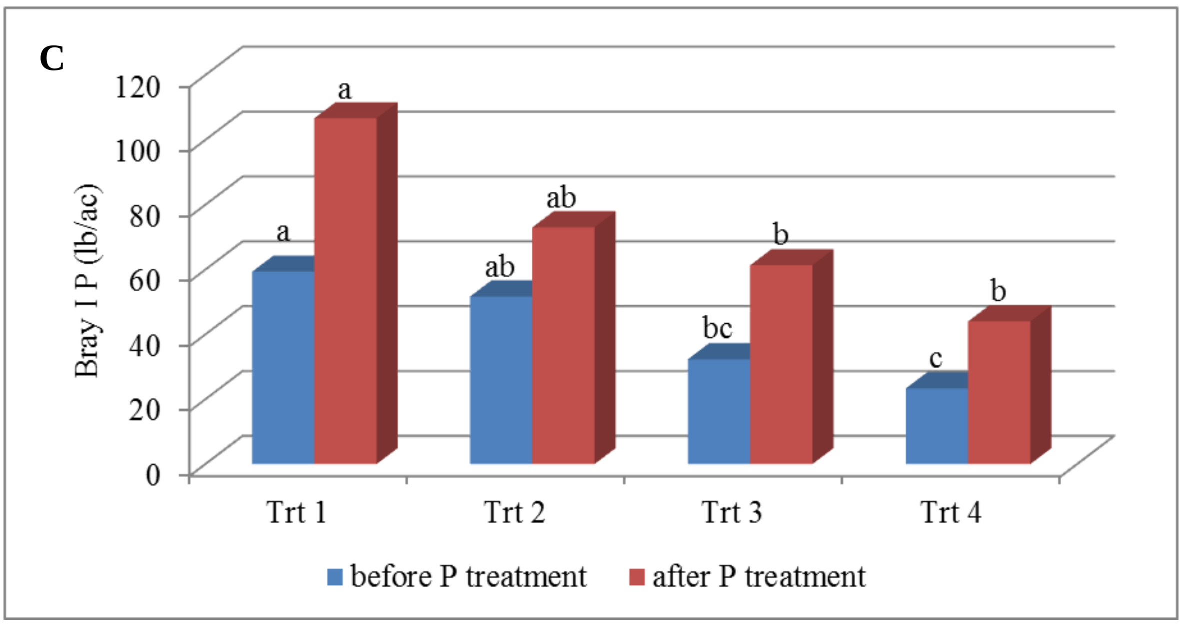
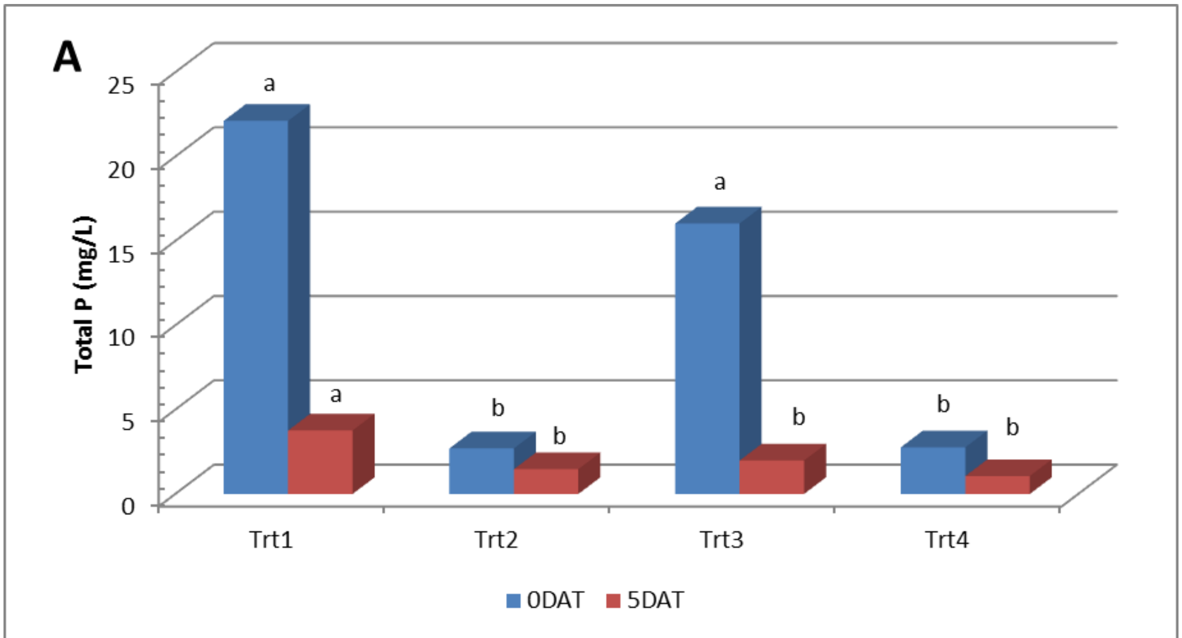


Figure 4. Concentrations of total P (mg/L) and dissolved P (mg/L) in runoff water collected at 0 (A) or 5 (B) days after the P fertilizer treatment (DAT) in fall 2011. Bars labeled by different letters at 0 or 5 DAT are not significantly different using Fisher's Protected LSD (*P*=0.05).


A
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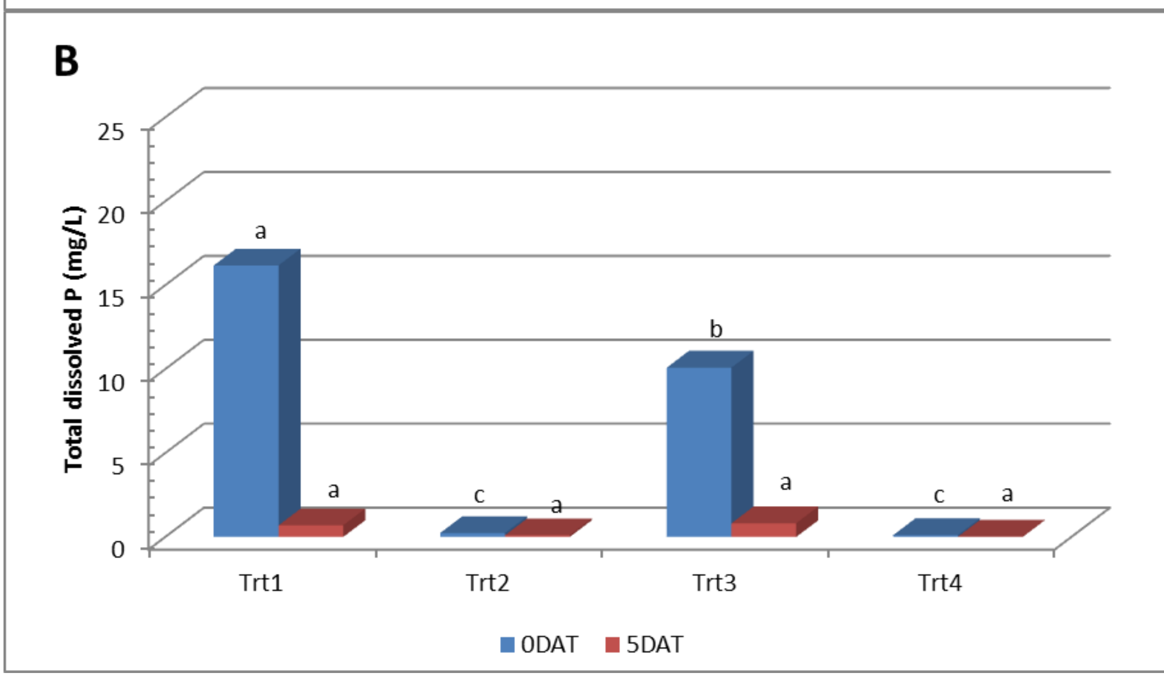
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Total dissolved P (mg/L)
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Trt3
Trt4
0DAT
5DAT

Figure 5. Concentrations of total P (mg/L, blue bars) and dissolved P (mg/L, red bars) in runoff water collected at 2 weeks after the P fertilizer treatment in spring 2012. Bars labeled by different letters are not significantly different using Fisher's Protected LSD (*P*=0.05).

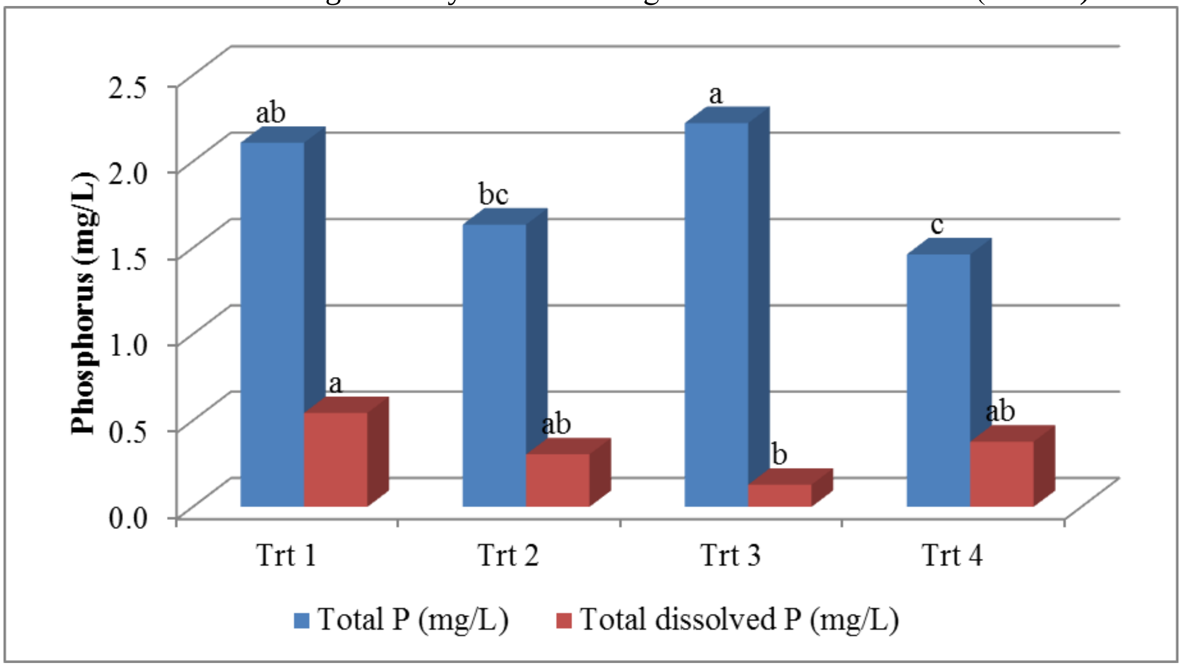

Figure 6. Concentrations of total P (mg/L, blue bars) and dissolved P (mg/L, red bars) in runoff water collected 4 weeks after the P fertilizer treatment in fall 2012. Bars labeled by different letters are not significantly different using Fisher's Protected LSD (*P*=0.05).

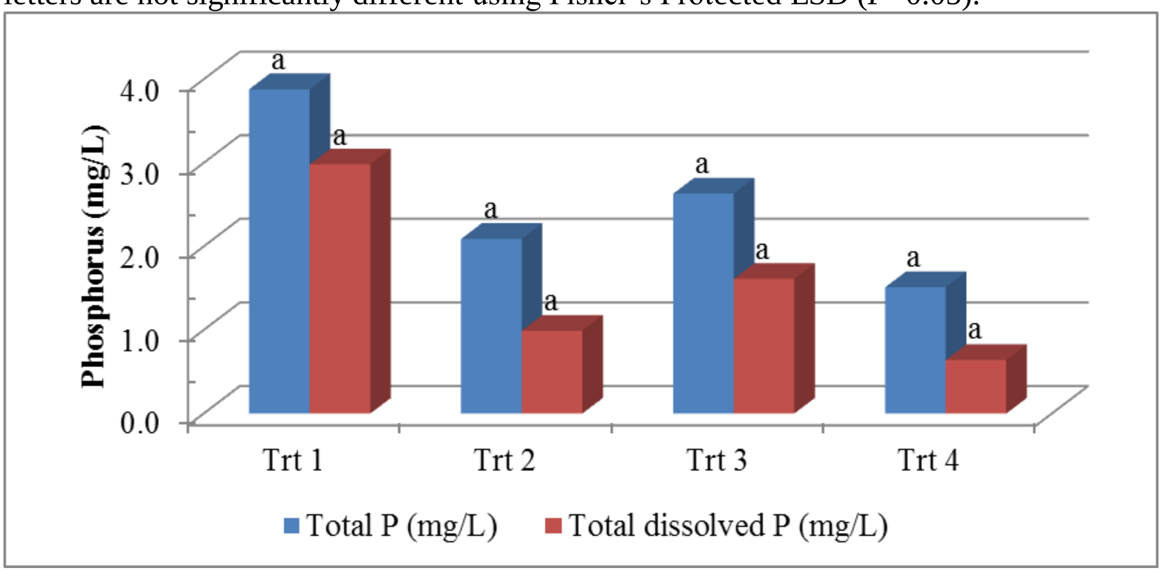

Figure 7. Precipitation (inches) at the South Farm during fall, 2011 (A) and for the year 2012 (B).

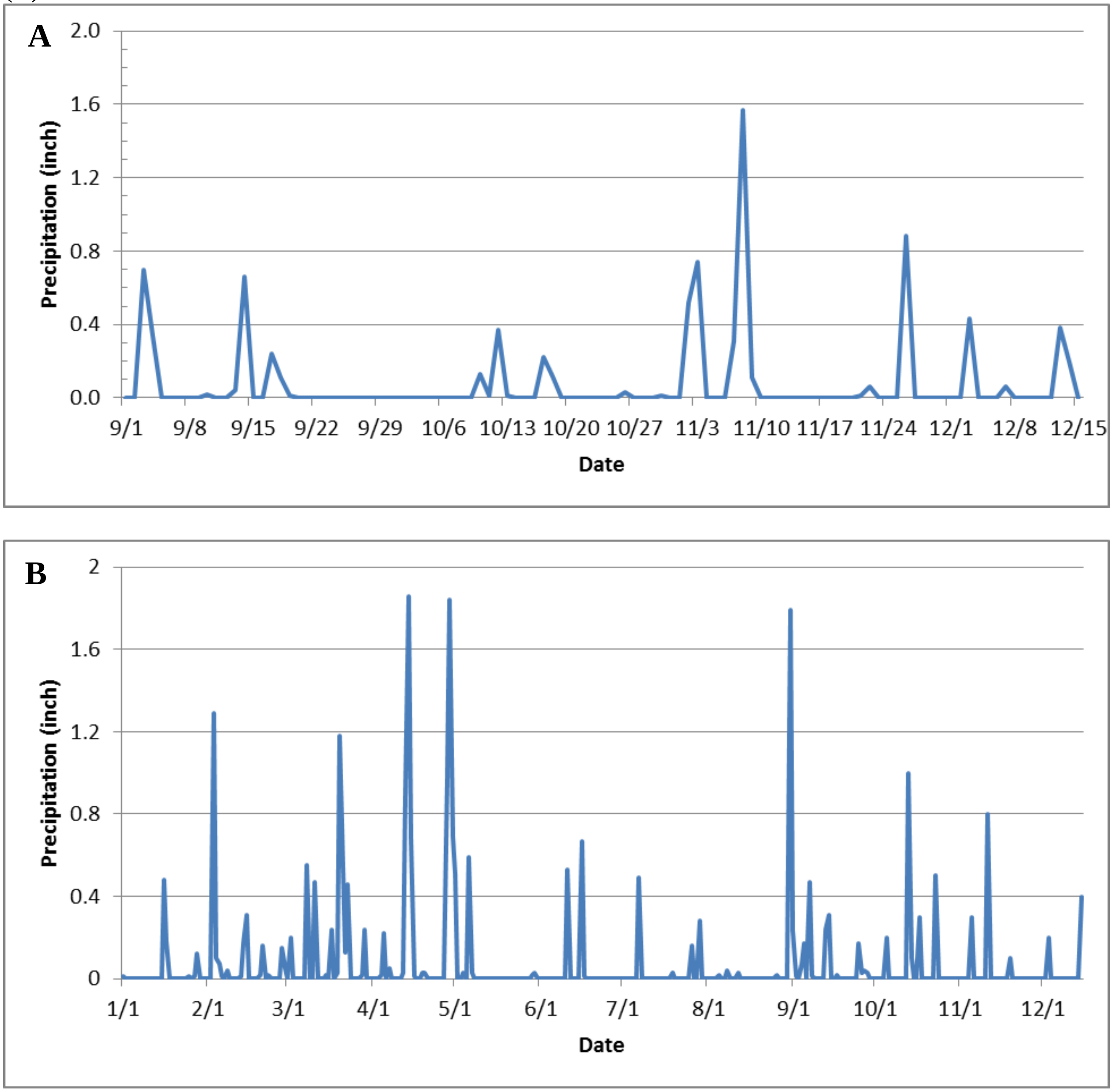

Figure 8. Discussing the phosphorus run-off study at the 2nd Annual Lawn-care Workshop on August 1, 2012.

Table 2. Total phosphorus loss in the runoff water from the plot area affected by the P fertilizer treatments at the different days after treatments (DAT) during fall 2011. Data included are total P (mg), dissolved P (mg), sediment P (mg), and the total runoff (L) from the plot area.

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

[*]Sediment P (mg) is indirectly presented by the difference between the total P and dissolved P.
[**]Mean separation is conducted only when significant differences were found by ANOVA. Means within a column followed by the same letter are not significantly different using Fisher's Protected LSD (*P*=0.05).

Table 3. Total phosphorus loss in the runoff water from the plot area affected by the P fertilizer treatments in spring and fall 2012. Simulated rainfalls were conducted at 2 weeks after P fertilizer treatment (WAT) in spring and 4 WAT in fall. Data included are total P (mg), dissolved P (mg), sediment P (mg), and the total runoff (L) from the plot area.

Trt #	Soil P	Practice	---Total P (mg) ---		--Dissolved P (mg) ---		---Sediment P (mg)[*] ---		-----Runoff (L) -----	
			Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
1	High P	Home owner	50.0**	52.5	11.5	37.8	38.1	14.6	8.8	5.3
2	High P	Soil test	60.0	21.2	6.1	8.0	54.2	13.2	8.5	3.1
3	Low P	Soil test	88.3	21.1	5.6	11.3	82.6	9.8	16.9	2.9
4	Low P	Restricted use	35.8	24.1	10.0	8.4	25.8	15.7	5.7	3.6

[*]Sediment P (mg) is indirectly presented by the difference between the total P and dissolved P.
[**]Mean separation is not conducted as no significant differences were found by ANOVA.

