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Soil Fertility and Fertilizers
Research Update
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Agronomy Department
College of Agriculture, Food and Natural Resources
University of Missouri

Thank You
Missouri Fertilizer and Ag Lime Distributors

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

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

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Agricultural Lime

The Influence of Liming Acid Soils on Plant Available Phosphorus, Magnesium,and Aluminum Levels in Tall Fescue

R.J. Miles and D.G. Blevins
E.J. Hamilton, Graduate Student

INTRODUCTION

This project was initiated in the late summer and early fall of 2004 with the selection of field plots at the Southwest Research Center (SWC) at Mt. Vernon and the Bradford Research and Extension Center (BREC) in Columbia. The soil resource at the SWC is a Gerald (fine, mesic, active, mesic Aeric Fragiaqualf) while the soil resource supporting the research plots at BREC is the Mexico (fine, smectitic, mesic Aeric Vertic Epiaqualf). Plots 10 ft by 25 ft with 10 ft borders are utilized at each location with each treatment being replicated 6 times. Limestone treatments which were applied in 2004 at each location were calcitic and dolomitic limestone applied at rates of 0X; 0.5X; 1X; and 2X relative to soil test recommendation. To accomplish the objectives of 2005, collared leaves were initially sampled in January for analysis of calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P), and aluminum (Al) content. Additionally, forage harvests were performed in May and August at each location.

ACCOMPLISHMENTS

Analysis of collared leaf samples was performed on a monthly basis with forage harvests in May and August. Forage yield data are illustrated in Figures 1 through 3. The May harvest at BREC (Figure 1) has an increasing yield with increasing limestone application from the control to the 1X application of both calcitic and dolomitic materials. Yields for both 2X applications tend to go down slightly relative to each 1X application. At SWC, the May yields (Figure 2) are slightly greater than the control but show little difference between the limestone materials or amount of each material applied. The August harvest data (Figure 3) illustrate a trend of slightly increasing forage yield from the control (0X) through the 1X applications for both liming materials with a slight decrease in yield with the 2X increments for both limestone species. There appears to be no consistent yield differences between the two limestone materials at the same application increment. It seems that the lack of definitive tall fescue yields between the two limestone materials and the various liming increments is because of the long-term influence of lime (3 to 5 years) on soil chemical properties. The 2005 data are the first full year of yield data therefore, long-term influences are likely to occur in later years.

Major accomplishments in analysis of nutrient content of the tall fescue have centered primarily on P content. Leaf P concentrations are illustrated in Figures 4 and 5 for plots at BREC and Figures 6 and 7 for plots at the SWC. Leaf P concentrations at BREC for January shows a general increase from the control to the 2X applications for both limestone materials with a range from slightly greater than 1.5 mg P/g for the control to slightly less than 2.0 mg P/g for both of the 2X application materials (Figure 4). Leaf P data in May for the BREC plots (Figure 5) follow a different trend in that the highest P concentration is in the control and few differences between the various application rates for both of the limestone materials.

Leaf P concentrations for the plots at the SWC show the same general trend in the April sampling period as the May period at BREC in that the control has the greatest P concentration with few P differences between the two liming materials and the various application increments (Figure 6). The May leaf P data at SWC (Figure 7) provide a different trend between the two limestone materials and their application increments. Within each application increment the dolomitic material provides the larger leaf P concentration. The occurrence of this trend at the SWC while not occurring at the BREC plots could be enhanced by the fact that the initial soil Mg content at the SWC is approximately one third (158 lbs/A versus 498 lbs/A) that of the soil resource at BREC. This trend may be a result of a response to Mg from the dolomite. Analysis of other mineral nutrients will be accomplished in the immediate future as the ICP unit in the Soil Testing Laboratory is now operational.

The overall lack of response of yield and leaf P concentration to limestone material and application increment could be explained by the fact that this is the first full year of data since the application of the limestone. Typically, the kinetics of the reaction of the limestone in soil is such that the comprehensive influence of limestone usually encompasses more than one year.

OBJECTIVES FOR 2006

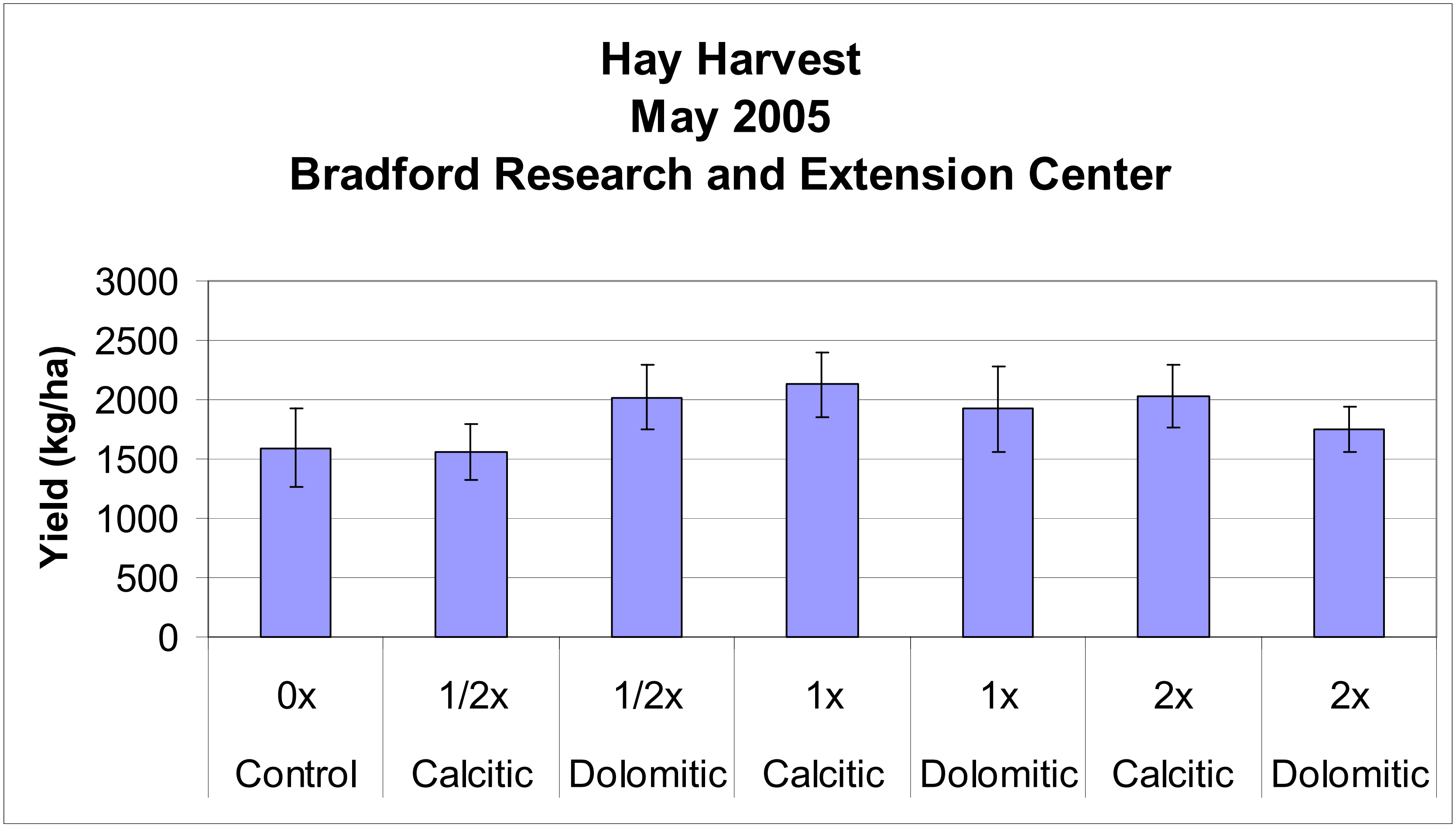
The objectives for 2006 parallel those for 2005. These objectives are to determine: 1.) the influence of calcitic and dolomitic aglime on the release of uptake of "fixed" phosphorus for use by tall fescue, and, 2.) the influence of these liming materials on the availability and uptake of magnesium and aluminum for tall fescue. The analysis of the Mg and Al will be performed on past and 2006 samples with the availability of the ICP. Additionally, the speciation of soil Al along with regular soil test parameters) pH, Bray PI and PII, exchangeable cations and Al will be performed. Also, May and fall harvests of tall fescue will be performed.

BUDGET

We request the same total for 2006 as in the original budget. We have not spent all of the 2005 allocation as we were waiting on the availability of the Soil Testing Laboratory ICP unit to perform a large array of elemental analysis. The left over portion of the 2005 will be utilized to perform all of the elemental analyses on the 2005 plant and soil samples. The requested 2006 budget will provide the 50% Graduate Research Assistant stipend and associated benefits as well as items originally budgeted for support for laboratory materials, travel, and part-time student labor.

ACKNOWLEDGEMENTS

We acknowledge the assistance of Matt Massie, Will McClain, Missy Remley, Maru Kering, David Kleinsorge, Matt Brown, Megan Perry, and Blair Mobley with the field and laboratory aspects of this project.



Hay Harvest
May 2005
Bradford Research and Extension Center
Yield (kg/ha)
3000
2500
2000
1500
1000
500
0
0x Control
1/2x Calcitic
1/2x Dolomitic
1x Calcitic
1x Dolomitic
2x Calcitic
2x Dolomitic

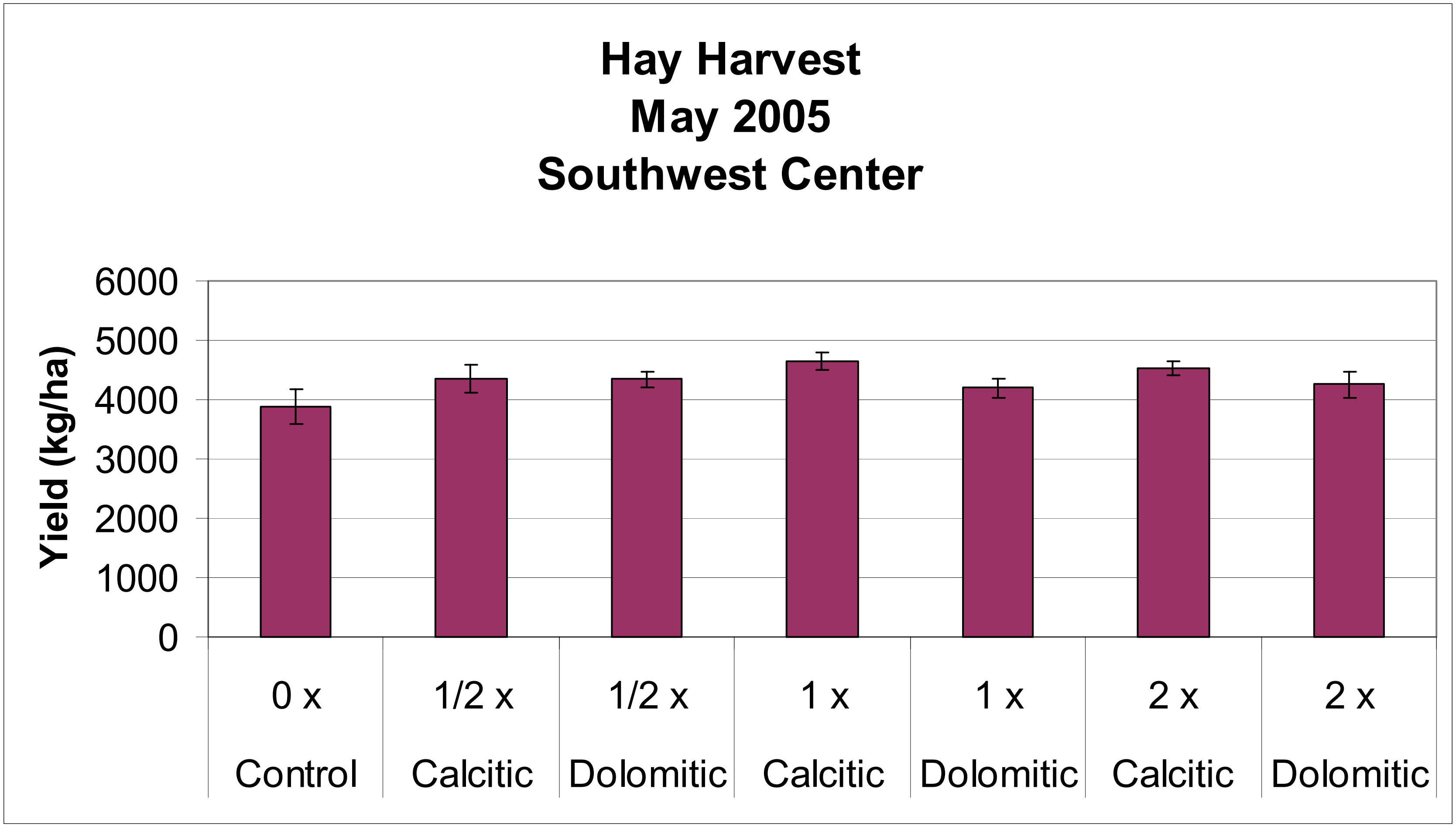


Figure 2. May 2005 tall fescue yields by liming treatment at SWC.

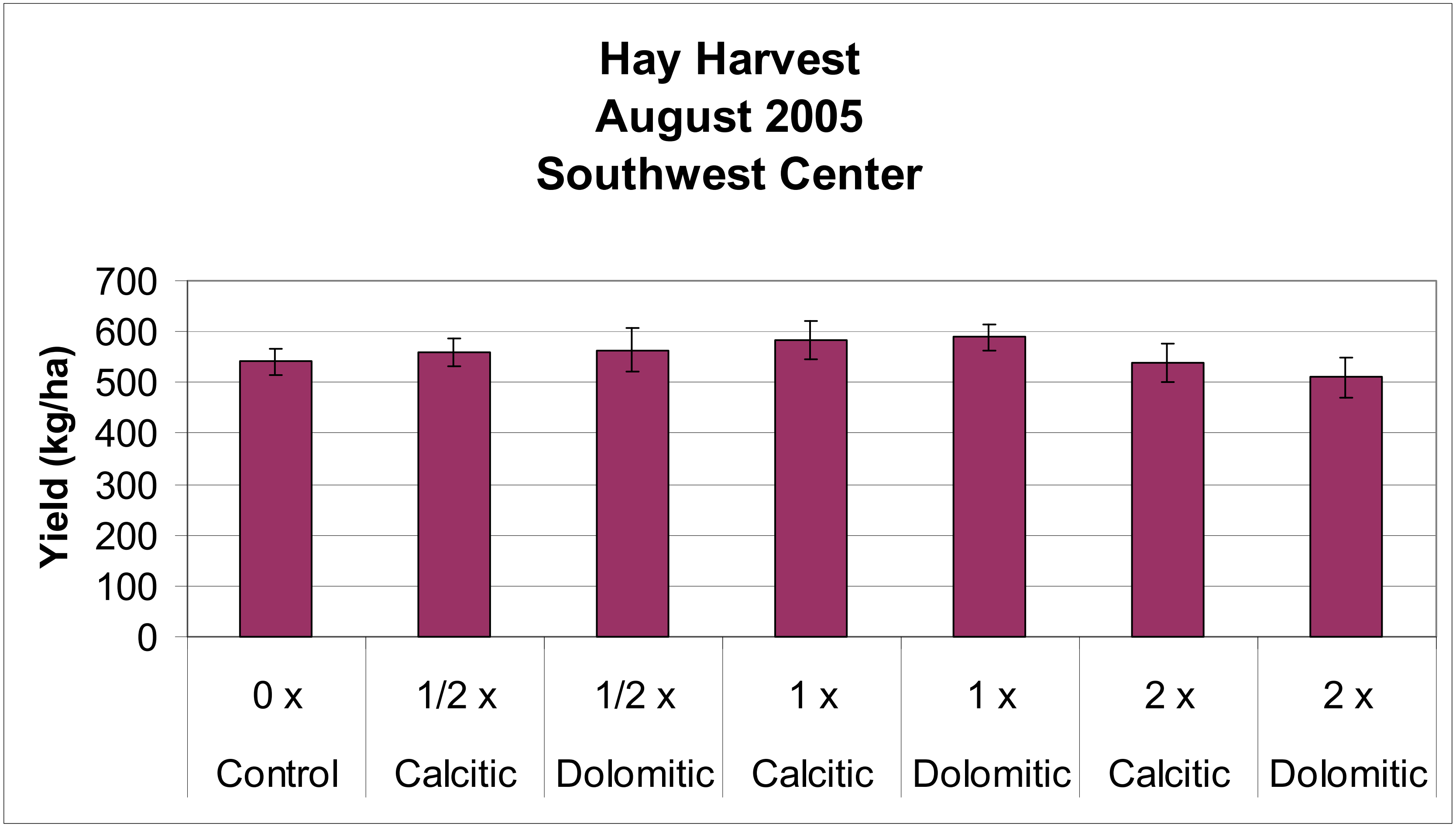


Figure 3. August 2005 tall fescue yields by liming treatment at SWC.