Table 4. Turfgrass tissue mineral concentrations, percent nitrogen (N%), phosphorous (P%), and potassium (K%) influenced by the P fertilizer treatments in fall of 2011 and 2012. Samples were taken within 4 weeks after treatment in each year.

Trt #	Soil P	Practice	N%*		P%		K%	
			2011	2012	2011	2012	2011	2012
1	High P	Home owner	2.22	2.79	0.36a	0.41a	1.70	2.28
2	High P	Soil test	1.85	2.75	0.32b	0.38ab	1.33	2.32
3	Low P	Soil test	1.87	2.75	0.29c	0.35ab	1.49	2.19
4	Low P	Restricted use	2.04	2.8	0.29c	0.33c	1.56	2.22

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

Table 5. Turf quality, canopy chlorophyll index, and Normalized Difference Vegetation Index (NDVI) affected by P fertilizer treatments. Data were collected at different days after fall 2011 treatments (DAT).

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

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

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

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

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

Table 6. Turf quality and Normalized Difference Vegetation Index (NDVI) affected by P fertilizer treatments. Data were collected at different days after 2012 treatments (DAT).

Trt #	Soil P	Practice	-------------------------Turf quality*--------------------------				------------NDVI†------------	
			1/3/2012	6/6/2012	8/31/2012	12/14/2012	1/3/2012	12/14/2012
1	High P	Home owner	6.3**	8.3	7.0	8.0	0.648	0.774
2	High P	Soil test	6.3	8.2	7.0	8.0	0.610	0.755
3	Low P	Soil test	6.3	8.3	7.0	8.0	0.581	0.772
4	Low P	Restricted use	6.6	8.5	7.0	8.0	0.625	0.767

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

**Means Mean separation is not conducted as no significant differences were found by ANOVA.

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

Enhanced Efficiency Phosphorus Application for a Corn-Soybean Rotation

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Objectives and Relevance:

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

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

The objectives of this research were to:

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

Procedures:

General. A two-year rotational crop study utilizing P fertilizer applications for corn was initiated in 2010, and evaluated the subsequent impact on soybean yield and/or uptake. Research trials were established at the Greenley Memorial Research Center near Novelty, Delta Center near Portageville, and Hundley-Whaley Center near Albany. Each site was arranged as a randomized complete block design with four replications. Soils were initially characterized for soil total organic C, pH (0.01 *M* $CaCl_2$), and exchangeable K, Ca and Mg at each site (Tables 1 and 2). Soil test P (Bray-1 P) concentrations were determined prior to application from each replication at each site. Soil test P was determined following soybean harvest for each treatment. Grain yields were determined and grain collected (Novelty and Albany) to evaluate for starch, protein, and oil concentration (Foss Infratec, Eden Prairie, MN). Whole plant tissue samples were collected at plant maturity and nitrogen, phosphorus, and potassium levels were determined. Apparent P recovery efficiency (APRE) was calculated as [((lbs P uptake/acre of treated - lbs P uptake/acre of control)/(lbs fertilizer applied P/acre))*100]. Grain moisture was adjusted to 15.5% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD ($P = 0.05$ or 0.1). Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented). The soybean tissue and soil data in 2012 is currently being analyzed (data not presented).

P placement, rate, and enhancer. Sites to accomplish objective 1 included Novelty and Albany. Corn fields were initiated at both locations in 2010 and 2011. Soybean followed corn in the same plots in 2011 and 2012. Treatments included a factorial arrangement of application placement (i.e., surface broadcast or strip-till), MAP rate (0, half the recommended rate, and recommended rate), and the presence and absence of two enhanced phosphorus efficiency products [AVAIL®(Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton and P_2O_5 Max® (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton]. Plots were 10 by 75 ft at Novelty and 15 by 75 ft at Albany. The previous crop before corn production was soybean at both locations. Phosphorus treatments were deep banded using a Yetter® 2984 strip-till system equipped with high residue Maverick® units (Yetter Manufacturing, Inc., Colchester, IL) with a rolling basket and dry fertilizer application tubes at the Novelty site. Phosphorus treatments were deep banded using a Yetter® 2984 strip-till system equipped with residue manager wheels (Yetter Manufacturing, Inc., Colchester, IL), B-33 mole knife, and opposing closing wheel disks at the Albany site. A Gandy Orbit Air® (Gandy Company, Owatonna, MN) fertilizer applicator was used to deliver fertilizer behind the applicator knife in the strip-till system. Phosphorus was broadcast surface applied with a hand spreader. Ammonium nitrate fertilizer was broadcast applied for the appropriate treatments to balance the N contribution of MAP as the rate was reduced. The planter was equipped with Shark-tooth® (Yetter Manufacturing, Inc., Colchester, IL) residue cleaners used in tandem with a no-till coulter. The residue cleaners performed well in heavy residue of the no-till plots and provided a smooth seedbed above strip-tilled plots. Management information is available in Table 3. Corn and soybean tissue samples were collected to determine crop N, P, and K uptake due to the effects of the treatments at both locations. Soil samples and soybean tissue for 2012 is currently being analyzed analyzed by the University of Missouri Soil and Plant Testing Laboratory (data not presented).

P source, P enhancer, and ag lime. Research to accomplish objective 2 was conducted at Novelty in 2010 and 2011 and Portageville in 2010. Corn fields were initiated at Novelty and Portageville in 2010 with an additional field started at Novelty in 2011. The field site at Portageville in 2011 was abandoned due to the impact of excessive rainfall on corn plant populations. Soybean followed the corn at Novelty and Portageville in 2011 and at Novelty in 2012. Treatments included a factorial arrangement of P sources [non-treated control and a broadcast application of DAP (diammonium phosphate) or TSP (triple superphosphate], presence or absence of the phosphorus efficiency products [AVAIL®(Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton and P_2O_5 Max® (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton], and broadcast surface application of ag lime [0 and recommended (3.6 ton/acre at Novelty 2010, 1.5 ton/acre at Novelty 2011, and 2.0 ton/acre at Portageville 2010)]. Plots were 10 by 45 ft. The Novelty site was no-till and rain fed, while the Portageville was conventional tillage with furrow irrigation. Management information is available in Table 4. Tissue (Novelty and Portageville) samples from both corn and soybeans were collected to determine crop N, P, and K uptake. Soil samples and soybean tissue for 2012 is currently being analyzed analyzed by the University of Missouri Soil and Plant Testing Laboratory (data not presented).

Results:

Corn-P placement, rate, and P stabilizer. The results from the corn portion of objective 1 were accepted for publication in the *Journal of Agricultural Science* (Dudenhoeffer et al., 2013). Strip-till/deep banding increased plant populations 6,200 plants/acre at Novelty and 1,400 plants/acre at Albany (Table 5). There was no effect of fertilizer placement on silage dry weights, but grain moisture was 0.3% greater in no-till compared to strip-till. Yields increased 24 bu/acre with use of strip-till/deep banding over no-till/broadcast at Novelty, but yields at Albany were affected by placement and MAP rate. When no MAP was added at Albany, no-till/broadcast increased grain yields 9 bu/acre over strip-till/deep banding. However, no difference was observed between no-till/broadcast and strip-till/deep banding with MAP at 50 or 100 lbs P_2O_5/acre. MAP at 0 lbs P_2O_5/acre yielded 11 bu/acre more than MAP at 50 lbs P_2O_5/acre rate under no-till/broadcast, but no difference was observed with MAP at 100 lbs P_2O_5/acre. This difference may be due to the ammonium nitrate that was added to balance the N contribution as the MAP rate increased.

Grain protein and starch concentrations had an interaction between year and placement at Novelty, but not Albany (Table 6). No-till/broadcast had 1.4% higher protein concentration point in 2010 than strip-till/deep banding and 0.6% higher protein concentration in 2011. In 2010, strip-till/deep banding increased starch by 0.8%, starch increased 0.3% in 2011. Grain oil concentration was affected by location, placement, and MAP rate. At Novelty, no-till/broadcast with MAP rate 0 lbs P_2O_5/acre had lower oil concentration than any other placement-MAP rate combinations. At Albany, strip-till/deep banding with MAP at 0 lbs P_2O_5/acre had a lower oil concentration than any other placement-MAP rate combination except for no-till/broadcast MAP at 100 lbs P_2O_5/acre. There was no effect of fertilizer placement on N, or K uptake, but no-till/broadcast increased APRE 20.7% over strip-till/deep banding (Table 7).

Plant population, silage dry weights, and grain moisture were not affected by MAP rate at the four site-years evaluated in this research (Table 8). MAP rate had a significant (*P*=0.1) effect on yields with P_2O_5 at 0 lbs/acre yielding 4 to 6 bu/acre more than MAP at 50 or 100 lbs P_2O_5/acre. This difference may be due to the ammonium nitrate that was added to balance the N contribution as the MAP rate increased. Grain protein concentration increased 0.3% with MAP at 50 and 100 lbs P_2O_5/acre compared to the non-treated control at Novelty in 2011, but no differences were observed at Novelty in 2010 or Albany. MAP at 0 and 100 lbs P_2O_5/acre increased starch concentration 0.2% over MAP at 50 lbs P_2O_5/acre at Novelty, but not at Albany. Plant tissue N, tissue P, tissue K, and APRE were not affected by MAP rate (Table 9).

Enhanced efficiency P products did not affect plant population, silage dry weights, grain moisture, yield, grain protein, or starch concentrations at the four site-years (Table 10). The non-treated control oil concentration at Albany was 0.2% greater than the P-Max treatment. Plant N uptake, plant K uptake, and APRE were not affected by P stabilizer (Table 11). Tissue P concentrations were affected by fertilizer placement and P stabilizer. In the no-till/broadcast and strip-till/deep banding, the addition of AVAIL or P-Max did not increase tissue P uptake over the non-treated controls. AVAIL increased tissue P uptake 5.1 lbs/acre over P-Max with strip-till/deep banding, while no differences between products were observed with no-till/broadcast. Phosphorus uptake increased 5.3 lbs/acre when P fertilizer was applied with P-Max and no-till/broadcast instead of strip-till/deep banding.

Corn-P source, P stabilizer, and ag lime. The results from the corn portion of objective 2 were published in the *Journal of Agricultural Science* (Dudenhoeffer et al., 2012). The recommended liming rate was 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010. Plant population was 1,000 plants/acre greater in the non-limed control compared to the recommended rate in 2011 at Novelty, while plant population was not affected at Portageville (Table 12). The recommended amount of lime increased grain yields 12 bu/acre at Portageville, but there was no effect at Novelty. Grain moisture, oil, protein, and starch concentrations were not affected by the lime treatment at either location.

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

Plant tissue N and tissue K was not affected by a lime application (Table 15). Phosphorus uptake increased 3 lbs/acre with the application of lime at Novelty, but was not affected at Portageville. However, the lime application decreased APRE 13.4 %. Plant P uptake was affected by P source and P stabilizer at Novelty, while P uptake was not affected at Portageville (Table 16). When the fertilizer was not treated with a P stabilizer, the tissue P uptake of DAP was 7.4 to 8.0 lbs/acre greater than the non-treated control and TSP. Neither of the P stabilizer combined with DAP increased P uptake over the non-treated control. Triple superphosphate treated with AVAIL increased tissue P uptake 7.7 lbs/acre compared to non-treated TSP and 6.3 lbs/acre compared to P-Max.

Plant K uptake was not affected by P stabilizer at Portageville or the 2011 growing season at Novelty (Table 16). The 2010 growing season at Novelty showed an interaction between P source and P stabilizer for K uptake. TSP treated with AVAIL increased tissue K uptake over all other P source-P stabilizer combinations except for P-Max applied with the non-treated P-source. When TSP was the P source, AVAIL increased K uptake 135 lbs/acre compared to the non-treated TSP and 89 lbs/acre compared to P-Max. The non-treated P source had higher tissue K uptake (67 lbs/acre) than TSP when no P stabilizer was applied.

Soybean-P placement, rate, and P stabilizer. There was no effect of fertilizer placement on soybean plant population or soybean dry weights (Table 17). Placement was the only factor that had an effect on soybean yields. Soybean following corn with no-till/broadcast yielded 0.8 bu/acre higher than strip-till/deep banding. Soybean dry weights and grain yields were not affected by MAP rates applied to corn the previous year at the four site-years evaluated in this research (Table 18). P-Max applied with 50 lbs P_2O_5/acre MAP had slightly lower plant populations compared to P-Max applied the other fertilizer rates and non-treated P, but P-Max applied with the 100 lbs P_2O_5/acre MAP increased plant populations 9,100 plants/acre over the same MAP rate with no enhancer (Table 19). However, there was no effect of P stabilizers on soybean dry weights or yields.

Soybean-P source, P stabilizer, and ag lime. When no P enhancer was applied at Novelty, the non-limed treatment increased soybean dry weights 0.23 ton/acre more compared to the lime treatment (Table 20). Soybean dry weights with AVAIL and P-Max were 0.18 to 0.22 ton/acre lower than the non-treated when no lime was applied. AVAIL increased soybean dry weights 0.21 ton/acre when lime was not applied compared to when lime was added. At Portageville, AVAIL applied with no lime increased dry weights 0.45 ton/acre over the non-treated control with no lime application and 0.63 ton/acre compared to AVAIL in conjunction with a lime application. Soybean dry weights were not affected by P source (Table 21). In 2011 at Novelty, TSP in conjunction with lime, DAP with no application of lime, and the non-P fertilized lime treatment had higher yields compared to DAP in combination with a lime application. DAP yielded 1.8 bu/acre lower than the non-treated control at Novelty in 2012. At Portageville, applying no fertilizer resulted in lower yields compared to when either DAP or TSP was applied. P-Max paired with TSP had soybean yields 3.8 bu/acre lower than P-Max paired with DAP, 2.8 bu/acre lower than AVAIL paired with TSP, and 2.5 bu/acre lower than TSP with no P stabilizer.

Summary of Accomplishments:

- Strip-till increased corn plant populations 6,200 plants/acre at Novelty and 1,400 plants/acre at Albany. Corn yields increased 24 bu/acre with use of strip-till/deep banding over no-till/broadcast at Novelty, but yields at Albany were affected by placement and MAP rate. When no MAP was added at Albany, no-till/broadcast increased grain yields 9 bu/acre over strip-till/deep banding. However, no difference was observed between no-till/broadcast and strip-till/deep banding, with MAP at 50 or 100 lbs P_2O_5/acre.
- Soybean with strip-till/deep banding placement had slightly lower grain yields (0.8 bu/acre) compared a no-till broadcast application of fertilizer to corn the previous year. Neither MAP rate, nor enhanced efficiency P products affected soybean yields the following year in this experiment (Objective #1).
- Enhanced efficiency P products did not affect corn plant population, dry weights, grain moisture, or yield in either objective at any of locations or site years.
    - In objective #2, triple superphosphate treated with AVAIL increased corn tissue P uptake 7.7 lbs/acre compared to non-treated TSP and 6.3 lbs/acre compared to P-Max.
- P enhancers showed limited improvements to soybean production when they were applied to the prior corn crop under the conditions observed in this experiment.
    - In objective #2, AVAIL applied with no lime increased dry weights 0.45 ton/acre over the non-treated control with no lime application only at Portageville.
    - P-Max with DAP increased soybean yields 2.9 bu/acre compared to the non-treated control at Portageville.
- TSP increased corn yields 5 bu/acre compared to the non-treated control in 2010 and 2011 at Novelty and in 2010 at Portageville. However, grain oil, protein, and starch concentration was not affected by P source.
- Lime increased grain yields 12 bu/acre at Portageville in 2010, but had no effect at Novelty.
- The application of lime to corn before soybeans had no effect on soybean dry weights or yields.

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

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

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

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

Table 3 . Management information for the P placement, rate, and enhancer experiment at Novelty and Albany for corn (2010 and 2011) followed by soybean (2011 and 2012).

	Novelty				Albany			
Management Information	Corn 2010 followed by soybean 2011		Corn 2011followed by soybean 2012		Corn 2010 followed by soybean 2011		Corn 2011 followed by soybean 2012	
Previous crop	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn
Hybrid or cultivar	DK 62-54	Ag 3731	DK 62-54	Ag 3731	DK 63-84	Ag 3803	DK 63-84	Ag 3803
Planting Date	14 Apr.	2 May	31 Mar.	12 Apr.	30 May	6 May	13 April	10 May
Seeding rate (seeds/acre)	30,000	160,000	30,000	180,000	30,000	160,000	29,500	160,000
Tissue harvest date	7 Sep.	29 Aug.	25 Aug.	9 Aug	9 Sep.	2 Sep.	26 Aug.	11 Sep.
Harvest date	30 Oct.	28 Sep.	8 Sep.	2 Oct.	15 Oct.	7 Oct.	27 Sept.	10 Oct.
Fertilizer								
P application date	13 Apr.	NA	30 Mar.	NA	15 Apr.	NA	15 Nov.	NA
Additional fertilizer (date, source, & rate)	6 May, Urea (180 lbs N/acre)+ Agrotain (1 gal/ton)	NA	NA	NA	19 Apr., urea (150 lbs N/acre)+ Agrotain (1 gal/ton)	NA	14 Apr., urea (150 lb)	NA
Weed management								
Burndown	NA	11 May, Roundup PowerMAX (22 oz/acre)+ 2,4-D (2/3 pt/acre)+ Quest (7 oz/acre)	11 Apr., Roundup PowerMAX (22 oz/acre)+ 2,4-D (2/3 pt/acre)+ Quest (7 oz/acre)	2 Apr., Verdict (5 oz/acre)+ Roundup PowerMAX (22 oz/acre)+ 32% UAN (1 qt/acre)+ NIS (0.25% v/v)	NA	NA	NA	10 May Roundup PowerMAX (24 oz/A)
Preemergence	16 Apr., Lumax (3 qt/acre)+ Banvel (1 pt/acre)	3 May, Optil (2 oz/acre)	13 Apr., Keystone (2.8 qt/acre)	11 May, Reflex (1.25 pt/acre)+ Roundup PowerMAX (32 oz/acre)+ 32% UAN (1 qt/acre)+ NIS (0.25% v/v)	15 Apr., Lumax (3.2 qt/acre); 30 May, Balance Pro (4 oz/acre)	7 May, Boundary (2.5 pt/acre)+ Roundup PowerMAX (24 oz/acre)	16 April., Lumax (3.2qt/acre)	10 May Boundary (2.5 pt/ acre)+ Roundup PowerMAX (24 oz/ acre)
Postemergence	22 June, Roundup PowerMAX (30 oz/acre)+ AMS (17 lbs/100 gal)	NA	NA	21 June, Roundup PowerMAX (32 oz/acre)+ NIS (0.25% v/v)+ AMS (17 lbs/100 gal)+ Warrior (20 oz/acre)+ Headline (6 oz/acre)	21 June, Roundup PowerMAX (24 oz/acre)	NA	7 June, Roundup PowerMAX (24 oz/acre)	NA
Insect management	16 Apr., Warrior (1.5 oz/acre)	NA	NA	16 Jul., Dimethoate (1 pt/acre)	NA	NA	NA	NA

[†]Abbreviations: NA, None applied; NIS, non-ionic surfactant; UAN, 32% urea ammonium nitrate.