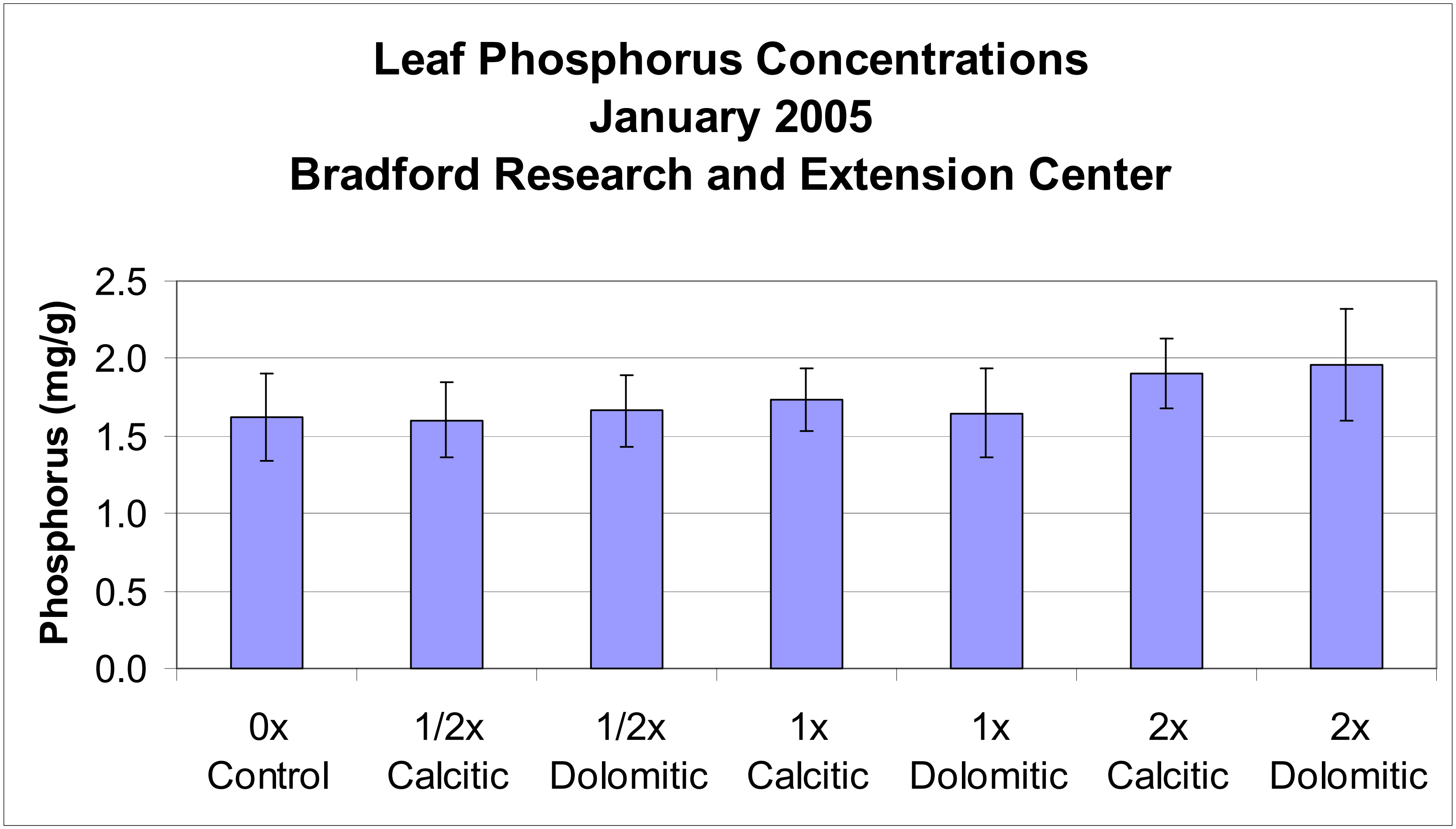


Figure 4. Leaf phosphorus concentrations in January 2005 for tall fescue by liming treatment at BREC.

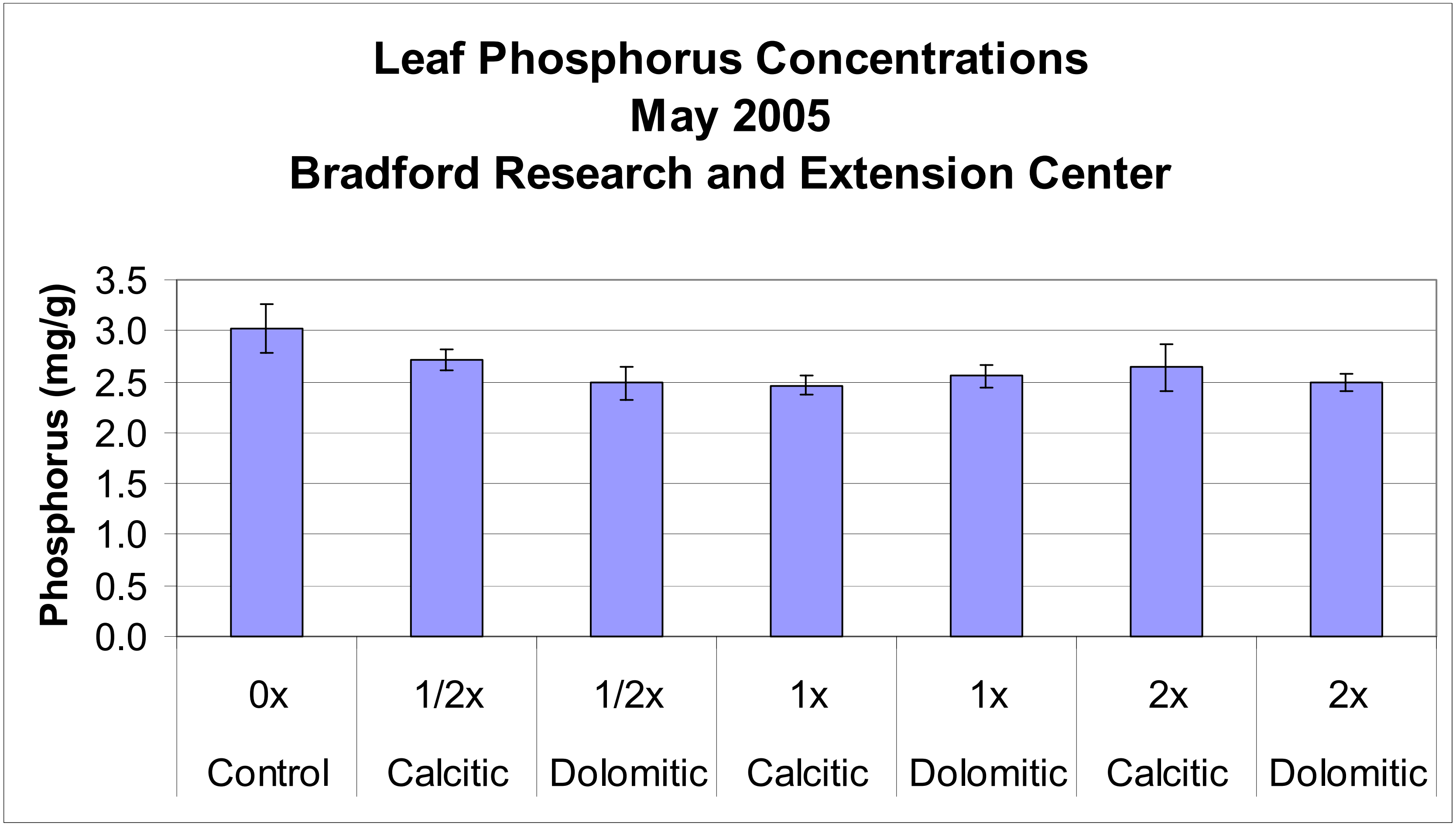


Figure 5. Leaf phosphorus concentrations May 2005 for tall fescue by liming treatment at BREC.