Table 4. Management information for the P source, P enhancer, and agriculture lime experiment at Portageville in 2010 and Novelty in 2010 and 2011 followed by soybean at Portageville in 2011 and Novelty in 2011 and 2012.

	Novelty				Portageville	
Management information	Corn in 2010 followed by soybean in 2011		Corn in 2011 followed by soybean in 2012		Corn in 2010 followed by soybean in 2011	
Previous crop	Corn	Corn	Wheat	Corn	Corn	Corn
Hybrid or cultivar	DK 61-69 VT3	Ag 3731	DKC 63-42	Ag 3731	CROPLAN 68-31	Pioneer P94Y70
Planting date	26 May	2 May	10 May	12 Apr.	7 Apr.	25 Apr.
Seeding rate (seeds/acre)	30,000	160,000	30,800	180,000	30,000	140,000
Tissue harvest date	7 Sep.	31 Aug.	25 Aug.	9 Aug.	16 Aug.	8 Sep.
Harvest date	1 Oct.	28 Sep.	14 Sep.	4 Oct.	8-9 Sep.	25 Sep.
Fertilizer						
P application date	27 Apr.	NA	31 Mar.	NA	6 Apr.	NA
Lime application date	1 Apr.	NA	29 Mar.	NA	1 Apr.	NA
Additional fertilizer (date, source, & rate)	12 Apr., Anhydrous ammonia (235 lbs N/acre)	NA	31 Mar., Anhydrous ammonia (180 lbs N/acre)	NA	7 Apr., Urea (50 lbs N/acre) + Agrotain (1 gal/ton)	NA
Sidedress N	11 June, 32% UAN (150 lbs N/acre)	NA	NA	NA	5 May, Urea (150 lbs N/acre) + Agrotain (1 gal/ton)	NA
Weed management						
Burndown	21 Apr., Roundup PowerMAX (15 oz/acre)	11 May, Roundup PowerMAX (22 oz/acre)+ 2,4-D (2/3 pt/acre)+ Quest (7 oz/acre)	11 Apr., Roundup PowerMax (22 oz/acre) + 2,4-D (2/3 pt/acre) + Quest (7 oz/acre)	2 Apr., Verdict (5 oz/acre)+ Roundup PowerMAX (22 oz/acre)+ 32% UAN (1 qt/acre)+ NIS (0.25% v/v)	5 Apr., Conerstone (32 oz/acre)	30 Apr., Glyphosate (32 oz/acre) + Prefix (3 pt/acre) + Sonic (6.45 oz/acre)
Preemergence	21 Apr., Bicep II Magnum (1.65 qt/acre)	3 May, Optil (2 oz/acre)	13 Apr., Bicep II Magnum (2.5 qt/acre)	11 May, Reflex (1.25 pt/acre)+ Roundup PowerMAX (32 oz/acre)+ 32% UAN (1 qt/acre)+ NIS (0.25% v/v)	9 Apr., Bicep II Magnum (1.5 qt/acre) + Atrazine (2 qt/acre)	NA
Postemergence	22 June, Roundup PowerMAX (22 oz/acre)	NA	NA	21 June, Roundup PowerMAX (32 oz/acre)+ NIS (0.25% v/v)+ AMS (17 lbs/100 gal)+ Warrior (20 oz/acre)+ Headline (6 oz/acre)	8 May, Atrazine (1 qt/acre) + Glyphosate (32 oz/acre)	13 June, Flexstar GT (2.6 pt/acre)

[†]Abbreviations: NA, None applied; NIS, non-ionic surfactant; UAN, 32% urea ammonium nitrate.

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

	Plant population				Yield			
						Albany[†]		
			Silage dry	Grain		MAP rate (lb P_2O_5/acre)		
Placement	Novelty[†]	Albany[†]	weights	moisture	Novelty[†]	0	50	100
	----plants/acre-----		ton/acre	%	--------------------bu/acre--------------------			
Broadcast	20,500	23,300	6.5	17.2	100	139	128	133
Strip-till	26,700	24,700	6.6	16.9	124	130	132	135
LSD (*P*=0.1)	1,300	1,200	NS	0.3	5	---------------7---------------		

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

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

	Protein			Starch			Oil					
							Novelty[†]			Albany[†]		
	Novelty			Novelty			MAP rate(lb P_2O_5/acre)			MAP rate(lb P_2O_5/acre)		
Placement	2010	2011	Albany[†]	2010	2011	Albany[†]	0	50	100	0	50	100
	-------------%-------------			-------------%-------------			----------%----------			----------%----------		
Broadcast	8.4	9.3	8.4	73.9	72.9	72.3	3.5	3.7	3.7	3.7	3.7	3.7
Strip-till	7.0	8.7	8.5	74.7	73.2	72.2	3.7	3.7	3.7	3.6	3.8	3.7
LSD (*P*=0.05)	0.3	0.2	NS	0.20	0.24	NS	----------0.1----------			----------0.1----------		

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

Table 7. Total tissue N and K uptake, and apparent P recovery efficiency (APRE) as affected by P fertilizer placement. Data were combined over site-year, P stabilizer, and monoammonium phosphate (MAP) rate.

Placement	Tissue N	Tissue K	APRE
	lbs/acre	lbs/acre	%
Broadcast	384	255	21.4
Strip-till	388	247	0.7
LSD (*P*=0.1)	NS	NS	11.5

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

MAP Rate	Plant population	Silage dry weights	Grain moisture	Yield	Protein: Novelty 2010	Protein: Novelty 2011	Protein: Albany†	Starch: Novelty†	Starch: Albany†
lb P_2O_5/acre	plants/acre	ton/acre	%	bu/acre	-----------%----------			-------%-------	
0	23,800	6.8	17.1	126	7.7	8.8	8.5	73.7	72.3
50	23,900	6.5	17.0	120	7.7	9.1	8.4	73.5	72.2
100	23,800	6.5	17.0	122	7.6	9.1	8.4	73.7	72.3
LSD (*P*=0.1)	NS	NS	NS	4	NS	0.2	NS	0.2	NS

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

Table 9. The effect of monoammonium phosphate (MAP) rate on total tissue N, tissue P, tissue K, and apparent P recovery efficiency (APRE). Data were combined over site-year, P stabilizer, and placement.

MAP rate	Tissue N	Tissue P	Tissue K	APRE
lb P_2O_5/acre	------------lbs/acre-----------			%
0	393	33.2	258	
50	383	34.0	241	12.9
100	383	35.2	254	9.1
LSD (*P*=0.1)	NS	NS	NS	NS

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

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

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

Table 11. P stabilizer effect on tissue N, tissue P, tissue K, and apparent P recovery efficiency (APRE). Data were combined over site-year, placement, monoammonium phosphate (MAP) rate except for tissue P which was combined over site year, and MAP rate.

P Stabilizer	Tissue N	Tissue P: Broadcast	Tissue P: Strip-till	Tissue K	APRE
	lbs/acre	-------lbs/acre-------		lbs/acre	%
Non-treated	375	35.3	34.0	250	16.1
AVAIL	384	33.9	35.5	249	13.1
P-Max	400	35.7	30.4	255	3.8
LSD (*P*=0.1)	NS	----------3.7----------		NS	NS

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

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

[†]Novelty location only.
[‡]Data were combined over years (2010 and 2011).
[§]The recommended liming rate was 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010.

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

P source	Silage dry weights, Liming rate: None	Silage dry weights, Liming rate: Recommended[‡]	Grain moisture[§]	Yield	Oil[§]	Protein[§]	Starch[§]	Tissue N	APRE
	-------------ton/acre-------------		%	bu/acre	%	%	%	lbs/acre	%
Non-treated	6.5	7.5	26.2	132	3.9	9.1	71.7	418	
DAP[†]	6.8	7.2	25.3	135	3.9	9.0	71.8	420	4.8
TSP[†]	7.4	7.1	24.9	137	3.9	9.0	71.9	439	-3.8
LSD (*P*=0.05)	--------------0.7--------------		0.8	5	NS	NS	NS	NS	NS

[†]DAP and TSP was applied at a 105 lbs P_2O_5/acre at Novelty in 2010, 100 lbs P_2O_5/acre at Novelty in 2011, and 50 lbs P_2O_5/acre at Portageville in 2010.
[‡]The recommended liming rate was 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010.
[§]Novelty location only.

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

P stabilizer	Plant population	Silage dry weights	Grain moisture†	Yield	Oil†	Protein†	Starch†	Tissue N	APRE
	plants/acre	ton/acre	%	bu/acre	%	%	%	lbs/acre	%
Non-treated	21,100	7.2	25.6	135	3.9	9.0	71.8	442	6.1
AVAIL	21,400	7.2	25.6	134	3.9	9.1	71.7	422	1.7
P-Max	20,400	6.9	25.3	136	3.9	9.0	71.7	414	-6.3
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS
P-value	0.31	0.48	0.69	0.65	0.44	0.97	0.48	0.45	0.43

†Novelty location only.

Table 15. Tissue N, tissue P, tissue K, and apparent P recovery efficiency (APRE) as affected by liming rate. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, P source, and P stabilizer except for Tissue P.

		Tissue P			
Liming Rate	Tissue N	Novelty	Portageville	Tissue K	APRE
	lbs/acre	----------lbs/acre----------		lbs/acre	%
None	421	29.3	45.1	254	7.2
Recommended†	430	32.3	43.9	258	-6.2
LSD (*P*=0.1)	NS	2.8	NS	NS	13.0

†The recommended liming rate was 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010.

Table 16. P stabilizer effect on tissue P and tissue K. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, and liming rate except for tissue K.

	Tissue P				Tissue K				
	Novelty				Novelty				
	P source				2010				
					P source				
P stabilizer	Non-treated	DAP†	TSP†	Portageville	Non-treated	DAP†	TSP†	2011	Portageville
	------------------------lbs/acre-------------------------				----------------------------------lbs/acre----------------------------------				
Non-treated	28.6	36.0	28.0	47.3	258	253	191	271	248
AVAIL	26.1	32.8	35.7	42.0	197	241	326	286	243
P-Max	31.5	29.0	29.4	44.1	261	229	237	297	229
LSD (P=0.1)	-----------------5.9-----------------			NS§	-----------------66-----------------			NS	NS
P-value	--------------0.033--------------			0.365	---------------0.010----------------			0.438	0.563

†DAP and TSP was applied at 105 lbs P_2O_5/acre at Novelty in 2010, 100 lbs P_2O_5/acre at Novelty in 2011, and 50 lbs P_2O_5/acre at Portageville in 2010.

Table 17. Phosphorus placement effect on soybean plant population, soybean dry weights, and yield. Data were combined over site-year, monoammonium phosphate (MAP) rate, and P stabilizer.

Placement	Plant population	Soybean dry weights	Yields
	plants/acre	tons/acre	bu/acre
Broadcast	151,000	3.20	45.4
Strip-till†	148,200	3.23	44.6
LSD (*P*=0.1)	NS	NS	0.7

†Strip-till treatment was for corn the previous year and soybean were no-till seeded the following year.

Table 18. Soybean dry weights and yields as affected by monoammonium phosphate (MAP) rate. Data were combined over site-year, placement, and P stabilizer.

P source	Soybean dry weights	Yields
lb P_2O_5/acre†	tons/acre	bu/acre
0	3.21	44.6
50	3.16	45.1
100	3.27	45.3
LSD (*P*=0.1)	NS	NS

†Phosphorus fertilizer was applied the previous year for corn production.

Table 19. The effect of P stabilizer on soybean plant population, soybean dry weights, and yield. Data were combined over site-year, placement, and monoammonium phosphate (MAP) rate except for plant population.

	Plant population MAP rate (lb P_2O_5/acre)†				
P stabilizer	0	50	100	Soybean dry weights	Yields
	-------------plants/acre-------------				
Non-treated	152,900	150,300	145,400	3.25	44.8
AVAIL	148,500	150,100	152,800	3.20	45.4
P-Max	149,600	142,000	154,500	3.19	44.9
LSD (*P*=0.1)	----------------7,600-----------------			NS	NS

†Phosphorus fertilizer and stabilizer were applied the previous year for corn production.

Table 20. P stabilizer effect on soybean dry weights. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, and P source.

	Soybean dry weights			
	Novelty		Portageville in 2011	
	Liming Rate		Liming Rate	
P stabilizer	None	Recommended†	None	Recommended
	------------tons/acre-----------		------------tons/acre-----------	
Non-treated	2.58	2.35	4.07	4.46
AVAIL	2.40	2.19	4.52	3.89
P-Max	2.36	2.43	4.35	3.98
LSD (*P*=0.1)	--------------0.17--------------		--------------0.45--------------	

†The recommended liming rate was applied to corn at 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010. Soybean was planted in the same plots the following year.

Table 21. Soybean dry weights and yield results based on P source. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, liming rate, and P stabilizer except for yield.

		Soybean Yield					
		Novelty 2011			Portageville		
		Liming Rate			P stabilizer		
P source	Soybean dry weights	None	Recommended‡	Novelty 2012	Non-treated	AVAIL	P-Max
	ton/acre	------------bu/acre------------		bu/acre	-----------------bu/acre-----------------		
Non-treated	2.92	47.4	47.2	20.6	56.3	56.8	55.6
DAP†	3.03	47.9	45.6	18.8	60.5	61.8	63.4
TSP	3.04	47.8	48.0	19.7	62.1	62.4	59.6
LSD (*P*=0.10)	NS	-------------1.4-------------		1.1	-------------------1.8-------------------		

†DAP and TSP were applied to corn at a 105 lbs P_2O_5/acre at Novelty in 2010, 100 lbs P_2O_5/acre at Novelty in 2011, and 50 lbs P_2O_5/acre at Portageville in 2010. Soybean was planted in the same plots the following year.
‡The recommended liming rate was applied to corn at 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010.

Miscellaneous Tests

Progress Reports

Impact of micronutrient packages on soybean yields in Missouri

Felix B. Fritschi and James H. Houx III,
Univ. of Missouri

Objectives and Relevance to the Missouri Fertilizer and Lime Industry:
The main objective of this research is to determine the effect of various micronutrient packages offered by the fertilizer industry on soybean yield and seed quality.
The specific objectives are to:

1) quantify the impact of pre-formulated micronutrient packages on yield and seed quality of glyphosate as well as glufosinate resistant soybean cultivars.
2) measure micronutrient uptake by the soybean plants and develop nutrient response curves.
3) determine effects of applications on soil micronutrient status.

The use of micronutrients is increasing as the costs of fungicides and pesticides have many growers and producers focused on balanced plant nutrition to optimize plant health (Brown, 2008). Pre-formulated micronutrient packages are advertised to improve yields and nutritional content of Missouri's crops. Increased yields and grain quality would translate into greater returns for Missouri producers and increased fertilizer sales. Statistics on micronutrient use and yield improvement in Missouri are scant. However, ever-higher crop yields and, with the advent of cellulosic biofuel production, increases in whole plant removal will result in more micronutrients leaving farmers' fields. This increase in micronutrients leaving the field and the potential reduction in soil supply power (associated with reductions in soil organic matter caused by the removal of not only grain yield but also crop residues) emphasize the importance to critically examine the role of micronutrient fertilization in Missouri.

Dozens of micronutrient formulations are available for the Ag market in general and soybean producers in particular (SoyScience, Pro Bean Mix, Bean Mix, and Crop Mix among others). However, evaluation of product performance by independent researchers is largely lacking, complicating the decision making process for farmers. For producers like Kip Cullers, micronutrient packages are likely a necessary management practice to meet the demands of ever-more productive soybeans. Although most producers do not aspire to achieve world record yields, applications of micronutrients may increase their yields and economic bottom line. Because glyphosate interacts with Mn both in tank mixtures and in the plant (Bernards et al., 2005), products that aim to combat GIMD may be particularly promising. However, because these products are relatively new to the Missouri market, their effect on the "average" soybean grower's yield is uncertain.

2011 ACCOMPLISHMENTS:

- This year was the first year of the project that evaluates micronutrient packages on soybean yield, micronutrient uptake and soil micronutrient status.

- The following treatments were applied to MorSoy RT3930N RoundUp Ready and MorSoy LL3939N LibertyLink soybean planted in 8-row, 15" row spacing, 20' long plots that were replicated four times.

1) United Suppliers' Sovereign (foliar; liquid; EDTA chelate)
2) Agrium's Bean Mix (soil; granular; non-chelated oxides and sulphates)
3) Tetra Micronutrients' Pro Bean Mix (foliar; liquid; citric acid and EDTA chelates)
4) Helena's HM609 (foliar or soil; liquid; Lignosulphonate sequestered)
5) AgExplore's SoyScience (foliar; liquid; non-chelated sulphates)
6) Stoller's X-tra Power (liquid; foliar or soil; MEA chelate)
7) Tetra Micronutrient's ManGro (foliar Mn; specifically for GIMD)
8) untreated control

- To assess the effect of herbicide interactions with the micronutrient applications the following herbicide x soybean treatments were imposed.
  1) RR soybean with glyphosate applications
  2) RR soybean without glyphosate applications
  3) LL soybean with glufosinate applications
  4) LL soybean without glufosinate applications

2011 PRELIMINARY RESULTS:

NOTE: Results are from one field season and are considered preliminary

- Despite adverse growing conditions that included wet, cool weather at planting and throughout much of May, severe hail damage in July, and extreme drought, soybean yields in this experiment were above average for the Bradford Research and Extension Center (Fig. 1, 2, 3, 4).

- Tetra Mangro (P<0.05) and Stoller X-tra Power (P<0.10) improved soybean yield relative to no micronutrient treatment when glyphosate was applied to MorSoy RR soybean as part of a typical weed management program (Fig. 1).

- When glyphosate was not applied to Morsoy RR soybean, both Tetra Micro ProBean and Stoller X-tra Power improved soybean yield (P<0.05). Other micronutrient treatments yielded similarly to the no micronutrient control.

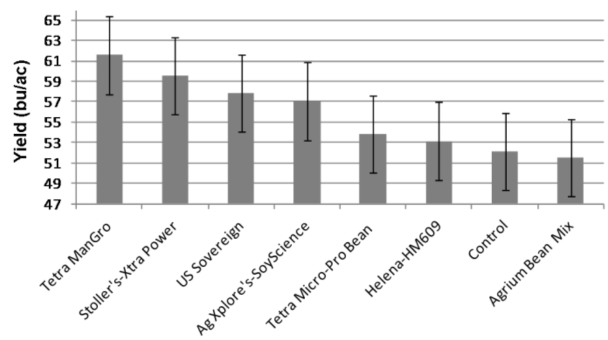


Figure 1. Yield response of RR soybean to micronutrient packages when soybean is treated with glyphosate.

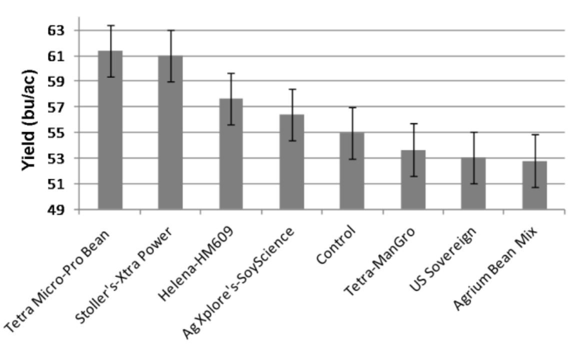


Figure 2. Yield response of RR soybean to micronutrient packages when soybean is not treated with glyphosate.

- When glufosinate was applied to MorSoy LL soybean as part of a typical weed management program, no micronutrient packages improved yield relative to the no micronutrient control (Fig. 3).

- Tetra ManGro (P<0.10) improved MorSoy LL soybean yield when glufosinate was not applied (Fig. 4).

- The interactions between soybean variety, whether or not they were sprayed, and the micronutrient packages were significant (P<0.01) suggesting that there is a genotype x micronutrient response as well as micronutrient x herbicide response.

- This experiment will be repeated in 2012 and results from 2012 could provide further evidence of these interactions.

- Seed and plant samples are currently being processed for evaluation of seed quality and plant tissue micronutrient concentrations.

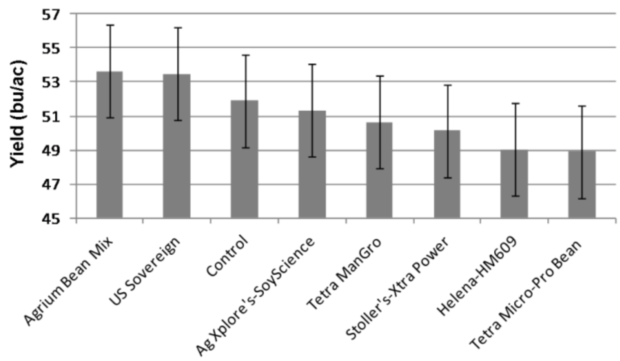


Figure 3. Yield response of LL soybean to micronutrient packages when soybean is treated with glufosinate.

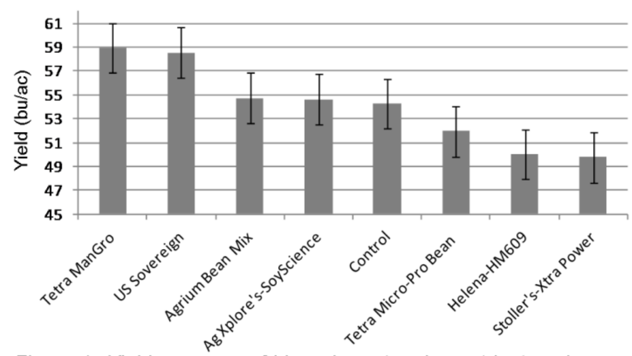


Figure 4. Yield response of LL soybean to micronutrient packages when soybean is not treated with glufosinate.

OBJECTIVES FOR YEAR 2:

In year two we will repeat the experiment as originally proposed. We will soil sample the plots from the 2011 experiment to determine any carryover micronutrient effects from soybean residue and roots. Further, we will plant the same or similar soybean varieties in a similar experimental design and sample plants five times from emergence to early reproductive stage. We will finish tissue nutrient and seed quality analyses from the 2011 season and continue with sampling protocol of harvest yield at the end of the season. We intend to present preliminary results of this research at the 2012 ASA-CSSA-SSSA annual meeting in October 2012.

BUDGET FOR YEAR 2:

Category	Year 2
Personnel	
Graduate Student	$18,000
Undergraduate help	$3,200
Field cost (fertilizers, herbicide, bags, etc.)	$2,000
Tissue and seed analyses	$4,300
Travel	$1,200
Total	**$28,700**

Managing phosphorus, manganese and glyphosate interactions to increase soybean yields

Felix B. Fritschi and James H. Houx III
Univ. of Missouri

Objectives and Relevance to the Missouri Fertilizer and Lime Industry

The overall objective of this project is to examine the two- and three-way interactions of P, Mn, and glyphosate in response to fertilizer treatments and herbicide regimes.

4) To determine if pop-up P applications will improve early season growth, soybean yield, and seed quality.
5) To determine if Mn fertilization will increase soybean yield and seed quality.
6) To examine if P and Mn fertilization individually or in concert increase yields of glyphosate and glufosinate tolerant soybeans.

A large number of soils in Missouri are low in plant available P (Bray-I P). It is well established that yields of P-deficient soybeans are reduced and that these soybeans have reduced N fixation rates. Low P can reduce the growth of the soybean plant *per se*, the growth and function of the nodules, and the growth of both the plant and the nodule (Israel, 1987; Israel, 1993; Sa and Israel, 1991; Almeida et al., 2000). Because P deficiency can strongly reduce yields, soil-test guided P fertilization recommendations have been developed and are commonly used by US farmers. However, because of its low mobility, P deficiencies can occur early in the season, even in soils with adequate soil-test P levels particularly when soil temperatures are cool and root growth is slow. Therefore, starter or pop-up fertilizers often contain P in an attempt to stimulate early growth.

Glyphosate tolerant soybeans are an amazingly important contribution to our soybean industry. However, when concerned about production of glyphosate tolerant soybeans, the question is whether or not P fertilization can stimulate Mn uptake to overcome the Mn interaction with glyphosate. We suggest that, for maximum soybean yields, a combination of Mn treatments and P fertilization may be required. This project will provide information on the impact of pop-up P, supplemental Mn, and their interactions on soybean yield responses and seed composition.

2012 ACCOMPLISHMENTS:

- This year was the first year for the project evaluating application of starter or pop-up P fertilizer with and without Mn in order to stimulate early-season plant growth and improve yields.

- The following treatments were applied to MorSoy RT3930N RoundUp Ready and MorSoy LL3939N LibertyLink soybean. Each variety treated with and without its respective herbicide. Soybean were planted in 8-row, 32 feet long plots on a 15 inch row spacing. The following treatments were applied in 4 replications.
    1) Pop-up P
    2) Pop-up P and 3 lb Mn
    3) Pop-up P and 7 lb Mn
    4) 3 lb Mn

5) 7 lb Mn
6) Control (Nothing Applied)

2012 PRELIMINARY RESULTS:
NOTE: Results are from one field season and are considered preliminary

- Even though Missouri experienced a severe drought and above average temperatures this summer yields of this project remained above the average soybean yield at the Bradford Research Station near Columbia, Missouri (Fig 1,2,3,4).

- Pop-up P plus 3 lb Mn (P<0.01), Pop-up P plus 7 lb Mn (P<0.05,) and 3 lb Mn (P<0.01) increased yields when glyphosate was applied compared to the control and the 7 lb per acre Mn treatment (Fig. 1).

- When glyphosate was not applied to the RoundUp Ready variety, Pop-Up P plus 7 lb Mn increased yield compared to having no starter fertilizer and in-furrow 7 lb Mn treatment at P<0.10 (Fig. 2).

- No significant differences in yield were observed for the Liberty Link variety in either of the two herbicide treatments (Fig. 3 and Fig 4.).

- Across all varieties untreated or treated with respective herbicide, Pop-Up P and 7 lb Mn increased yields compared to both starter fertilizer treatments consisting of just Mn (3 lb and 7 lb Mn) and the control at P<0.10 (data not shown).

- Seed and plant samples are currently being processed for evaluation of seed quality and plant tissue micronutrient concentrations.

OBJECTIVES FOR YEAR 2:

In years two and three we will repeat the experiment as originally proposed. Further, we will plant the same or similar soybean varieties in a similar experimental design and measure plant growth at every growth stage. We will

Figure 3. Liberty Link with Glufosinate Applied Treatment Yields

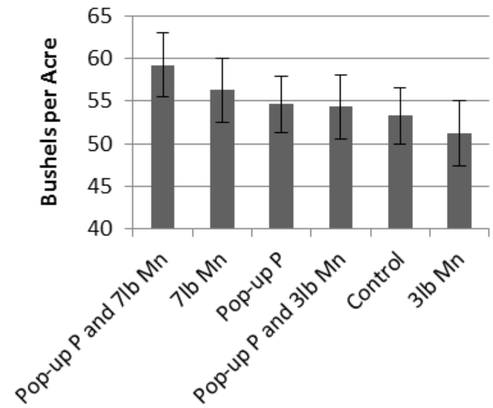


Figure 4. Untreated Liberty Link Yields

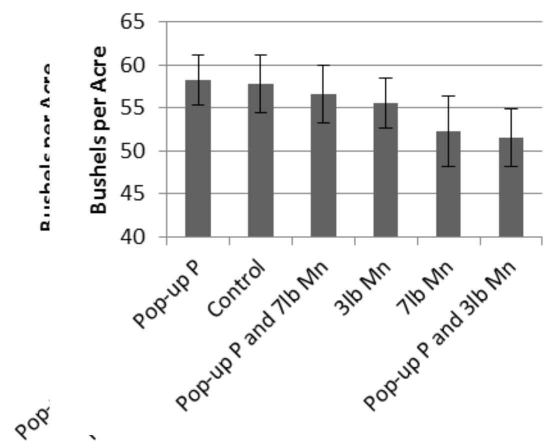
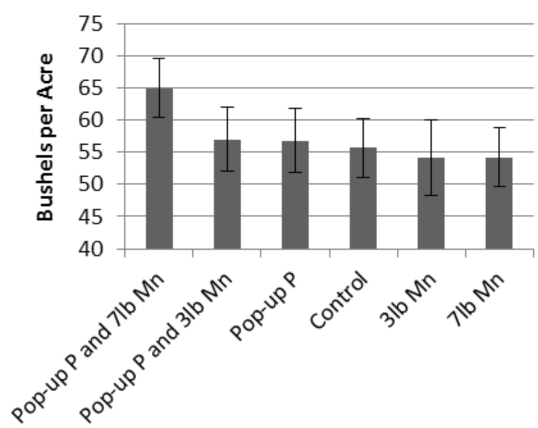


Figure 2. RoundUp Ready without Glyphosate Applied Treatment Yields



finish tissue nutrient and seed quality analyses from the 2012 season in year two. Preliminary results of this research will be presented at the 2013 ASA-CSSA-SSSA annual international meeting in October 2013.

PROPOSED BUDGET

Category	**Year 2**
Personnel	
PhD Student	$19,570
Undergraduate help	$3,200
Field cost (fertilizers, herbicide, bags, etc.)	$2,500
Tissue and seed analyses (ICP, NIR, ureide)	$3,200
Travel	$1,500
Total	**$29,970**

Title:

Impact of Fertilization Rate and Harvest Management on Cool-Season Grass Hay Yields, Forage Quality, and Hay Production Economics

Investigators:

Gene Schmitz, Todd Lorenz, Kent Shannon, Joni Harper, Wendy Rapp, Brent Carpenter, and Rob Kallenbach.

A previous localized research/demonstration project in Central Missouri illustrated the increase in forage yield and economic value of following MU Soil Testing Laboratory recommendations. However, this previous project did not answer questions about forage yield, forage quality and hay production economics if hay is aggressively harvested (mid-May, August and November) compared to a more lax harvest schedule (late-June and November or August and November). As fertilizer prices increase, it is important to make sure the dollar investment in fertilizer is captured.

Will an aggressive hay harvest management strategy capture more of the fertilizer investment than a lax harvest management system? This is what we would like to investigate.

Our objectives are: (1) To determine forage yield, quality and economic performance of two different hay harvest systems using proven fertilizer strategies, and (2) Evaluate the use of ultrasonic forage yield equipment in hay production systems.

2012 Results

Seed and fertilizer treatments were applied on March 5, 2012. Fertilizer rates were based on soil test results. Harvest dates were selected based on aggressive or more lax hay harvest management. Fertilizer rate, red clover seeding and harvest dates are listed in Table 1.

At each harvest, four samples were harvested in each plot. Plots were harvested with a flail chopper. Wet weight and harvest distance were recorded for each sample. Forage samples were collected and sent to a commercial lab for nutrient analysis. Dry matter yields were calculated on a per acre basis. After each plot was harvested for yield and quality measurements, the remaining plot area was mowed with a mower/conditioner and baled for hay.

Prior to plot harvest, standing forage yield estimates were made using an ultrasonic forage reader. Harvested areas within each plot were re-measured with the forage reader in an attempt to compare estimated harvested yield with actual harvest yield data. That data is currently being analyzed.

Total yield and weighted average forage quality data for each fertilizer / harvest date treatment is presented in Table 2. Weighted quality data was calculated by multiplying dry matter yield by the percentage crude protein (CP), percentage total digestible nutrients (TDN) and relative feed value (RFV) for each harvest. Total amounts of CP, TDN, and RFV produced were divided by total annual yield to get a representative annual estimate of forage quality and feed value.

One question we hoped to answer was the impact of aggressive harvest management compared to lax harvest management. Table 3 lists harvest yields by first cutting, first plus second cutting (if applicable), and a final, fall harvest. With the exception of the 0-0-0 treatment, delaying the initial hay harvest until August numerically reduced total hay yield. Delayed harvest also generally reduced forage quality as indicated by RFV. It appears that as inputs increase, there generally is a benefit to more aggressive harvest management.

Additional observations based on treatment averages include:

- If no fertilizer was used, harvest date wasn't as important. However RFV was higher with more cuttings.
- If not fertilized, but seeded with red clover, there appears to be a slight benefit in yield and forage quality to more cuttings and earlier cuttings.
- If fertilized for red clover, there was a benefit in yield and forage quality to more and earlier cuttings.
- If fertilized with the dealer package, forage quality benefitted from more cuttings, and there was a yield and quality penalty for delaying the initial harvest until August.
- If fertilized to soil test, there was a quality benefit with more cuttings, and a yield and forage quality penalty for delaying the initial harvest until August.
- High forage yields can be achieved even in extreme drought years with adequate fertilization and harvest management.

Economic and statistical analysis will be completed and reported at a later date. The project will be repeated during the 2013 growing season.

Table 1. Fertilizer Treatment and Harvest Dates for 2012.

Fertilizer Treatment	Number of Harvests	Harvest Date 5/23/12	Harvest Date 7/11/12	Harvest Date 8/15/12	Harvest Date 11/5/12
0-0-0	3	x		x	x
0-0-0	2		x		x
0-0-0	2			x	x
50-30-30	3	x		x	x
50-30-30	2		x		x
50-30-30	2			x	x
100-60-120	3	x		x	x
100-60-120	2		x		x
100-60-120	2			x	x
0-0-0 + RCl*	3	x	x		x
0-0-0 + RCl	2		x		x
0-0-0 + RCl	2			x	x
0-60-120 + RCl	3	x	x		x
0-60-120 + RCl	2		x		x
0-60-120 + RCl	2			x	x

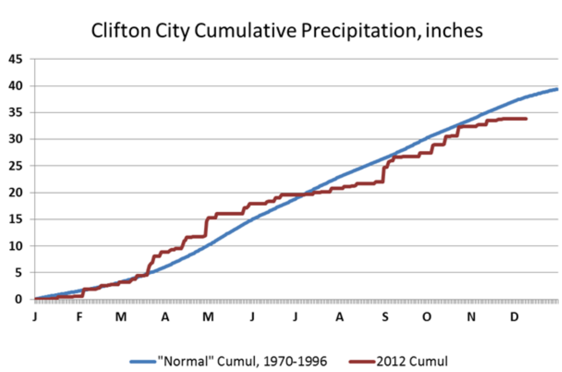
* = Red Clover

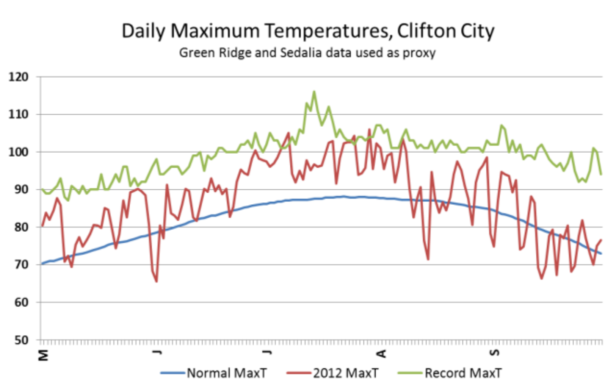
Table 2. Total Dry Matter Yield and Weighted Average Forage Quality, 2012.

Fertilizer Treatment	Harvest Months	Total Yield, lbs. DM/Acre	Total Yield, Tons DM/Acre	Weighted Avg. % CP	Weighted Avg. % TDN	Weighted Avg. RFV
0-0-0	May, Aug, Nov	2925	1.46	10.5	56.4	91.6
50-30-30	May, Aug, Nov	7303	3.65	9.7	54.3	86.7
100-60-120	May, Aug, Nov	9300	4.65	12.5	54.2	90.9
0-0-0 + RCl	May, July, Nov	5895	2.95	12.8	54.1	100.9
0-60-120 + RCl	May, July, Nov	8939	4.47	14.6	55.2	103.8
0-0-0	July, Nov	3539	1.77	8.3	53.0	76.7
50-30-30	July, Nov	6926	3.46	8.9	52.5	82.4
100-60-120	July, Nov	10,051	5.03	11.2	53.7	82.4
0-0-0 + RCl	July, Nov	5909	2.95	12.4	50.9	96.1
0-60-120 + RCl	July, Nov	6849	3.42	13.7	52.2	101.5
0-0-0	Aug, Nov	3296	1.65	9.8	52.3	81.3
50-30-30	Aug, Nov	4553	2.28	9.1	51.4	78.9
100-60-120	Aug, Nov	7940	3.97	11.3	48.5	78.6
0-0-0 + RCl	Aug, Nov	4973	2.49	12.7	49.4	92.1
0-60-120 + RCl	Aug, Nov	5949	2.97	13.5	48.6	93.0

Table 3. Hay Yields by Harvest Date.