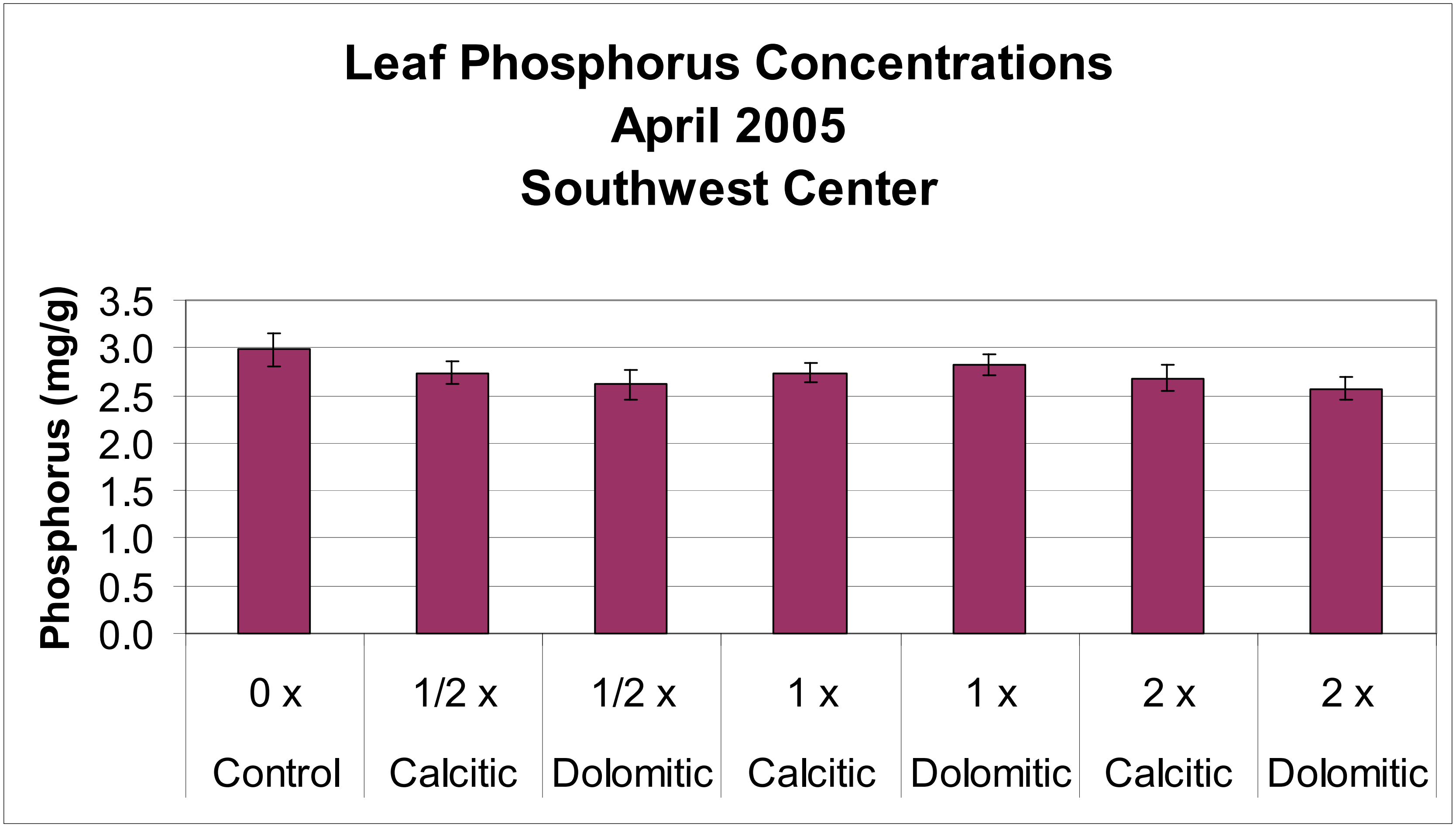


Figure 6. Leaf phosphorus concentrations April 2005 for tall fescue by liming treatment at SWC.

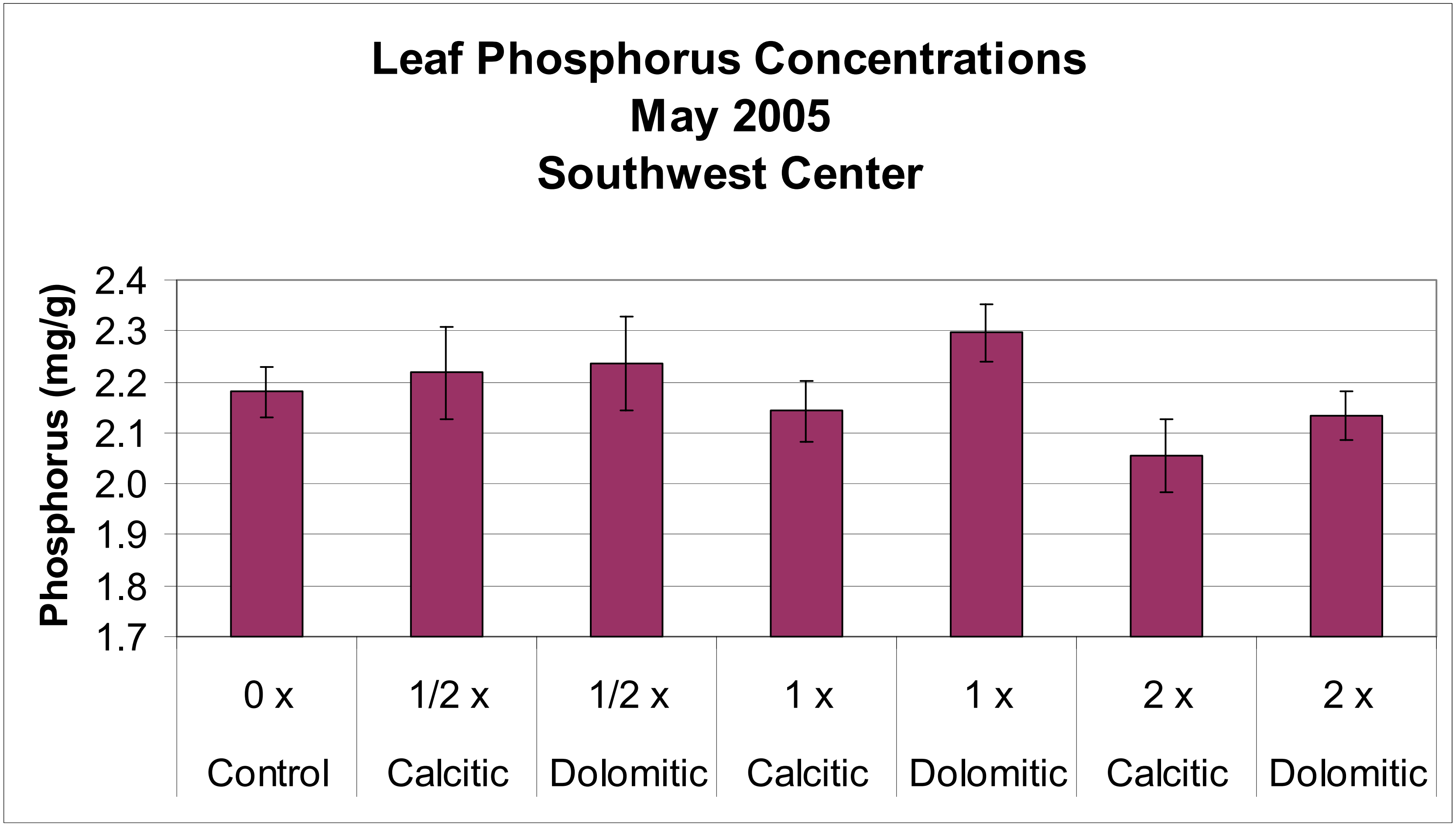


Figure 7. Leaf phosphorus May 2005 for tall fescue by liming treatment at SWC.