Fertilizer Treatment	Harvest Month	1st or 1st + 2nd Harvest lbs. DM/Acre	Nov. Harvest Lbs. DM/Acre	Total Yield, Lbs. DM/Acre
0-0-0	May + Aug	2442	483	2925
0-0-0	July	2648	891	3539
0-0-0	Aug	2739	551	3296
50-30-30	May + Aug	6354	949	7303
50-30-30	July	5856	1070	6926
50-30-30	Aug	4062	490	4553
100-60-120	May + Aug	7926	1373	9300
100-60-120	July	8274	1777	10,051
100-60-120	Aug	6684	1256	7940
0-0-0 + RCl	May + July	4922	973	5895
0-0-0 + RCl	July	4124	1786	5909
0-0-0 + RCl	Aug	3758	1215	4973
0-60-120 + RCl	May + July	6267	2672	8939
0-60-120 + RCl	July	4978	1871	6849
0-60-120 + RCl	Aug	4563	1386	5949





Effectiveness of Long-Term Variable Rate Fertilizer and Lime

Gene Stevens, Matthew Rhine, Jim Heiser
University of Missouri – Delta Research Center

From 1996 to 2004, we conducted cotton field experiments at the Delta Center and on growers' fields to evaluate the effectiveness of variable rate lime and fertilizer. Results showed trends towards higher yields with variable rate technology (VRT) compared to uniform applications, but often the differences were not dramatic or statistically significant. The most important information that we determined was that less fertilizer was applied with VRT in most fields. Variable rate applications generally rely on electro conductivity (EC) technology to identify differences in soil texture. This can be helpful when nutrient deficiencies may be attributed to soil type or texture. However, VRT may not accurately identify differences that may be man-made. In many cases, grid sampling may be better suited to identify man-made problems. Fertilizer dealers usually charge farmers $10 to $15 per acre for grid soil sampling and $1 to $3 per acre for VRT applications. Soil test results are good for 3 to 4 years, but the VRT charge is an annual expense. In the past, with relatively cheap fertilizer prices, many farmers were not willing to pay the extra costs for VRT applications. However, over the years, fertilizer costs have dramatically increased, causing the need to reevaluate the cost effectiveness of variable rate technology.

The objective of this research was to evaluate the soil test results of cotton fields on Missouri farms that have had VRT applications in the past. Fields were chosen that had received VRT phosphorus (P), potassium (K), and lime applications for several years, as well as fields that had been uniformly applied for comparison. Soils samples were taken on 0.25 acre grids and analyzed for P, K, and salt pH levels at the University of Missouri's Soil Testing Lab in Portageville, MO. Soil P and K levels were evaluated based on whether or not they surpassed critical levels. Critical P and K levels were determined for each field based on cotton production and cation exchange capacity. Different fields were used in each year.

Overall, results have shown that VRT applications of both fertilizer and lime promote fewer deficiencies throughout the fields (Table 1). Generally, fields in southeast Missouri do not test low for P levels. However, VRT P applications reduced P deficient areas by 3% in this study compared to similar uniformly applied fields. Potassium fertilizer, on the other hand, is more mobile in the soil, and therefore tends to be more deficient in these locations. Variable rate K applications reduced K deficiency by 25% over uniform applications documented in this experiment. Lime applications also followed the same trend, with VRT lime applications producing soil tests results with 36% fewer deficiencies that uniform lime applications. However, when looking at each individual field, not all VRT applications have shown to reduce soil test variations in the field.

Over the course of this study, results have shown that soil test variations can be both man-made and due to soil texture variability. In the first year, many fields under VRT applications of P, K, and lime were found to be below critical nutrient levels compared to uniformly applied fields. The general trend found in most of these fields was that nutrient variability appeared to be man-made rather than due to soil type. Our research concurred with previous published studies showing nutrient variability was highest across rows and lowest within rows. Fertility tended to be highest in rows closest to the field entrance and decline in rows farther away (Figure 1). This suggests that spreader trucks in the past may have adjusted the gates down or the chain drives delivered less as they had less product in the trucks at the far side of the fields. Another pattern that we found was "streaks" of high pH in rows surrounded by lower pH rows to the right and left (Figure 2). These patterns were also found for P and K soil test levels. This pattern may have been caused by improper swath width spacing and not enough overlap in the spreaders. Since these amendments are residual in the soil, application uniformity mistakes may have occurred many years in the past with obsolete spreader technology but are being observed in the cotton fields today. When variability in nutrients is man-made, differences can be found when sampling based on a grid compared to sampling based on EC management zones. Problems shown in the field may be too generalized based on soil texture when looking at EC zones.

During the next season new fields that were sampled under VRT P and K applications were found to be above soil critical levels in most situations. Only minor problems of one to eight samples per field were recorded if there were any problems at all (Figure 3). In total, cotton fields with VRT applications this season averaged 0.8 % of samples low in P and 1% of samples low in K. In all but one of the uniformly applied fields, however, widespread areas were found to be below critical levels for P, K, or both nutrients (Figure 4). Uniformly applied fields in the second season averaged 15% of samples low in P and 35% of samples low in K. This could be caused by either producers not applying enough P and K to cover soil deficits, or by some natural soil causes. Soil K can be leached due to low cation exchange capacities as well as absorbed by particles such as illite clays, while soil P may be lost in runoff water from the field. Other uniformly applied fields were found to be excessively high in P and K, signaling that too much fertilizer had been applied over the years. This could be avoided if these soils were sampled on a regular basis. As recorded in our previous year's research, several fields showed man-made P and K variability rather than soil type variability. Streaks of low P and K levels were found in both VRT and uniformly applied fields, signifying improper application techniques or spreader malfunction (Figure 5).

Variably applied fields in the final year showed to be more deficient of K than P, which is typical for their location. In total, 2% of samples from VRT fields were low in P, while 8% were deficient of K. Many samples also showed an excess of both nutrients, although maintenance applications were still being recommended. Uniformly applied fields also showed that K was deficient in more samples than P, with 12% requiring K fertilization to surpass critical K levels. These deficiencies appeared to be a function of soil texture variability, with sand eruptions found throughout each of the fields. In this instance, soil texture mapping may be better equipped to identify deficient areas.

Summary

Although VRT can be used to reduce fertilizer costs, special care must be taken that applications are done according to soil analysis. Many of the nutrient deficiencies found in these VRT fields appeared to be man-made problems, which can be identified easier with grid sampling. However, soil sampling in such a small grid is not economically feasible for growers. Using variable rate applications that utilize EC technology is a suitable option when problems could be due to soil type. When applied correctly, fields under VRT generally corrected soil deficits of P and K, while using less fertilizer than uniformly applied fields. Adhering to regularly scheduled soil sampling every few years is key to addressing whether or not field problems have been corrected. This is also important in uniformly applied fields, where either too much fertilizer could be applied or nutrient deficiencies may not properly be addressed.

Table 1. Percentage of deficient P, K, and pHsalt soil test samples among uniformly (UR) and variably (VR) applied fields across southeast Missouri.

Field	% P Defecit	% K Defecit	% pHs <6.0	% pHs 6.0-6.7	% pHs 6.7+
UR1	0%	39%	86%	14%	0%
UR2	54%	65%	100%	0%	0%
UR3	6%	4%	99%	1%	0%
UR4	0%	10%	100%	0%	0%
UR5	14%	59%	24%	56%	19%
UR6	13%	84%	74%	26%	0%
UR7	0%	12%	18%	23%	59%
UR AVG	**13%**	**39%**	**71%**	**17%**	**11%**
VR1	0%	0%	42%	57%	1%
VR2	0%	1%	44%	54%	1%
VR3	2%	0%	98%	2%	0%
VR4	2%	6%	6%	72%	21%
VR5	0%	0%	33%	64%	4%
VR6	19%	39%	13%	74%	13%
VR7	24%	40%	59%	41%	0%
VR8	41%	35%	5%	78%	17%
VR9	2%	80%	10%	67%	23%
VR AVG	**10%**	**14%**	**35%**	**57%**	**9%**

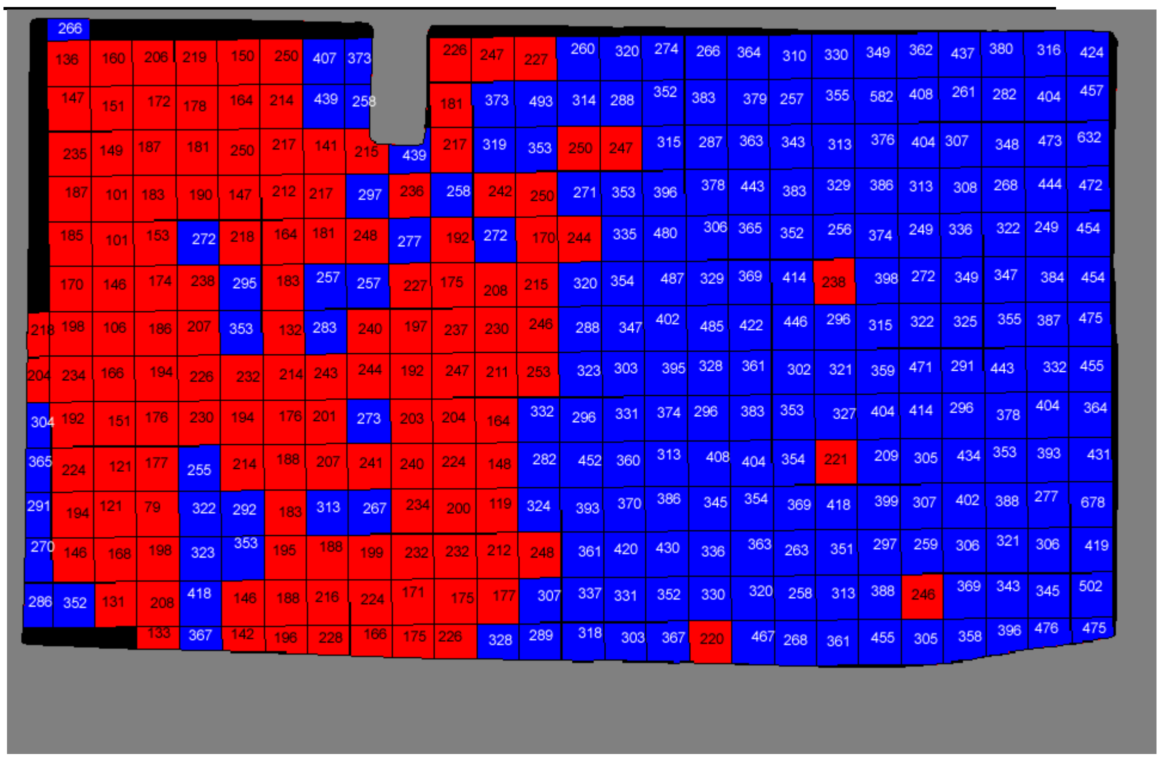


Figure 1. Extractable soil test K (lb/acre) in cotton field near Malden, MO showing high K (blue cells) in rows on east side compared to low K in rows on west side (red cells).

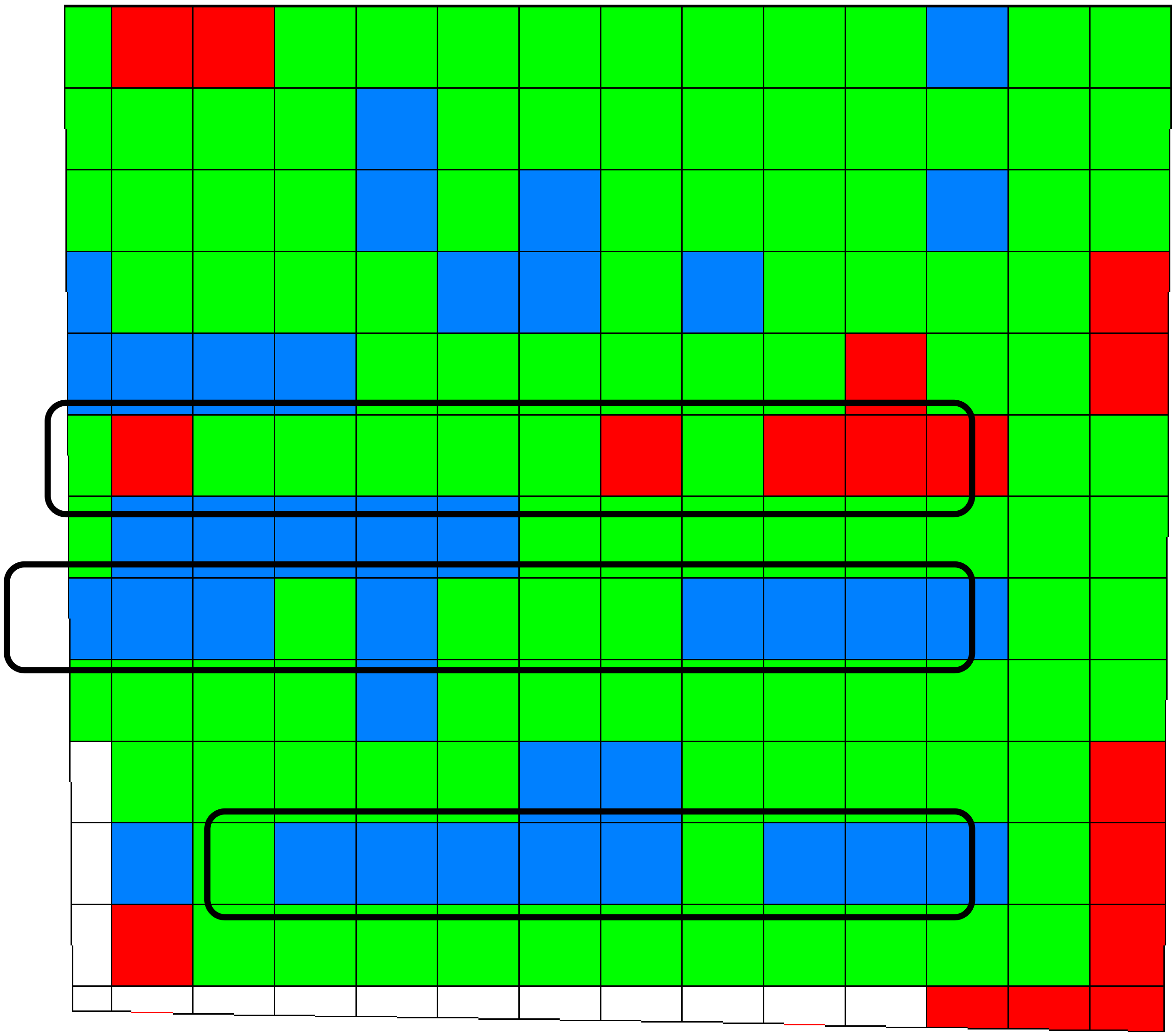


Figure 2. Soil test results of salt pH in a cotton field near Risco, MO showing streaks of high pH rows (blue cells), low pH rows (red cells), and optimum pH rows (green cells).

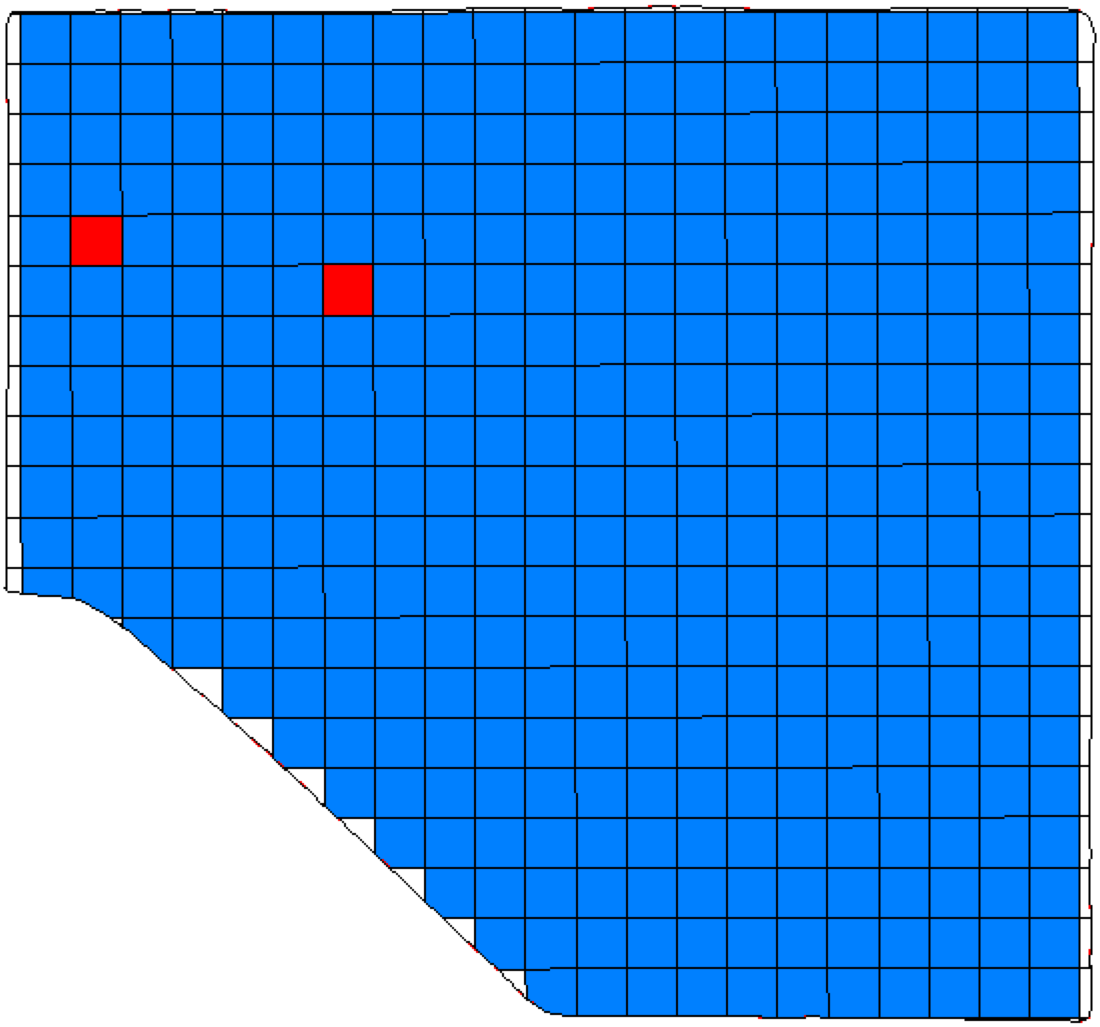


Figure 3. Extractable soil test K (lb/acre) in a variably applied cotton field near New Madrid, MO showing high K (blue cells) in rows on east side compared to low K in rows on west side (red cells).