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

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

INTRODUCTION

This project was initiated during the summer of 2005 with the selection of field plots at the Southwest Research Center (SWC) at Mt. Vernon. An established tall fescue stand with a diverse plant community was selected for the study. The soil resource in the plot area is primarily the Gerald silt loam (fine, mixed, active, mesic Aeric Fragiaqualf) with some inclusions of the Creldon silt loam(fine, mixed mesic, Oxyaquic Fragiudalf). Soil test samples from the plot area had the following values:

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

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

The calcitic limestone used possessed an ENM value of 396 and the dolomitic limestone exhibited an ENM of 452. The soil limestone recommendation (1X) for the limestone materials was 3.67 T/A and 3.22 T/A for the calcitic and dolomitic materials, respectively.

ACCOMPLISHMENTS

In addition to selection and layout of the research plots, initial species composition assessment of the plot site as well as documentation of the species composition via photographs was accomplished.

The general initial species compositions are provided in Figures 1 and 2. The north half of the study area (Figure 1) was dominated by tall fescue at slightly greater than 55 % cover followed by sumac, unshaded litter, purple top, and eastern gammagrass. It should be noted that broomsedge comprised less than 5 percent of the coverage in the northern sector. The southern portion of the study plots was more diverse with a lesser dominance of tall fescue (slightly less than 30 percent) and much greater coverage of broomsedge followed by sumac, unshaded litter, purple top, and western panicgrass. This species diversity variance over the total plot area is reflective of what the PI's for this project have viewed in many low-level management tall fescue pastures in southern Missouri.

OBJECTIVES FOR 2006

The objective of this study for 2006 will be to ascertain the effect of aglime and P additions on species composition in a diverse tall fescue pasture with little management. In late winter 2006, a mixture of red clover and annual lespedeza will be overseeded on the plots. Species composition will be measured on each of the six replications of each of the treatments in May and August via a line transect method. In January, March, May, and November forage quality will be assessed by Near-Infared Analysis (NIR) for ADF and NDF. Samples will also be digested and analyzed for percent P, K, Ca, and Mg. Additionally, forage harvests will take place in May and August to compare yields with treatment. Sequential pictures of plant species coverage will be performed during the growing season to provide visual evidence of species composition with treatment.

BUDGET

We are requesting the $39,825 for year 2 (2006) as stated in the original proposal. Although we have not dedicated a graduate student to this project we are utilizing part-time student labor for much of the project along with graduate students on other liming and tall fescue research projects.

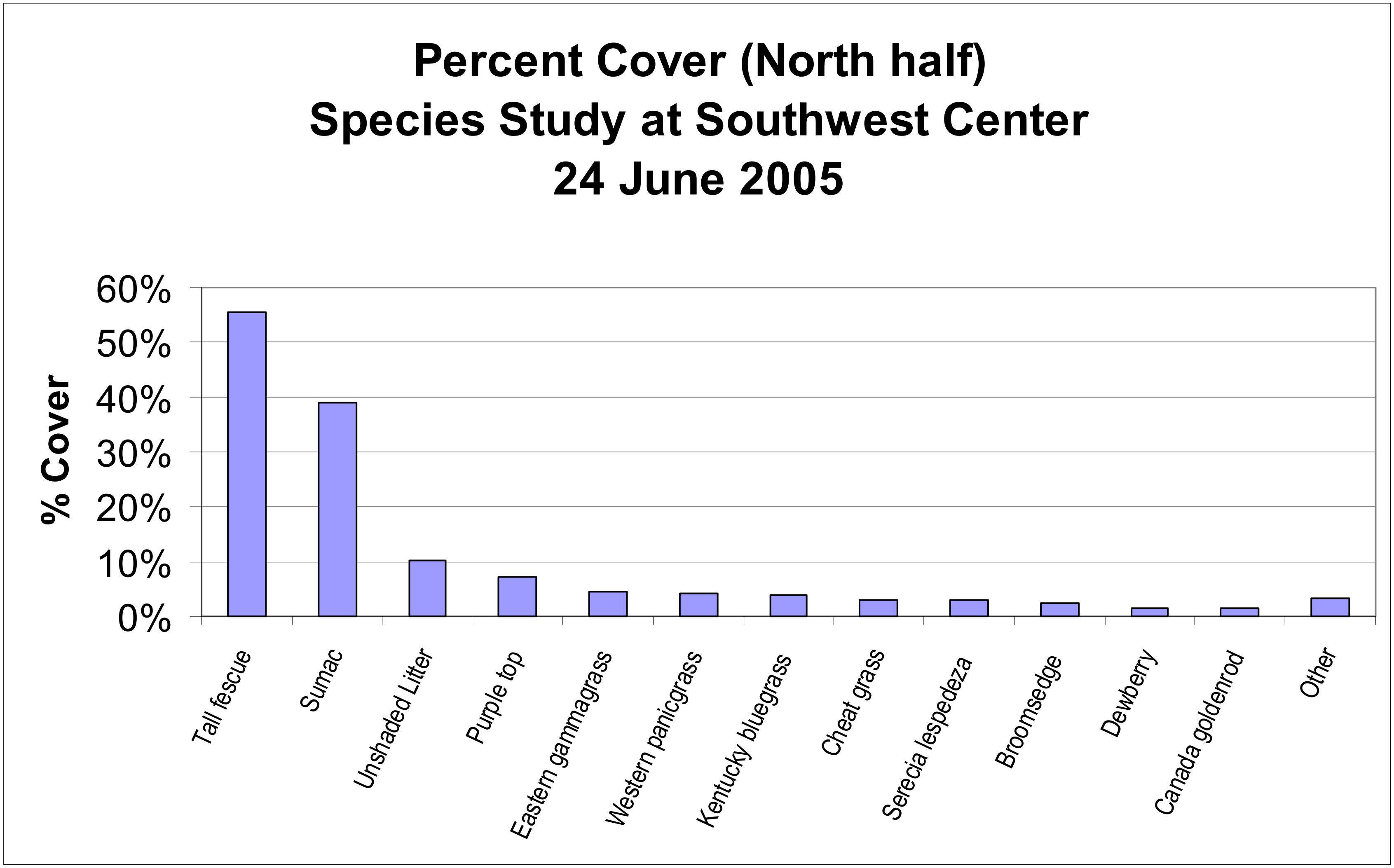


Figure 1. Percent cover of plant species on the north half of the ag-lime tall fescue species study in June 2005.

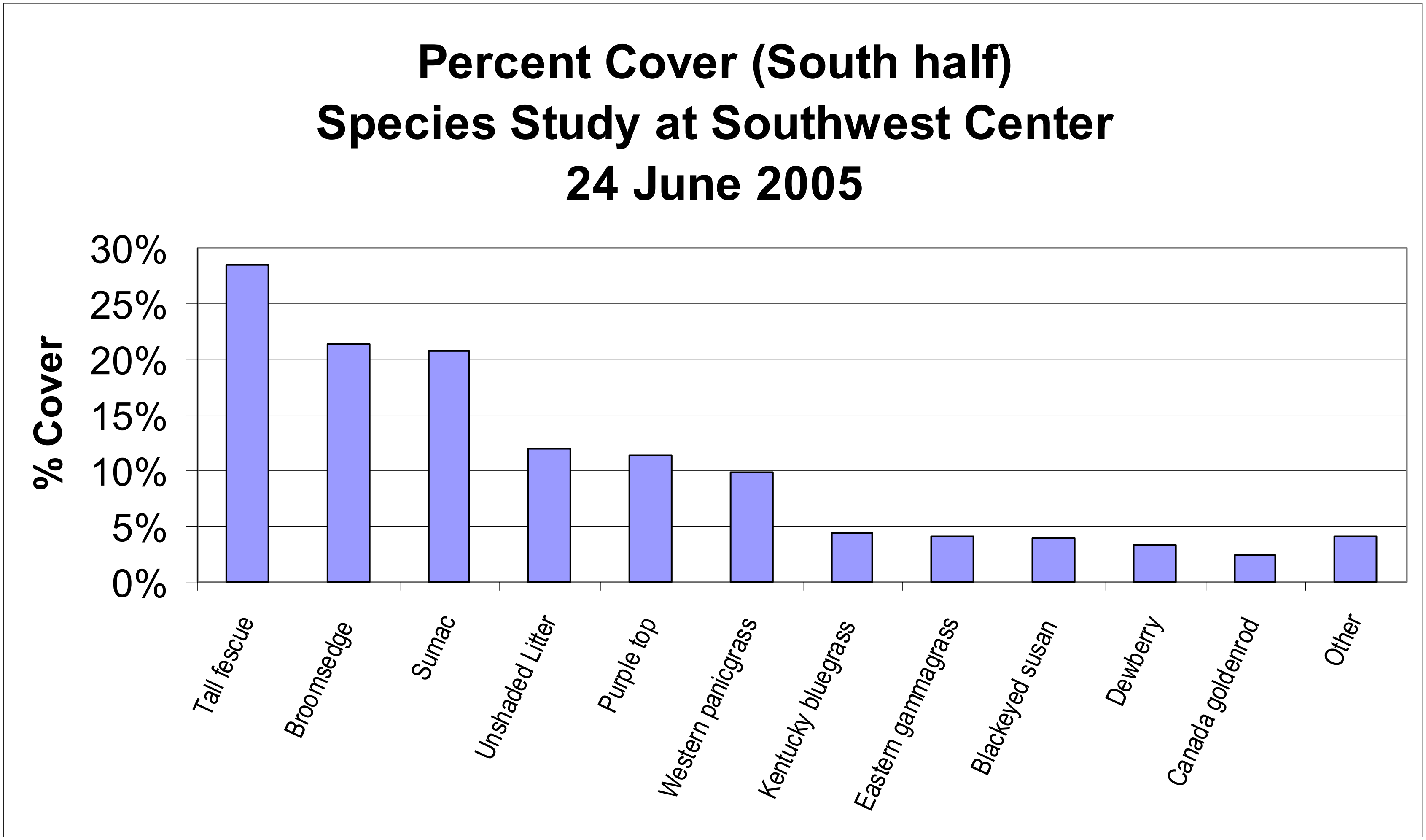


Figure 2. Percent cover of plant species on the south half of the ag-lime tall fescue species study in June 2005.

Pelletized Lime for Short-Term Treatment of Soil Acidity

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

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

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

A study was initiated to evaluate the general philosophy of using finely ground lime to provide a short-term, "quick fix" of soil acidity and compare corn and cotton yield response of pelletized lime to agricultural lime.

Accomplishments in Year 1

Elemental sulfur (2000 lb/acre) was applied to acidify a non-irrigated Tiptonville sandy loam soil at the Delta Research Center at Portageville in February. Soil samples collected in early May indicated average soil pH_{salt} 4.6 and 3.5 neutralizable acidity (NA). University of Missouri Lime recommendations showed 1209 ENM/acre was needed. Ag lime (514 ENM/ton) and pelletized lime (720 ENM/ton) were applied to 10' X 40' plots with four replications. Lime materials were incorporated with tillage before soybean planting. Each lime was evaluated at ¼ recommended ENM, ½ recommended ENM, ¾ recommended ENM, and 100% of the recommended ENM per acre (Table 1). Pelletized lime treatments were included with low rates dribbled over the seed furrow behind the planter press wheel and applied directly in the seed furrow with soybean seeds.

In Missouri soils, manganese (Mn) availability increases as soil pH decreases. Soybean leaf samples collected at R2 growth stage showed Mn was present at toxic levels in all lime treatments (Table 1). Levels greater than 200 ppm Mn in leaves are toxic in soybean plants. At the 100% MU recommendation rate, soybean plants grown in soil receiving agricultural lime had 374 ppm Mn and soybean receiving pelletized lime had 459 ppm Mn. Soybean yields were very low in all plots because of lack of rainfall and low soil pH. At 75 and 100% of MU recommended lime rates yields were generally higher with agricultural lime than with pelletized lime. Applying low rates of pelletized lime over or directly in the soybean seed furrow did not increase soybean yields.

Objectives for Year 2

Neither lime material had adequate time to neutralize soil acidity before soybean planting. We will plant the field in soybeans again in 2005 and monitor soil pH and Mn levels in plants. We also plan to evaluate ag and pelletized lime with corn.

Table 1. Effect of agricultural lime and pelletized lime treatments on R2 apex soybean trifoliate leaf tissue nitrogen, phosphorus, potassium and manganese contents at Portageville, MO in 2005 on a Tiptonville sandy loam with initial pH_{salt} 4.6 and 1209 ENM/acre University of Missouri Lime recommendation.

Trt	Lime	MU Rec	Material	N	P	K	Mn[1]
		% applied	per acre	---------------	% in leaves	--------	ppm in leaves
1	check	0	0	5.3	0.28	1.66	510
2	Ag lime[2]	100	2.3 Tons	3.1	0.32	1.71	374
3	Ag lime	75	1.7 Tons	4.5	0.27	1.77	343
4	Ag lime	50	1.2 Tons	4.5	0.35	1.63	386
5	Ag lime	25	0.6 Tons	4.4	0.24	1.48	400
6	Ag lime	12	0.3 Tons	5.5	0.32	1.55	482
7	Ag lime	6	0.1 Tons	4.4	0.32	1.77	533
8	Pell lime[3]	100	1.7 Tons	4.8	0.36	1.72	459
9	Pell lime	75	1.3 Tons	6.2	0.24	1.53	422
10	Pell lime	50	0.8 Tons	4.3	0.27	1.54	393
11	Pell lime	25	0.4 Tons	4.9	0.25	1.60	390
12	Pell lime	12	0.2 Tons	4.9	0.29	1.57	492
13	Pell lime	6	0.1 Tons	2.7	0.23	1.48	511
14	Infur Pell[4]	<1	4 lbs.	5.1	0.35	1.62	440
15	Infur Pell	<1	8 lbs.	4.9	0.34	1.52	389
16	Infur Pell	<1	12 lbs.	5.7	0.34	1.53	491
17	Infur Pell	<1	16 lbs.	3.5	0.32	1.42	452
18	Drib Pell[4]	<1	4 lbs.	4.8	0.36	1.50	512
19	Drib Pell	<1	8 lbs.	5.3	0.36	1.68	407
20	Drib Pell	<1	12 lbs.	5.3	0.39	1.65	427
21	Drib Pell	<1	16 lbs.	4.2	0.28	1.55	440

1 **Leaf manganese greater than 200 ppm is usually toxic to soybean plants.**
2 Agricultural lime tested 514 ENM per ton.
3 Pelletized lime teste 720 ENM per ton.
4 Pelletized lime was placed in seed furrow at planting with soybean seeds.
5 Pelletized lime was dribbled over seed furrow behind the planter press wheels.

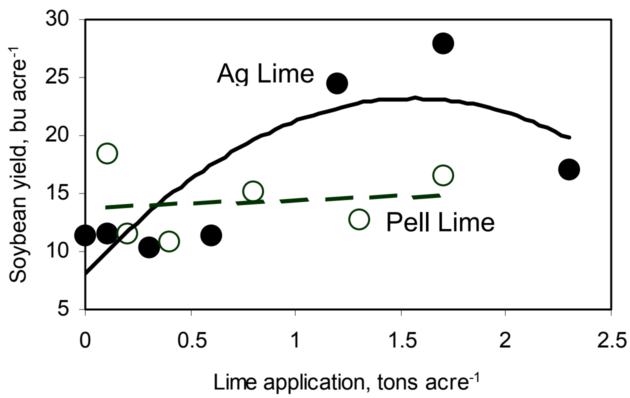


Figure 1. Soybean yields following broadcast lime treatments incorporated before planting at Portageville, MO in 2005 on a a Tiptonville sandy loam with initial pH_{salt} 4.6.

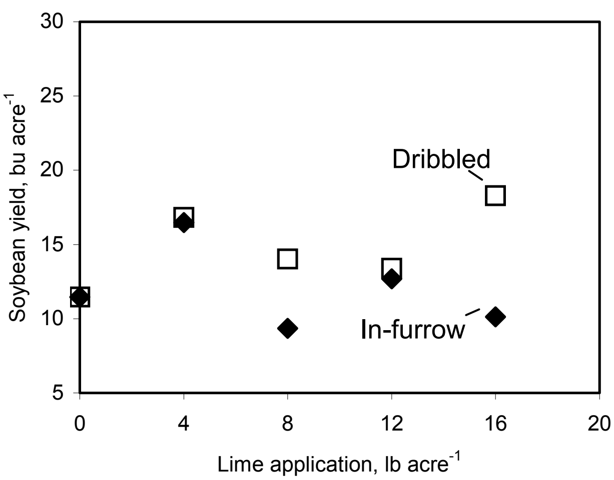


Figure 2. Soybean yields following low rate pelletized lime treatments incorporated before planting at Portageville, MO in 2005 on a a Tiptonville sandy loam with initial pH_{salt} 4.6. Dribbled treatments received pelletized lime behind the planter press wheels. In-furrow treatments received pelletized lime with soybean seeds in the furrow.