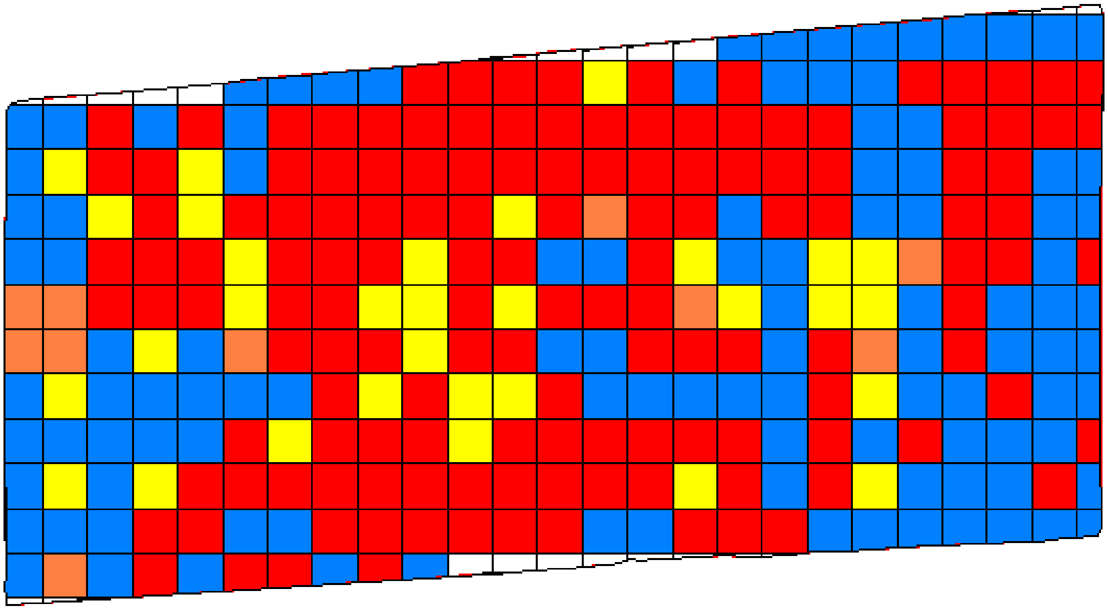


Figure 4. Extractable soil test P (lb/acre) and K (lb/ac) in uniformly applicated cotton field near Portageville, MO showing high P and K (blue cells) with low P (orange cells), low K (red cells) and combined low P and K (yellow cells).

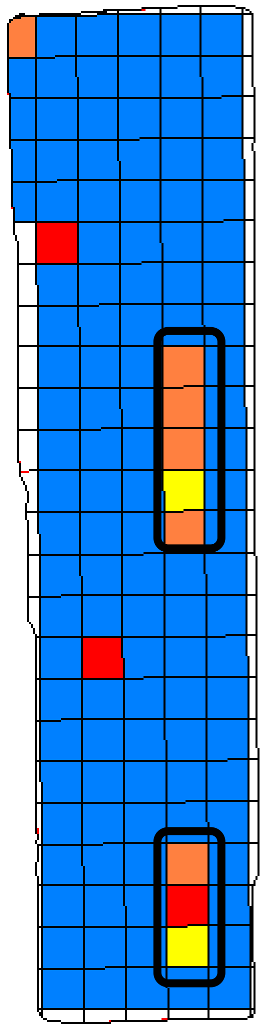


Figure 5. Extractable soil test P (lb/acre) and K (lb/ac) in uniformly applicated cotton field near Hayward, MO showing high P and K (blue cells) with low P (orange cells), low K (red cells) and combined low P and K (yellow cells). Black boxes indicate streaks of low fertility within rows through the field.

Title:

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

Investigator(s):

Kent Shannon, Todd Lorenz, Joni Harper, Peter Scharf, Brent Carpenter, Gene Schmitz, and Wendy Rapp

Objectives:

The objectives of this project are:

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

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

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

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

Procedures:

In the spring of 2010, three crop fields were chosen for the project. Fields ranged in size from 63 to 108 acres. The fields selected are in a corn-soybean rotation for the duration of the project with the possible addition of wheat depending on the year. All three fields have been grid soil sampled on a 1 acre grid. The three fields received fertility treatments in the fall of 2011 or the spring of 2012.

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

1) A control which receives no fertilizer.
2) Whole field management of P and K fertilizer.
3) Variable rate fertility management of P and K based on grid soil sampling using current University of Missouri fertilizer recommendations.
4) Variable rate fertility management of P and K based on grid soil sampling using proposed University of Missouri fertilizer recommendations using soil test critical values of 30 lbs/acre for P and 150 lbs/acre for K.

The four treatments were laid out to minimize any differences in soil type and terrain within the field. Each treatment was replicated at least 12 times in each of the three fields where treatments were applied in the fall of 2011 or the spring of 2012. Plots were 80’ x 300’ in size. The 80’ width was chosen because of the width of fertilizer application equipment and the 300’ length to assure quality as-applied fertilizer rate data and yield map data for analysis. Plot layout for the three fields implemented can be seen in Figure 1. Plots were embedded in a variable rate application map and applied with standard variable rate fertilizer application equipment. Plots were harvested with a yield mapping equipped combine collecting data using a one second time interval.

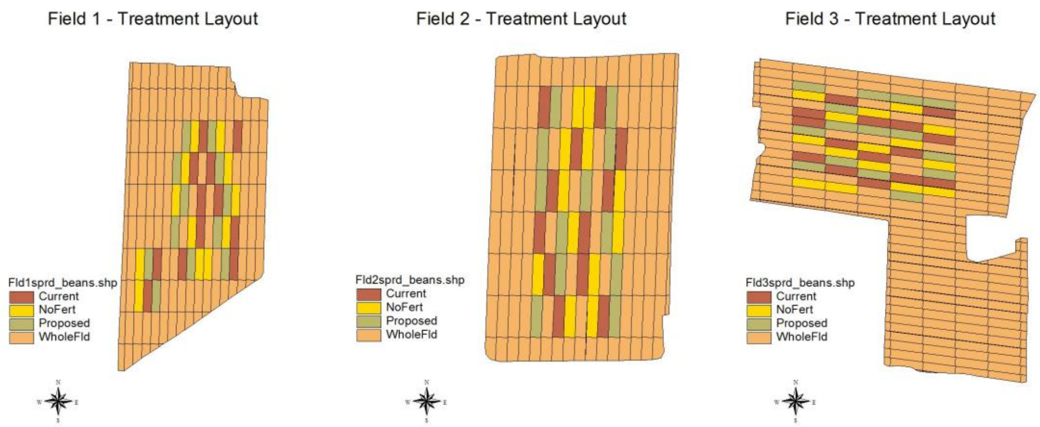


Figure 1. Plot Layout for Field 1, 2, and 3

<u>Results for 2012:</u>

With the effects of the drought during the growing season, yield results were collected and processed with some adjustments. Field 1 was adjusted with wheat being added to the crop rotation for the 2012 growing season. Fields 2 and 3 were planted to corn. Because of the drought, Field 2 was decided to be harvested for corn silage. With this change, 3 replications of hand-harvested silage yields were collected.

Plot yields ranged from 25.5 to 39.4 bu/acre with the mean of 30.6 bu/acre for Field 1. Field 2 had plot yield ranging from 5.8 to 12.5 tons/acre with a mean of 8.71 tons/acre. Field 3 had plot yield ranging from 5.7 to 91.7 bu/acre with a mean of 43.9 bu/acre. There were no significant yield differences between treatments at the 5% probability level in Fields 2 and 3. Though there were significant yield differences between replications in Field 3 which is believed to be contributed from the drought. Field 1 had a significant yield difference between both treatment and replication at the 5% probability level. It should be noted Field 1 was affected by hail damage directly before harvest so analysis main not give any understandable conclusions. A detailed summary of each field can be found in the following tables.

Wheat Yield Results for Field 1

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Treatment Mean
Treatment	---- bu/acre ----					
Current Recommendations	28.0	32.5	26.0	32.4	27.4	29.3
No Fertilizer	28.2	30.1	34.3	37.3	32.1	32.4
Proposed Recommendations	29.5	33.6	29.6	39.4	28.1	32.0
Whole Field	25.5	28.4	28.6	32.9	28.7	28.8
Block Mean	27.8	31.2	29.6	35.5	29.1	30.6
Was significant treatment differences (P=0.05) Was significant differences between replications (P=0.05)						LSD 3.0

Silage Yield Results for Field 2

	Rep 1	Rep 2	Rep 3	Treatment Mean
Treatment	---- tons/acre ----			
Current Recommendations	8.5	8.6	9.8	8.95
No Fertilizer	9.5	5.8	6.7	7.33
Proposed Recommendations	11.0	12.5	9.75	11.08
Whole Field	7.2	5.8	9.4	7.47
Block Mean	9.05	8.18	8.90	8.71
No significant treatment differences (P=0.05)				LSD 2.89

Corn Yield Results for Field 3

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Treatment Mean
Treatment	---- bu/acre ----					
Current Recommendations	91.7	10.3	76.4	9.8	74.3	52.5
No Fertilizer	58.8	14.2	32.4	7.9	87.3	40.1
Proposed Recommendations	86.2	19.7	5.7	12.5	82.0	41.2
Whole Field	84.1	36.6	11.4	9.8	50.4	40.8
Block Mean	80.2	16.0	31.5	10.7	81.4	43.9
No significant treatment differences (P=0.05) Was significant differences between replications (P=0.05)						LSD 23.9

Also included are tables summarizing fertilizer recommendations for P_2O_5 and K_2O for the three fields by treatment for the 2012 growing season. As in the past two years, it should be noted by using the proposed University of Missouri fertilizer recommendations decreased fertilizer requirements of both P_2O_5 and K_2O in all fields. These differences were considerably less than current University of Missouri recommendations. In Field 1, the P_2O_5 recommendation was 1762 lbs less and the K_2O recommendation was 2831 lbs less. Field 2 and 3 shows the same trend. The P_2O_5 recommendation was 6686 lbs less and the K_2O recommendation was 4147 lbs less for Field 2. In Field 3, the P_2O_5 recommendation was 2160 lbs less and the K_2O recommendation was 6802 lbs less.

Fertilizer Recommendations for P_2O_5 and K_2O by Treatment for Field 1 - Wheat

Treatment	Total Pounds of P_2O_5	Total Pounds of K_2O
Whole Field	1782	3564
Current Recommendations	2346	3662
Proposed Recommendations	584	831

Fertilizer Recommendations for P_2O_5 and K_2O by Treatment for Field 2 - Corn

Treatment	Total Pounds of P_2O_5	Total Pounds of K_2O
Whole Field	10766	5700
Current Recommendations	11099	6220
Proposed Recommendations	4920	2073

Fertilizer Recommendations for P_2O_5 and K_2O by Treatment for Field 3 - Corn

Treatment	Total Pounds of P_2O_5	Total Pounds of K_2O
Whole Field	2046	10742
Current Recommendations	2160	10505
Proposed Recommendations	0	3703

Objectives for 2013:

1. Applied fertilizer treatments to all fields in the fall of 2012.
2. All fields were soil sampled by plots in the fall of 2012 to further analyze effects of fertilizer treatments, yield removal of P and K, and any further drought effects
3. Conduct a field day in the summer of 2013 to discuss results from the past years.
4. Conduct final after harvest soil sampling of plots in fall of 2013.
5. Finalize all year’s results and publish a final report for the project.

BUDGET for 2012 and 2013

Item	Description	2012	2013
Soil Tests			
800 post harvest @ $10.00			4,000
Plot Specific Soil Tests – *40 post @$10.00*			200
Supplies	bags, markers, sign		125
Field Days		500	500
Publication		300	400
Travel		260	780
Sub total	by year	$1,060	$6,005
Support Salary	25% of the above total	$265	$1,501
Grant Total	by year total	$1,325	$7,506

Budget Request for 2013 $7,506

Nutrient Management for Biofuel Crop Production

Tim Reinbott, Manjula Nathan, Kelly Nelson, Robert Kremer

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

Objectives:

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

Procedures:

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

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

Fertilizer Treatments:

Fertilizer treatments for 2012 (Table 1) were determined using the University of Missouri recommendations from spring 2012 soil test measurements (Reinbott, et. al, 2012) or based upon crop removal from 2011harvest (Reinbott et al., 2012). Nutrient removal was calculated based upon grain, stover, and dry matter nutrient concentration and yield. Each plot was measured individually and fertilizer treatments were applied based upon individual measurements.

Results:

Soil Test Results:

After four years soil P and K content was higher across all treatments and locations when following either MU recommendations for a four year buildup or when based on nutrient removal (Tables 2 and 3) in most of the cropping systems. However, this wasn't the case for soil test K in Miscanthus and switchgrass systems. At both locations soil K content was greater in those treatments harvested for grain, (corn and soybean) following MU recommendations than either the control or when based entirely upon crop removal. However, in species harvested for biomass (mainly in Miscanthus and tall fescue), K content tended to be greater when based upon removal rather than buildup (Tables 2 and 3) with the exception of switchgrass. This was especially true with tall fescue at both locations and sweet sorghum at Greenley and Miscanthus at Bradford. Soil P content tended to be similar with either MU recommendation or when based upon removal with a few exceptions. At both locations tall fescue P content based upon removal was significantly higher than when compared to the MU recommended (buildup+maintenance). Miscanthus soil P content was also much greater under the removal treatment at Bradford. In each of these instances a large amount of biomass was produced during the summer. However, the large accumulation of P and K in the upper 6 inches of the soil profile with these species may indicate that a large amount of P and K that is being taken up by the biomass crops is most likely coming from the subsoil (Table 4 and 5) through their deep root systems.

After four years P and K levels at both locations in the MU recommendation treatments are either near or exceed the targeted levels of 45 lb P/acre and 290 lb K/acre for grain crops and 230 lb K/acre for forages. When using removal based upon MU recommended with four year build up treatment tended to be below target levels with the exception of Miscanthus and tall fescue.

Grain and Biomass Yield:

The 2012 growing season was extremely hot and dry with records and near records for heat being set almost daily from May until mid-August. From May-August the Bradford Research Center received only 5.18 inches of rainfall with 1.74 of those inches coming on August 31st and the Greenley Research Center received 8.44 inches of rainfall during that four month period with 2.49 of those coming on August 31st. This extra rainfall was enough to enhance biomass yields somewhat at Greenley over Bradford (Tables 6 and 7). As a consequence grain and biomass yields were severely reduced. The extremely dry top soil conditions in early and mid-May made it difficult getting adequate soybean stands due until light showers developed in early June. Sweet sorghum was planted after wheat harvest in mid-June at both locations but did not emerge at Bradford until late August when some rain finally fell. As a result of the severe drought there was little difference in grain or biomass yield between treatments at either location.

Nutrient Uptake:
Generally, P and K uptake mirrored that of soil levels with slightly higher P and K concentrations grains and biomass when soil levels were near targets (Tables 4 and 5). However, as documented in previous years there were large amounts of P and K removed with the annual biomass crops, tall fescue and sweet sorghum, with both fertility treatments and Miscanthus when following MU recommendations. Each of these species and fertility treatments could be categorized as “Luxury Consumption”. Large amounts of P and K were also removed following corn stover harvest across both fertility treatments (Table 4 and 5). Sweet sorghum and corn plants appear to be utilizing P and K from the upper soil profile based on that soil P and K values are not excessive whereas tall fescue and Miscanthus soil test values for P and K are extremely high in the upper soil profile indicating that they are mining deeper within the soil profile (Tables 2 and 3).

With the high cost of P and K fertilizer (over $0.5/lb) growers must consider the amount of removal when setting a price for the biomass even if the nutrients are coming from below the normal plow layer. It also seems that the four year build up maybe too quick resulting in luxury consumption by many of the biomass crops. As a result an 8-year P and K build up maybe more appropriate when utilizing annual and perennial crops for biofuels.

The high concentration of K in switch grass and Miscanthus is somewhat surprising regardless of soil fertility treatment. Typically, we would have thought that much of the K would have been already remobilized to the roots. These results show that it is important to recognize that when these two crops are harvested in fall for biofuel that a large amount of K will be exported.

Soil Quality Analysis
After four years of treatments and two years of establishment changes in soil quality are starting to become evident (Table 8). Total C is slightly higher at Bradford in the biomass crops than the corn and soybean treatments. Whereas, total C is the Miscanthus plots is much higher than any other crops at Bradford. At Greenley there was significantly more soil total C and total N in the annual biomass crop treatments: tall fescue and sweet sorghum. It is surprising that at both locations total N was significantly lower in the switch grass treatment compared to the other biomass or grain crop treatments raising the question if switchgrass under N fertilized? When we began this study we thought that removing the corn stover would result in lower soil C and N but so far that is not the case since total C and N are very similar to the continuous corn without stover removal or a corn/soybean rotation. More specific soil properties such as aggregate stability and soil microbial activity will are still being determined will help evaluate treatment effects on soil quality.

Outreach and Extension Activities:
These plots are very unique to the University System and even to the United States. We were told that this is the only P and K study with Miscanthus in the US. We have utilized these plots at many field days, workshops, and specialty tours over the past three years. At the Greenley Center

these plots were used as a stop at the annual field day in August. These plots were also part of the Crop Injury and Diagnostic Clinic in 2010 and 2012. It has also been showcased at the "Integrating Bobwhite Quail Management in an Agricultural Setting" field day in 2011 and 2012. These plots also serve as an education tool for the NRCS, MDC, and FSA tours each year. Each year at both locations these plots are part of the tour route for visitors from across Missouri, USA, and the world. We have presented this data at the annual American Society of America meetings in 2010 and 2011 years and at the Missouri Natural Resources Conference in 2012.
We plan to write up the complete four years of data for journal publication in 2013. Once all of the data is summarized we will also work with CAFNR communications for a news article release.

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Table 1. Average fertility treatments based on soil test recommendations and crop removal at Bradford and Greenley in spring , 2012

Cropping Systems	Fertilizer	N lb/a	P_2O_5 lb/a	K_2O lb/a	N lb/a	P_2O_5 lb/a	K_2O lb/a
		---------	Bradford	---------	--------	Greenley	-------
Continuous Corn (Grain only)	0 P and K	220	0	0	220	0	0
	MU Recommend	220	140	120	220	45	110
	Removal	220	75	40	220	40	35
Continuous Corn (Grain + stover)	0 P and K	220	0	0	220	0	0
	MU Recommend	220	70	165	220	60	165
	Removal	220	135	120	220	100	165
Soybean/Corn Rotation-Corn in 2012	0 P and K	220	0	0	220	0	0
	MU Recommend	220	45	135	220	70	120
	Removal	220	30	50	220	45	80
Miscanthus	0 P and K	60	0	0	60	0	0
	MU Recommend	60	20	110	60	45	175
	Removal	60	50	160	60	20	95
Corn/Soybean Rotation-Soybean in 2012	0 P and K	0	0	0	0	0	0
	MU Recommend	0	40	180	0	70	185
	Removal	0	65	40	0	55	32
Wheat+ Sweet Sorghum	0 P and K	120	0	0	120	0	0
	MU Recommend	120	85	190	120	110	185
	Removal	120	40	80	120	60	280
Switchgrass	0 P and K	60	0	0	60	0	0
	MU Recommend	60	20	80	60	30	120
	Removal	60	35	60	60	25	70
Tall Fescue	0 P and K	120	0	0	120	0	0
	MU Recommend	120	30	100	120	110	185
	Removal	120	75	320	120	60	280

Table 2. Soil test characteristics at Bradford in Fall 2012

Cropping Systems	Fertilizer	OM %	CEC	pHs	P1 lb/acre	K lb/acre
Continuous Corn (Grain only)	0 P and K	2.48a	13.7a	5.7a	26c	154b
	Buildup	2.68a	12.6a	5.4b	56b	249a
	Removal	2.80a	13.3a	5.3b	71a	211a
Continuous Corn (Stover removed)	0 P and K	2.58a	13.0a	5.7a	30c	131b
	Buildup	2.58a	13.5a	5.5b	54b	256a
	Removal	2.70a	13.3a	5.5b	78a	211a
Corn/Soybean Rotation	0 P and K	2.63a	13.3a	5.9a	24b	124b
	Buildup	2.80a	14.1a	5.7a	50a	234a
	Removal	2.65a	14.1a	5.7a	42a	186a
Miscanthus	0 P and K	3.30b	11.5a	5.6a	50b	296a
	Buildup	3.63a	12.1a	5.7a	53b	379a
	Removal	3.98a	12.2a	5.5a	84a	494a
Soybean/Corn Rotation	0 P and K	2.55a	13.1a	5.4a	35a	140b
	Buildup	2.48a	13.5a	5.4a	44a	234a
	Removal	2.70a	12.8a	5.5a	35a	155b
Wheat+Sweet Sorghum	0 P and K	2.88a	14.0a	5.5a	30a	159a
	Buildup	2.60a	12.3a	5.6a	45a	180a
	Removal	2.65a	13.0a	5.7a	47a	188a
Switchgrass	0 P and K	3.15a	12.5a	5.8a	35a	153b
	Buildup	2.78b	13.0a	5.8a	35a	245a
	Removal	2.75b	12.4a	5.7a	38a	181b
Tall Fescue	0 P and K	2.88a	13.4a	5.6a	31b	130c
	Buildup	3.05a	13.6a	5.5a	40b	226b
	Removal	2.85a	13.6a	5.6a	55a	392a
Cropping Systems		**OM %**	**CEC**	**pHs**	**P1 lb/acre**	**K lb/acre**
Continuous Corn (Grain only)		2.65d	13.2a	5.4c	51b	204c
Continuous Corn (Stover removed)		2.62d	13.3a	5.6b	54b	199c
Corn/Soybean Rotation		2.69c	13.8a	5.7a	39d	181d
Miscanthus		3.63a	12.0b	5.6b	62a	390a
Soybean/Corn Rotation		2.58b	13.2a	5.4c	38d	177d
Sweet Sorghum		2.71c	13.1a	5.6b	41c	176d
Switchgrass		2.89b	12.6b	5.8a	36d	193c
Tall Fescue		2.93b	13.5a	5.6b	42c	249b
Pr>F		*0.001*	*0.004*	*0.001*	*0.001*	*0.001*
0 P and K		2.80a	13.1a	5.7a	32c	161b
Buildup		2.82a	13.1a	5.6b	47b	250a
Removal		2.88a	13.1a	5.6b	56a	252a
Pr>F		*0.408*	*0.995*	*0.021*	*0.001*	*0.001*

Table 3. Soil test characteristics at Greenley in Fall 2012

Cropping Systems	Fertilizer	OM %	CEC	pHs	P1 lb/acre	K lb/acre
Continuous Corn (Grain only)	0 P and K	3.53b	15.2a	5.5a	33b	191b
	Buildup	4.27a	15.4a	5.2a	107a	344a
	Removal	3.63b	13.9a	5.5a	76a	247a
Continuous Corn (Stover removed)	0 P and K	3.60a	15.4a	5.7a	46b	191b
	Buildup	3.70a	14.4a	5.8a	87a	275a
	Removal	3.53a	13.4a	5.8a	91a	315a
Corn/Soybean Rotation	0 P and K	3.63a	14.5a	5.6a	34b	208a
	Buildup	3.73a	13.9a	5.6a	67a	257a
	Removal	3.73a	13.7a	5.6a	84a	227a
Miscanthus	0 P and K	3.57a	14.1a	5.7a	17c	203a
	Buildup	3.60a	12.7a	5.5a	37a	294a
	Removal	3.67a	14.3a	5.9a	27b	223a
Soybean/Corn Rotation	0 P and K	3.03b	13.4a	5.5a	26b	156b
	Buildup	3.50a	15.0a	5.5a	72a	251a
	Removal	3.47a	13.8a	5.7a	60a	199b
Wheat+ Sweet Sorghum	0 P and K	4.03a	15.5a	5.5a	24b	158c
	Buildup	4.13a	14.9a	5.3a	87a	290b
	Removal	4.87a	14.9a	5.6a	98a	422a
Switchgrass	0 P and K	3.43a	15.6a	6.1a	33a	210a
	Buildup	3.40a	14.8a	5.5a	42a	296a
	Removal	3.27a	13.3a	5.7a	49a	234a
Tall Fescue	0 P and K	4.43a	13.3a	5.3a	19b	122b
	Buildup	3.80b	12.9a	5.4a	40b	183b
	Removal	4.33a	14.2a	5.2a	99a	320a

Cropping Systems	OM %	CEC	pHs	P1 lb/acre	K lb/acre
Continuous Corn (Grain only)	3.81b	14.8a	5.4e	72a	260b
Continuous Corn (Stover removed)	3.61c	14.4a	5.8a	75a	260b
Corn/Soybean Rotation	3.70b	14.0b	5.6c	62b	230c
Miscanthus	3.61c	13.7b	5.7b	27e	240c
Soybean/Corn Rotation	3.33d	14.1b	5.6c	53c	202d
Sweet Sorghum	4.34a	15.1a	5.5d	69a	290a
Switchgrass	3.37d	14.5a	5.8a	41d	247b
Tall Fescue	4.19a	13.5b	5.3f	53c	208d
Pr>F	*0.001*	*0.181*	*0.042*	*0.001*	*0.029*
0 P and K	3.66a	14.6a	5.6a	29b	180b
Buildup	3.77a	14.2a	5.5a	67a	274a
Removal	3.81a	13.9a	5.6a	73a	273a
Pr>F	*0.201*	*0.202*	*0.225*	*0.001*	*0.001*

Table 4. Grain and biomass nutrient concentration, and nutrient removal based on 2012 harvest grain, stover, and biomass at Bradford.

Cropping Systems	Fertilizer	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	0 P and K	1.56a	0.29a	0.39a	4.6a	3.2a
	Buildup	1.56a	0.30a	0.38a	6.7a	4.5a
	Removal	1.67a	0.31a	0.42a	5.5a	3.9a
Continuous Corn (Grain+Stover removed)	0 P and K	1.40a	0.21a	0.50a	15.5a	18.6b
	Buildup	1.38a	0.23a	0.57a	22.3a	28.3a
	Removal	1.51a	0.22a	0.50a	23.6a	28.2a
Corn/Soybean Rotation-soybean in 2012	0 P and K	6.33a	0.54a	1.59a	12.8a	19.7a
	Buildup	6.31a	0.54a	1.64a	15.9a	25.5a
	Removal	6.29a	0.52a	1.63a	17.7a	28.7a
Miscanthus	0 P and K	1.04a	0.15a	0.82ab	38.6a	117.0a
	Buildup	0.80a	0.15a	0.97a	36.6a	128.5a
	Removal	0.87a	0.12b	0.68b	34.1a	96.7a
Soybean/Corn Rotation-corn in 2012	0 P and K	1.64a	0.29a	0.38a	8.7a	5.8a
	Buildup	1.56a	0.28a	0.32b	10.1a	6.1a
	Removal	1.61a	0.30a	0.37a	11.7a	7.4a
Wheat only	0 P and K	1.70a	0.37a	0.47a	24.6a	16.2a
	Buildup	1.67a	0.37a	0.43b	27.3a	16.8a
	Removal	1.59a	0.36a	0.45ab	24.7a	16.3a
Switchgrass	0 P and K	0.62a	0.15a	0.36b	17.2a	21.7b
	Buildup	0.74a	0.14a	0.51a	17.5a	33.6a
	Removal	0.72a	0.15a	0.38ab	18.9a	25.5ab
Tall Fescue	0 P and K	2.08a	0.19b	1.53b	28.8a	120.0b
	Buildup	2.06a	0.23a	2.14a	31.7a	157.3ab
	Removal	2.15a	0.24a	2.28a	37.4a	189.5a

Cropping Systems	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	1.60c	0.30c	0.40ef	5.6d	3.9d
Continuous Corn (Stover removed)	1.43d	0.22d	0.52d	20.4c	25.0c
Corn/Soybean Rotation	6.31a	0.53a	1.62b	15.5c	24.6c
Miscanthus	0.90e	0.14e	0.82c	36.4a	114.1b
Soybean/Corn Rotation	1.60c	0.29c	0.36f	10.2d	6.5d
Wheat	1.65c	0.37b	0.45e	25.5b	16.4cd
Switchgrass	0.69f	0.15e	0.42ef	17.8c	26.9c
Tall Fescue	2.10b	0.22d	1.99a	32.7a	155.6a
Pr>F	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
0 P and K	2.04a	0.28a	0.75b	18.9a	40.3b
Buildup	2.01a	0.28a	0.87a	21.0a	50.1a
Removal	2.05a	0.28a	0.84a	21.7a	49.5a
Pr>F	*0.586*	*0.750*	*0.001*	*0.174*	*0.067*

Table 5. Grain and biomass nutrient concentration, and nutrient removal based on 2012 harvest grain, stover, and biomass at Greenley

Cropping Systems	Fertilizer	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	0 P and K	1.63a	0.28a	0.32a	14.4a	8.6a
	Buildup	1.64a	0.28a	0.38a	14.3a	9.9a
	Removal	1.65a	0.27a	0.31a	13.9a	8.4a
Continuous Corn (Grain+ Stover removed)	0 P and K	1.51a	0.28a	0.34a	41.2a	27.1a
	Buildup	1.47a	0.24b	0.41a	35.8a	33.5a
	Removal	1.36a	0.21c	0.32a	30.0a	24.0a
Corn/Soybean Rotation-soybean in 2012	0 P and K	6.75a	0.55a	1.62a	21.1a	32.9a
	Buildup	6.48b	0.55a	1.66a	22.7a	36.3a
	Removal	6.56b	0.58a	1.66a	19.0a	28.8a
Miscanthus	0 P and K	0.62a	0.08a	0.56b	23.7ab	91.1b
	Buildup	0.57a	0.09a	0.76a	31.9a	136.5a
	Removal	0.57a	0.09a	0.58b	20.4b	72.4b
Soybean/Corn Rotation-corn in 2012	0 P and K	1.64a	0.26a	0.30a	20.1a	12.3a
	Buildup	1.63a	0.28a	0.36a	19.3a	13.5a
	Removal	1.62a	0.27a	0.34a	17.2a	11.3a
Wheat+Sweet Sorghum	0 P and K	1.05a	0.16b	0.56b	59.4b	109.9b
	Buildup	1.12a	0.19a	0.92a	89.1a	228.1a
	Removal	1.30a	0.20a	1.10a	90.6a	264.0a
Switchgrass	0 P and K	0.67a	0.12ab	0.37b	30.1a	46.9b
	Buildup	0.66a	0.10b	0.61a	30.9a	95.0a
	Removal	0.74a	0.13a	0.60a	35.1a	80.6a
Tall Fescue	0 P and K	2.30a	0.19b	0.86b	37.7a	90.7b
	Buildup	2.07a	0.26a	2.40a	53.7a	262.3a
	Removal	2.38a	0.22b	2.25a	53.9a	284.1a

Cropping Systems	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	1.64c	0.28b	0.34f	14.2f	9.0e
Continuous Corn (Stover removed)	1.44d	0.24c	0.35f	35.7c	28.2de
Corn/Soybean Rotation	6.60a	0.56a	1.65b	20.9de	32.7d
Miscanthus	0.59f	0.09g	0.63d	25.3d	100.0b
Soybean/Corn Rotation	1.63c	0.27b	0.33f	18.9ef	12.3de
Wheat	1.16e	0.18e	0.86c	79.7a	200.7a
Switchgrass	0.69f	0.12f	0.53e	32.0c	74.1c
Tall Fescue	2.25b	0.22d	1.84a	48.4b	212.4a
Pr>F	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
0 P and K	2.02a	0.24b	0.62b	31.0b	52.4b
Buildup	1.95a	0.25a	0.94a	37.2a	101.9a
Removal	2.02a	0.25a	0.90a	35.0a	96.7a
Pr>F	*0.167*	*0.057*	*0.001*	*0.003*	*0.001*

Table 6. Grain yield at the Greenley Research Center and Bradford Research Center, Missouri in 2012

Cropping Systems	Fertilizer	GrainYield bu/acre	Means bu/acre	Grain Yield bu/acre	Means bu/acre
		Greenley		Bradford	
Continuous Corn (Grain only)	0 P and K	40.2a	40.0b	12.2a	14.5c
	Buildup	40.0a		17.4a	
	Removal	39.8a		13.8a	
Continuous Corn (Stover removed)	0 P and K	58.2a	57.4a	13.5a	15.8c
	Buildup	63.7a		18.3a	
	Removal	50.3a		15.6a	
Corn/Soybean Rotation-soybean in 2012	0 P and K	27.9a	27.4c	17.2a	21.1b
	Buildup	30.3a		21.5a	
	Removal	24.0a		24.7a	
Soybean/Corn Rotation-corn in 2012	0 P and K	61.1a	54.5a	23.4a	27.5b
	Buildup	52.8a		28.4a	
	Removal	49.5a		30.6a	
Wheat	0 P and K	31.1a	30.8bc	48.3a	50.7a
	Buildup	31.6a		53.3a	
	Removal	29.8a		50.3a	

Table 7. Biomass yield at the Greenley Research Center and Bradford Research Center, Missouri in 2012

Cropping Systems	Fertilizer	Biomass Yield tons/acre	Means tons/acre	Biomass Yield tons/acre	Means tons/acre
		Greenley		Bradford	
Continuous Corn (Stover removed)	0 P and K	1.6a	1.6d	1.2a	1.6c
	Buildup	1.5a		1.6a	
	Removal	1.7a		1.9a	
Miscanthus	0 P and K	6.5a	6.3b	5.7a	5.8a
	Buildup	7.5a		5.5a	
	Removal	4.9a		6.2a	
Sweet Sorghum	0 P and K	7.3b	8.5a		
	Buildup	9.2a			
	Removal	9.0a			
Switchgrass	0 P and K	5.3a	6.0bc	2.5a	2.7b
	Buildup	6.6a		2.7a	
	Removal	6.0a		2.9a	
Tall Fescue	0 P and K	4.3a	4.7c	3.3a	3.2b
	Buildup	4.5a		3.0a	
	Removal	5.3a		3.4a	

Table 8. Total organic carbon, total nitrogen and C:N ratios for bio-fuel cropping systems, Fall 2012

Cropping Systems	TC $g\ kg^{-1}$Soil	TN $g\ kg^{-1}$Soil	C:N	TC $g\ kg^{-1}$Soil	TN $g\ kg^{-1}$Soil	C:N
		Bradford			Greenley	
Continuous Corn (Grain only)	15.7d	1.73c	9.05d	22.0b	2.16b	10.18b
Continuous Corn (Stover removed)	15.5d	1.74c	8.89e	21.8b	2.19b	9.96c
Corn/Soybean Rotation	15.6d	1.69d	9.22d	21.9b	2.12c	10.31b
Miscanthus	22.1a	2.10a	10.54a	21.2b	2.03c	10.44b
Soybean/Corn Rotation	14.8d	1.69c	8.75e	20.2c	2.05c	9.84c
Wheat+Sweet Sorghum	16.2c	1.77b	9.15d	24.3a	2.25a	10.76a
Switchgrass	16.6c	1.69d	9.86b	19.4c	1.95d	9.97c
Tall Fescue	17.3b	1.81b	9.57c	24.4a	2.26a	10.78a
Pr>F	*0.001*	*0.001*	*0.001*	*0.001*	*0.006*	*0.001*
0 P and K	1.63b	1.75b	9.30a	21.5a	2.10a	10.23a
Buildup	1.67b	1.77b	9.41a	21.8a	2.11a	10.28a
Removal	1.71a	1.81a	9.42a	22.4a	2.16a	10.34a
Pr>F	*0.073*	*0.121*	*0.354*	*0.301*	*0.517*	*0.631*

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

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

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

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

Procedure: Soil samples were collected from fields at the Fisher Delta Center at Portageville, Rhodes Farm at Clarkton, Greenley Center at Novelty, and Missouri Rice Research Farm at Qulin, Missouri. Soybean and cotton was planted in small plots in fields with soil test levels in the low and medium ranges for potassium and manganese. Cotton was also planted at Clarkton to evaluate N quick tests. Fertilizer treatments for K , Mn, and N included a untreated check, recommended dry preplant fertilizer and several timings and sources of foliar fertilizer. Each treatment was replicated five times. Leaves and petioles from each soybean and cotton plot were collected. Samples were collected at V7, R1, and R1+ 1 week growth stages followed by foliar sprays of each nutrient on treatments using a CO_2 backpack sprayer. Plots were visually rated for leaf burn at 3, 7, and 14 days after foliar applications. Leaf and petiole samples were frozen in plastic bags until they could be processed. A garlic press was used to squeeze leaf and petiole sap. Cotton tissue nitrate-N was measured by Horiba® Cardy nitrate meter, Hach® Colorimeter, and Quant® Nitrate test Strips. Duplicate samples were oven dried and tested in the Delta Center Lab with a nitrate ion-selective electrode. A plot combine and cotton picker were used to mechanically harvest plots. Yield response to foliar spray will be correlated with leaf sap meter reading to determine best growth stages and leaf stems to sample.