Proposed budget:

Expenses	2005	2006	2007
Res. Specialist salary (0.3)	$8,400	$8,736	$9,085
Fringe benefits	$2,100	$2,184	$2,271
Supplies	$1,500	$1,560	$1,622
Travel	$1,000	$1,040	$1,082
Total	$13,000	$13,520	$14,061

Nitrogen Management

Final Reports

Determining the Correct Nitrogen Rate for Cotton Following Soybeans

Bobby Phipps, Gene Stevens, and David Dunn
University of Missouri-Delta Center

Objectives

1) Determine the optimum rate of nitrogen fertilization for cotton in a cotton/soybean rotation.
2) Evaluate midseason plant N status monitoring methods.

Introduction

Cotton requires supplemental nitrogen fertilization to achieve maximum lint yields. Proper N rates are critical as lower rates may limit yields while higher rates promote excessive vegetative growth. This delays the harvest and reduces fiber quality. Higher than optimal N rates may also contribute to increased disease and insect pressure. Optimizing N rates also reduces environmental impacts by limiting the potential for run off or leaching. Studies at the University of Missouri-Delta Center have shown that our current soil test recommendations are valid for continuous cotton cultivation. University of Missouri soil test recommendations suggest lowering the N rate by 20-30 lbs/a N following soybeans. Cotton producers have raised concerns about the relevance of our N recommendations for cotton following soybeans.

Research methods

This evaluation was conducted on a silt loam and a clay soil at the University of Missouri-Delta Center. The following 5 Nitrogen treatments were evaluated:

1. 0 lbs N/a	
2. Soil test recommended rate minus 50 lbs. N/a	60 lbs total N
3. Soil test recommended rate minus 25 lbs. N/a	85 lbs total N
4. Soil test recommended rate	110 lbs total N
5. Soil test recommended rate plus 25 lbs. N/a	135 lbs total N

The soil test recommendation for nitrogen at both locations was 110 lbs N/a. With soybeans as the previous crop this rate could be reduced by 25 lbs to 85 lbs N/a. A pre-plant rate of 60 lbs N/a was applied to all plots except the untreated check using a four row liquid applicator. At pinhead square the remainder of the nitrogen, as ammonium nitrate, was applied by hand. Beginning at first square plant N status was monitored weekly using a Chlorophyll meter, Cardy meter and by petiole nitrate analysis. Petioles were randomly collected from each plot. For both sampling times 25 to 30 petioles and associated leaves were collected from the center two rows of each plot. These samples represent the fourth node below the uppermost fully expanded leaf. Prior to each sampling the Cardy and SPAD-502 meters were calibrated according to the manufactures instructions. SPAD-502 meter readings were conducted on each collected leaf. The petioles were then separated from the leaves and Cardy meter determinations were conducted on sap extracted from the lower one half of the petioles using a garlic press. The remaining half was dried and ground. The resulting sample was analyzed for NO_3 using an Aluminum sulfate extraction and an Ion Selective Electrode determination.

Each plot was harvested and the lint yield measured. The cotton produced was ginned and the gin turnout calculated. The lint was then analyzed for the fiber quality properties: micronaire, length, strength, uniformity, color grade and trash percentage. These fiber quality properties were determined at the International Textile Research Center in Lubbock Texas using high volume instrument analysis.

Statistical analyses of the data were preformed with SAS (1990) using General Linear Modeling procedures. Fisher's Protected Least Significant Difference (LSD) was calculated at the 0.05 probability level for making treatment mean comparisons. Regression and correlation analysis were performed in accordance with procedures outlined by the SAS Institute (SAS, 1997). Returns to producers were calculated by using Commodity Credit Corporation Cotton loan rates for each crop year's White Upland Cotton warehoused in

Missouri. Discounts or premiums for fiber properties were applied to the base rate. Input costs for nitrogen were computed at a rate of $0.24 per lbs of N and an application cost of $5.00 per acre. Returns for cottonseed were calculated using a price of $110.00 per ton.

Project Accomplishments:

Data collected during this study is presented as tables 1, 2, 3, 4, 5, 6, & 7, and Figure 1. The clay soil and the silt-loam sites responded differently to N fertilization in each of the tree years. Nitrogen fertilization significantly increased lint yields at the clay soil site each year (Table 1). Yields for the recommended rate and the higher rate were statistically equivalent. This supports the current University of Missouri soil test recommendations. However the highest rate of N produced the numerically highest yields each year. Based on this data a reduction of N rates following soybeans on clay soils would not be warranted. There was no significant response to N fertilization at the silt-loam site during any of the three years. This would indicate that the previous soybean crop had supplied sufficient N to maximize cotton lint production. Based on this data a reduction of 25 lbs N/a for cotton following soybeans on a silt-loam soil would be warranted. In each year there were significant differences in gin turn out %. On the clay soil there was no consistent trend. However at the silt-loam site increasing N rates decreased gin turnout % two of the three years studied.

Cotton fiber data collected during this study is presented in Tables 2 & 3. At the clay site (Table 2) the fiber property Micronaire was significantly increase by N applications each of the three years. Fiber length was significantly increased two of the three years. Fiber strength was significantly increased with increasing N rate one of the three years. During one of the other two years (2005) there was a numerical trend to increasing fiber strength with higher N rates. Fiber uniformity was significantly increased two of the three years. These differences in fiber properties did lead to significant differences in the lint price available to producers in all three years (Table 5). These differences were not correlated to N rate. At the silt-loam site (Table 3) Micronaire was significantly affected by N rate in 2003 only; however there was no consistent trend to the data. Fiber length was significantly effected by N rate in 2003 & 2005. In 2003 there was no consistent trend to the data, but in 2005 N fertilization produced generally longer fibers. Both fiber strength and uniformity were not significantly affected by N in any of the three years.

At the clay site net returns to producers indicate that N fertilization was profitable (Tables 4 & 5). Each year of the study the highest N rate produced numerically higher but statistically equivalent to the recommended N rate. In terms of valued added by N fertilization at the clay site adding 25 lbs N above the recommended rate increased returns to producers by an average $268/a when compared to the untreated check and $19/acre when compared to the recommended N rate. At the silt-loam site N fertilization did not significantly increase returns to producers (Tables 6 & 7) in any of the tree years studied. Numerically the valued added by N fertilization was negative two of the three years (2003 & 2005). When averaged over the three years the only treatment to have positive net returns over the untreated check was the soil test recommended rate.

Cardy meter readings were well correlated with laboratory NO_3 determinations (Figure 1). This indicated that Cardy meter could be used in place of the traditional method of petiole analysis to monitor crop N status during the growing season.

In 2003, 2004, & 2005 this data was presented at the Belt-Wide Cotton Conferences. Results were also presented at the 2004 & 2005 Southern Plant Nutrition Conferences held in Olive Branch, MS. This information was also presented as an oral presentation at the 2004, 2005, and 2006 Missouri Cotton Producers Conference in Kennett, MO. In 2005 a two hour CCA continuing education hands on training course in cotton- nitrogen management was conducted using the field plots. At present a manuscript is being prepared for submission to the online publication, Journal of Cotton Science.

Table 1. Cotton lint yields and gin turn out % for nitrogen treatments on a clay and a silt-loam soil, 2003, 2004 & 2005.

N Treatment	Cotton lint yields lbs/acre						Turn out %					
	Clay			Silt loam			Clay			Silt loam		
	2003	2004	2005	2003	2004	2005	2003	2004	2005	2003	2004	2005
0	491d	315d	279c	761a	825a	1197a	0.40ab	0.40b	0.37b	0.38a	0.39a	0.38a
60	750c	633c	441b	680a	817a	1212a	0.41a	0.43a	0.39b	0.36b	0.37ab	0.39a
85	956b	761b	480b	721a	940a	1255a	0.40ab	0.42a	0.39b	0.36b	0.38ab	0.38a
110	1059a	923a	641a	870a	942a	1256a	0.39bc	0.41ab	0.39b	0.36ab	0.36b	0.38a
135	1098a	934a	689a	764a	979a	1204a	0.38c	0.41ab	0.40a	0.36b	0.37b	0.38a
LSD 0.05	94	100	156	244	243	256	0.014	0.019	0.026	0.0019	0.02	0.016
CV %	7.1	9.1	20.0	20.4	17.54	10.8	2.3	3.0	4.4	3.4	3.5	2.2

Table 2. Average Micronaire , length, strength and uniformity of cotton fiber cultivated on a clay soil for N treatments in 2003, 2004, & 2005.