Preliminary Results: A significant lint yield increase was found in cotton by applying KNO3 at the R1 + one week growth stage (Table 1). At Clarkton, significant leaf burn occurred with white soluble potash when applied more than once to flowering cotton. The white potash was applied dry this season to avoid solubility issues while spraying. Yields of soybean were significantly increased from two applications of ReNForce K after bloom. All yields from other K applications were not significantly different from untreated check plots for cotton and soybean. No significant soybean yield increases were found from Mn soil or foliar fertilizers at Novelty or Clarkton (Table 2). Soybean yields were reduced in Clarkton under three applications of chelated ETDA Mn, as well as one application of $MnSO_4$ with glyphosate. Leaves were burned at Novelty by applications of chelated EDTA Mn at R1 + one week. Soybeans at Clarkton were significantly burned by both chelated EDTA Mn and gluco Mn when combined with glyphosate. Although lint yield of cotton was numerically highest with 120 pounds N per acre, no N application was significantly higher than the untreated check (Table 3). This field had been used in winter legume cover crop research in the past and may have N released from organic matter during the year. We are currently in the process of making quick test measurements from frozen samples collected during the 2012 season and comparing the results to duplicate leaf and petiole samples test at the Delta Center Soil Lab (Figure 1).

Table 1. Soybean and cotton yield response to soil and foliar potassium treatments at Novelty, Qulin, and Clarkton, Missouri in 2012.

Trt	Fertililizer	Preplant	V7	R1	R1 + 1 wk	Novelty	Clarkton	Clarkton
						soybean		cotton
		----------------lb K20/a-----------------				--------bu/a----------		lb lint /a
Check			0	0	0	33 a†	25 b	863 bc
Soil	Potash	120	0	0	0	35 a	29 ab	1059 abc
Bdcst	Potash	0	0	0	60	33 a	27 ab	908 abc
Bdcst	White Sol Potash	0	19	19	19	35 a	25 b	1134 ab
Bdcst	White Sol Potash	0	0	19	19	35 a	25 b	824 bc
Bdcst	White Sol Potash	0	0	0	19	35 a	26 b	760 c
Foliar	KNO3	0	4.62	4.62	4.62	35 a	25 b	918 abc
Foliar	KNO3	0	0	4.62	4.62	34 a	24 b	1031 abc
Foliar	KNO3	0	0	0	4.62	33 a	28 ab	1213 a
Foliar	Re-NforceK	0	4.68	4.68	4.68	33 a	30 ab	1000 abc
Foliar	Re-NforceK	0	0	4.68	4.68	35 a	33 a	962 abc
Foliar	Re-NforceK	0	0	0	4.68	36 a	27 ab	936 abc

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

Table 2. Soybean yield response to soil and foliar manganese treatments at Novelty and Clarkton, Missouri in 2012.

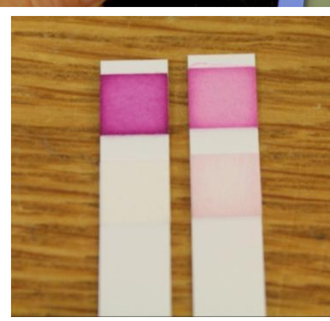
Trt	Fertililizer	Preplant	V7	R1	R1+1 wk	Novelty	Clarkton
			----------lb Mn/acre--------			-----bu/acre----	
Check		0	0	0	0	37 a†	52 a
Soil	Mn sulfate 6%	4	0	0	0	38 a	52 ab
Foliar	Chelated EDTA Mn	0	0.25	0.25	0.25	37 a	48 b
Foliar	Chelated EDTA Mn	0	0	0.25	0.25	37 a	53 a
Foliar	Chelated EDTA Mn	0	0	0.5	0	37 a	50 ab
Foliar	Chelated EDTA Mn + glyphosate	0	0	0.5	0	37 a	49 ab
Foliar	Mn sulfate + glyphosate	0	0	0.5	0	37 a	48 b
Foliar	Gluco Mn + glyphosate	0	0	0.5	0	38 a	48 ab
Foliar	glyphosate alone	0	0	0.5	0	37 a	49 ab

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

Table 3. Cotton yield response to soil and foliar nitrogen treatments at Clarkton, Missouri in 2012.

Treatment	Fertilizer	Preplant	V12	First Blm	Blm +1 wk	Cotton
		-----------------lb N/acre----------------				lb lint/acre
Check	----	0	0	0	0	974 ab†
med N	soil	40	0	0	0	1099 ab
high N	soil	120	0	0	0	1145 a
low N foliar	Foliar KNO3	0	4.62	4.62	4.62	940 ab
low N foliar	Foliar KNO3	0	0	4.62	4.62	863 b
low N foliar	Foliar KNO3	0	0	0	4.62	989 ab
med N foliar	Am nitrate + foliar KNO3	40	4.62	4.62	4.62	1118 ab
med N foliar	Am nitrate + foliar KNO3	40	0	4.62	4.62	965 ab
med N foliar	Am nitrate + foliar KNO3	40	0	0	4.62	905 ab

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



Budget:

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

Fertilizing Summer-Annual Grasses for Forage Production

Robert L. Kallenbach

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

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

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

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

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

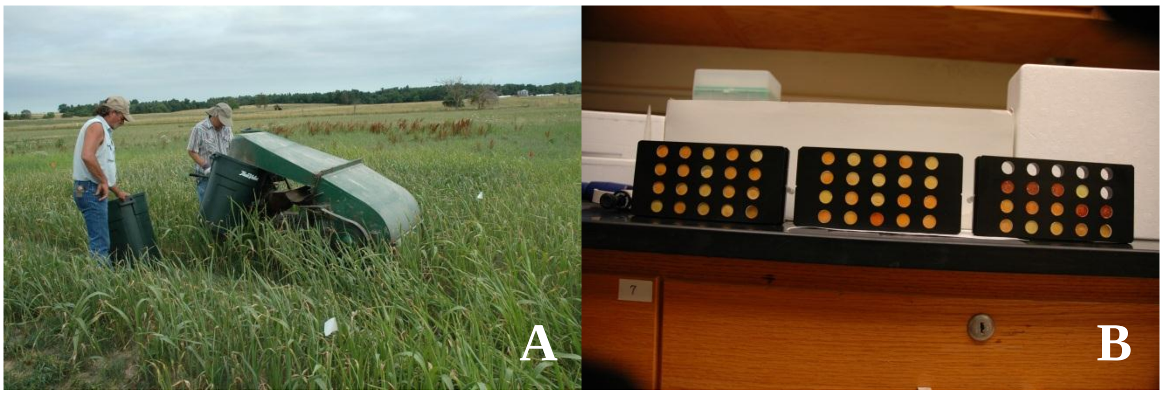
Procedures:
Treatments: This experiment has 32 treatments; four forage entries and eight N rates x timing applications. The four forage entries are 'Big-n-Quick' crabgrass, dwarf BMR sorghum x sudangrass, BMR sorghum-sudangrass and pearl millet. The eight nitrogen treatments are described in the table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

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

Cultural practices: Stands of each annual forage were established in early May at the Southwest Center, near Mt. Vernon, MO and at the Forage Systems Research Center near Linneus, MO. Both sites were planted using a Truax no-till drill. The seeding rates (PLS) for each species were as follows; crabgrass 4 lb/acre, sorghum-sudangrass 40 lb/acre, and pearl millet 30 lb/acre.
Design: Each treatment was replicated three times in a randomized complete block design in a split-block arrangement. Forage entries were main plots and nitrogen treatments sub-plots.

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

Figure 1. (A) Forage being harvested in field plots near Mt. Vernon, MO.
(B) Laboratory assay showing the variation in prussic acid toxicity potential of forage harvested from the plots. The brick red color indicates a large concentration of cyanide gas was released and forage was toxic.



Results:
Naturally, the extreme drought experienced across the Midwest in 2012 limited forage yields at both locations. The impact of the drought was most severe at Mt. Vernon, where the only forage species that showed a response to N fertilization was pearl millet (Table 2). The pearl millet control plots yielded poorly (almost 1,000 lb/acre less) compared to unfertilized plots of the other species. This unusual drought-related response likely led to the N yield response shown for pearl millet at Mt. Vernon.

Table 2. Annual yield of four species of summer annual grasses under eight different N fertilization regimes. Data were collected near Mt. Vernon, MO in the summer of 2012.

Annual N rate	No. of Applications	Crabgrass		Dwarf Sorg x sudan		BMR Sorg x sudan		Pearl Millet	
lb/acre	#	----------------------------		lb/acre		----------------------------			
0	-	4349	a	5164	a	4829	a	3436	c
50	1	3994	a	6012	a	4721	a	4364	b
100	1	4245	a	5196	a	4803	a	4942	ab
100	2	4562	a	6121	a	5270	a	4666	ab
150	1	4091	a	5833	a	5483	a	5040	ab
150	3	4075	a	6191	a	5418	a	4677	ab
300	2	4186	a	5719	a	5127	a	5071	a
300	3	4423	a	5950	a	5436	a	4949	ab

At Linneus MO, dry matter yields were greater than those at Mt. Vernon (Table 3). Crabgrass did not respond to N applications but the sorghum x sudangrass hybrids and the pearl millet did. As an aside, the dwarf sorghum-sudangrass was a victim of spotty germination and ended up with only 3 out of 8 N treatments that were able to be harvested. The preliminary data show that early applications of N were more favorable than late-summer applications. Dry matter yields were often no better if N was spread out over the summer in 2 or 3 applications. This result was likely influenced by the precipitation shortage in late summer; we expect the later N applications to stimulate more growth when summer precipitation is more evenly distributed.

Table 3. Annual yield of four species of summer annual grasses under eight different N fertilization regimes. Data were collected near Linneus, MO in the summer of 2012.

Annual N rate	No. of Applications	Crabgrass		Dwarf Sorg x sudan		BMR Sorg x sudan		Pearl Millet	
lb/acre	#	----------------------------		lb/acre		----------------------------			
0	-	6534	a	3981	b	4715	b	5811	d
50	1	8043	a	3700	b	4996	b	5792	d
100	1	7131	a			6855	a	6511	cd
100	2	7905	a			6957	a	6541	cd
150	1	7787	a	5058	a	5135	b	7331	ab
150	3	7631	a			7399	a	6809	bc
300	2	8349	a			7519	a	7610	a
300	3	6968	a			7703	a	7528	ab

While the yields for 2012 were below average for both sites, it does show how variable summer annual forage yields can be in Missouri and the need to conduct multi-year studies to develop sound agronomic recommendations.

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

Spray existing perennial forage in plot areas with glyphosate	3/15/13
No-till plant forage at the Southwest Center and at the Forage Systems Research Center	*Late April or Early May
Take plate meter readings to guide forage harvests	*Weekly from 1 June until frost.
Apply appropriate nitrogen fertilizer treatments (see table on page 1 for details)	*May, June, July
Harvest appropriate plots for forage yield and retain subsamples for forage quality, prussic acid, and nitrate analysis	*Variable based on plant growth - expect 3 to 5 harvests per yr.
Analyze latest results & report findings to Fertilizer/Ag Lime Advisory Council	*December
Incorporate results into soil testing reports, grazing school materials and forage conferences. Work with press on articles.	October 2013 through December 2014
Submit manuscript on this research to a peer-reviewed journal	March 2014

Year 3

Salary and Benefits

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

Operating Expenses

Fertilizer, bags, repair parts for harvester and other field supplies	$ 1,500
NIR charges for forage quality analysis (1280 samples @ $4 each)	$ 3,840
Wet chemistry for NIR calibration (90 samples @ $10.50 each)	$ 945
Prussic acid and nitrate analysis	$ 1,250
Travel to research locations (mileage, lodging, and meals for 8 trips/yr)	$ 1,600
Publication charges	$ 850
Total Operating Expenses	$ 9,985

Equipment

None requested	$ 0
Total Equipment	$ 0

Total Proposal Request for Year #3 **$22,657**

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

Manjula Nathan, Peter Scharf, David Dunn

Manjula Nathan, Associate Professor/Director, MU Soil and Plant Testing Laboratory
Division of Plant Sciences, University of Missouri
Peter Scharf, Professor, State Nutrient Management Specialist, Division of Plant Sciences, University of Missouri
David Dunn, Extension Associate/Manager, Delta Soil Testing Lab

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

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

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

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

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

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

Implementing recommendation changes has been limited by the ability to include the revisions in the MU Soil Testing Database Program that benefits thousands and thousands of growers who receive the fertilizer and lime recommendations from the MU soil testing labs each year. The soil test database program that we currently use is a client based system that was written in VB6. Within the code for this system is where all of our calculations and recommendations are stored. This has limited our ability to implement new calculations and recommendations. Our current program was also written for specific versions of Microsoft Office and this has limited our ability to generate new reports for our customers. One of our biggest challenges is that VB6 is no longer a supported system and every time there is an update to either operating system or Microsoft Office we have to find someone to fix our program. Therefore, the new soil test database program will be developed as a web-based system (independent of the operating systems) with enhancements to include the revisions in the future with ease.

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

Procedures:

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

Status Report:

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

	Oct-Dec 2011	Jan-Mar 2012	Apr-Jun 2012	Jul-Sep 2012	Oct-Dec 2012	Jan-Mar 2013	Apr-Jun 2013	Jul-Sep 2013
Tasks	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Qtr 5**	**Qtr 6**	**Qtr 7**	**Qtr 8**
Specifications	X	X						
Develop System	X	X	X	X				
System Testing					X	X	X	
Implementation							X	X
Data Migration							X	X
Training					X	X	X	X

Current Status

The Soil Lab rewrite (SoilLabV2) is behind schedule. At this point in time system testing should be under way; however, work is still progressing on the development of the first major portion of the program.

The database underlying the old SoilMain has been reviewed and has been mapped into a new fully relational database design. In addition to creating a relational database structure, the new database will support the collection of all of the various samples processed by the Soil Testing Lab. The relational database structure for the new system is very nearly completed. However, frequently a table in the old database is closely reviewed for data importation, significant alternate uses of the table appear and end up requiring modifications to the related tables in the new database structure, some of these modifications are fairly significant.

The major sections of SoilLabV2 include Data Management, Recommendations, Reporting, Accounting, and Administration. Progress has been made only in the Data Management portion of the programming. The old SoilMain program used hard coded forms for each of the different type[1] of data collected. This new system uses a single polymorphic[2] form that will redraw itself for each of the different data types. The implementation of this polymorphic form has taken longer than expected. The advantage is that additional forms can be added to the system easily. Current testing shows that it would take about an hour to add data collection forms Commercial Horticulture, Lawns and Gardens. The Field Crops is the primary form on which development of the polymorphic form has been tested.

There are three tasks that all data collection systems need to support, Adding, Editing and Deleting. The polymorphic form currently supports the adding of records for the Soil System. Validating editing is in progress. There are some known issues in the editing that need to be solved. Deletion is relatively simple. However, there are a couple of methods of deleting records, each with their own advantages. A determination as to exactly which method is to be used will have to be made in consultation with the Soil Testing Lab.

[1] Field Crops, Commercial Horticulture, Lawns and Gardens, Research and Plants

[2] having or occurring in several distinct forms

I have reviewed both the SoilMain code and Soil Test Interpretations and Recommendation Handbook. Based on the handbook the calculations of the individual recommendations do not appear to be too complicated. The code in SoilMain that performs the recommendations is extremely convoluted and includes statements which are inconsistent and unexpected. This, and the presence of over 200 recommendation related messages, indicates that the recommendation process is not as simple as is implied by the handbook. Because of the actual complexity of the recommendations portion of the SoilLabV2 program, the recommendations module will be initially hard coded in the manner of the code in the SoilMain program. This will allow the development of a working prototype that can be tested and used by the Soil Testing Lab. Additionally, and more significantly, the development of a hard coded recommendations engine will allow a thorough and complete understanding of the numerous specific details that will need to be handled by the recommendation engine.

There has been a lot of debate and differing opinions on how to handle the reporting aspect of SoilLabv2. I advocate an all-electronic system where the Soil Testing Lab does no physical printing. All distribution of soil reports should be done through the e-mail system. Should anyone desire a physical copy of the report, they can incur the costs themselves. At times, members of the Soil Testing Lab appear to want to maintain the status quo and continue to run a paper centric system.

It is clear from the complaints about the SoilMain's accounting system failing to bill all the samples run, the number of times I have been told about hand revision of records and bills, and the general convolution of the data tables that the porting of the accounting system to the new system will present a significant number of challenges. On-going discussion is needed to clarify the specifics of the billing system. For example, if the Soil Testing Lab receives a request not to process a sample, after tests on the sample have been run, should that sample be billed? What if only a portion of the requested tests have been performed when the request not to process arrives?

The administration portion of the new program should pose relatively little problem, up to the point where people start complaining about the user interface.

Discussion

Part of the reason for rewriting the SoilMain program is to bring the technology up to date. SoilMain is written in Visual Basic 6, a technology that was first introduced in 1998. Microsoft stopped supporting Visual Basic 6 in 2005. The move from Visual Basic 6 to VB.NET using the .NET Framework 4.0 brought the application to modern standards; however, the use of this new technology and other new technologies, retarded early development efforts. As familiarity with these technologies has increased, so has productivity.

A not inconsequential portion of the delay has been caused by inconsistencies between stated observation of how the SoilMain system (is thought to) works and the values in the database which clearly indicate something else is happening. These sorts of data disparities require extensive discussion with the Soil Testing Lab to determine not only how data has been processed, but also to determine how the system should proceed in the future.

The translation of the existing unstructured SoilMain data into the new highly structured SoilLabV2 database creates the need to review every field in every record in the entire SoilMain database[3]. This review identifies lots of what appear to be erroneous data. However, sometimes these out of normal records, are in fact, a work around for failing in SoilMain to handle some specific case. Determining how and when to correct the pseudo-erroneous data[4] to reflect what was intended, and not was recorded

Summary

[3] I don't personally look at each record, I run a series of queries to test for data consistency.

[4] Pseudo-erroneous data is data that only looks wrong.

While the development of the SoilLabv2 is behind the predicted phase, the development is gaining speed due to the increasing familiarity with technologies employed and familiarity with both the new and old database structures. The complexity of the data used by the Soil Testing Lab requires extensive testing to ensure that all necessary data is collected and migrated. A version of the SoilLabV2 should be on-line for testing by mid-December.

Budget:

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

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

Non-Profit
U.S. Postage
PAID
University of Missouri

Address Service Requested

Also Available on the Web at:

http://aes.missouri.edu/pfcs/research