N Treatment	Micronaire			Length			Strength			Uniformity		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
0	4.63c	4.05b	4.40b	1.047b	1.047a	1.083bc	27.90b	26.00a	30.32a	82.30c	82.52a	83.00b
60	4.67bc	4.50a	4.63a	1.047b	1.035a	1.080c	28.45ab	26.38a	30.00a	82.88bc	82.95a	82.95b
85	4.88ab	4.57a	4.68a	1.08a	1.043a	1.085bc	28.83ab	26.10a	30.17a	83.55ab	82.30a	83.05b
110	4.90a	4.53a	4.78a	1.082a	1.050a	1.097ab	28.97ab	26.12a	30.47a	83.88a	82.75a	83.13a
135	4.95a	4.55a	4.77a	1.09a	1.047a	1.105a	29.63a	25.67a	30.72a	83.52ab	82.75a	83.78b
LSD 0.05	0.21	0.16	0.20	0.03	0.02	0.0151	1.29	0.736	1.388	0.89	0.75	0.614
CV %	2.8	2.4	2.8	1.7	1.1	0.9	2.9	1.88	3.0	0.7	0.6	0.5

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 3. Average Micronaire , length, strength and uniformity of cotton fiber cultivated on a silt-loam soil for N treatments in 2003, 2004, & 2005.

N Treatment	Micronaire			Length			Strength			Uniformity		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
0	4.68a	4.80a	4.70a	1.095bc	1.070a	1.073ab	28.58a	26.08a	27.97a	82.95a	83.05a	83.10a
60	4.47ab	4.68a	4.63a	1.113a	1.067a	1.073ab	29.07a	25.13a	28.50a	83.17a	82.95a	83.00a
85	4.23b	4.57a	4.55a	1.110ab	1.082a	1.065b	28.70a	25.75a	28.95a	83.23a	83.20a	82.80a
110	4.50ab	4.78a	4.70a	1.080c	1.070a	1.077ab	28.85a	25.22a	28.80a	82.82a	82.90a	82.73a
135	4.18a	4.63a	4.63a	1.095bc	1.080a	1.083a	29.15a	25.67a	24.43a	83.05a	83.23a	83.17a
LSD 0.05	0.45	0.21	0.30	0.016	0.023	0.014	1.07	0.97	1.60	0.94	0.84	0.77
CV %	6.5	2.9	3.4	0.9	0.7	0.6	0.7	11.6	2.9	0.6	0.7	0.5

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 4. Pounds of lint & seed, lint price, and gross returns to producers from nitrogen treatments, on a clay soil 2003, 2004, & 2005.

N Treatment	Lint (lbs/a)			Seed (lbs/a)			Lint price ($/lbs)			Total gross return ($/a)		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
0	491d	315d	279c	737e	482d	475	0.529ab	0.529a	0.5689ab	300d	193d	184c
60	750c	633c	441b	1093d	850c	690	0.508b	0.502b	0.5554b	438c	365c	283bc
85	956b	761b	480b	1452c	1066b	751	0.558a	0.500b	0.5726a	613b	440b	316b
110	1059a	923a	641a	1677b	1342a	1003	0.546a	0.510ab	0.5768a	670ab	544a	425a
135	1098a	934a	689a	1830a	1330a	1034	0.549a	0.523a	0.5648ab	704a	565a	447a
LSD 0.05	94	100	156	151	135	260	0.032	0.019	0.0150	66	61	104
CV %	7.1	9.1	20.0	7.2	8.6	21.1	3.9	2.5	1.7	7.8	9.4	20.3

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 5. N costs, total net returns and value added by N fertilization on clay soil 2003, 2004, & 2005.

N Treatment	N cost ($/a)	Total net returns ($/a)			Value added by N fertilization ($/a)		
		2003	**2004**	**2005**	**2003**	**2004**	**2005**
0	0	300d	193d	184c	0	0	0
60	19.4	419c	346c	264c	119	153	80
85	30.40	583b	410b	286bc	238	110	102
110	36.40	634ab	508a	389ab	334	208	205
135	42.40	662a	523a	404a	362	223	220
LSD 0.05	NA	66	61	67.21	NA	NA	NA
CV %	NA	8.2	10.1	22.0	NA	NA	NA

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 6. Pounds of lint & seed, lint price, and gross returns to producers from nitrogen treatments, on a silt-loam soil 2003, 2004, & 2005.

N Treatment	Lint (lbs/a)			Seed (lbs/a)			Lint price ($/lbs)			Total gross return ($/a)		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**	**2003**	**2004**	**2005**
0	761a	825a	1197a	1246a	1267a	1933a	0.555a	0.490a	0.543a	490a	475a	757a
60	680a	817a	1212a	1221a	1374a	1910a	0.568a	0.489a	0.532a	453a	477a	730a
85	721a	979a	1255a	1298a	1628a	2012a	0.567a	0.473a	0.539a	480a	552a	757a
110	870a	942a	1256a	1534a	1635a	2014a	0.556a	0.469a	0.536a	568a	532a	748a
135	764a	940a	1204a	1378a	1612a	1955a	0.563a	0.481a	0.541a	505a	542a	717a
LSD 0.05	244	243	256	359	338	407	0.014	0.025	0.018	153	149	165
CV %	20.4	17.5	10.8	17.0	14.6	1.6	1.6	3.4	1.8	19.4	18.8	11.5

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 7. N costs, total net returns and value added by N fertilization on a silt-loam soil 2003, 2004, & 2005.

N Treatment	N cost ($/a)	Total net returns ($/a)			Value added by N fertilization ($/a)		
		2003	**2004**	**2005**	**2003**	**2004**	**2005**
0	0	490a	475a	757a	0	0	0
60	19.4	434a	485a	711a	-56	10	-46
85	30.40	450a	521a	726a	-40	31	-31
110	36.40	532a	496a	712a	42	6	-45
135	42.40	464a	499a	674a	-26	9	-83
LSD 0.05	NA	153	149	165	NA	NA	NA
CV %	NA	20.5	19.7	11.9	NA	NA	NA

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

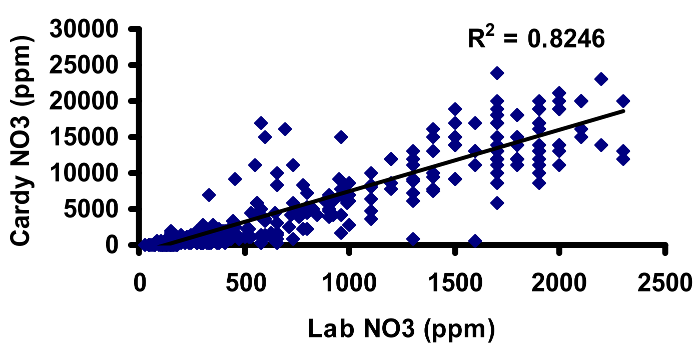


Figure 1 Relationship between laboratory cotton petiole analysis and Cardy meter NO_3-N determinations for both sites in 2003, 2004, & 2005.

Use of Slow-Release N Fertilizer to Control Nitrogen Losses Due to Spatialand Climatic Differences in Soil Moisture Conditions and Drainage

Peter Motavalli, Kelly Nelson, Steve Anderson, and John Sadler

Summary:

Research was conducted in 2004 and 2005 in Missouri with the objectives of examining the agronomic performance and cost-effectiveness of polymer-coated urea compared to conventional N fertilizer sources under different soil moisture and drainage conditions and of assessing environmental N losses under these conditions. Among the findings of this study were:

- Soil nitrous oxide (N_2O) gas efflux was generally lower with application of polymer-coated urea compared to conventional urea. This decrease in gaseous N loss was affected by differences in soil water content due to the relatively wet (2004) and dry (2005) growing seasons experienced during this research and the use of artificial drainage and/or irrigation. Gaseous losses of nitrous oxide can be a significant proportion of N loss after N fertilizer applications in claypan soils and possibly in other soils with restrictive subsoil layers that affect soil moisture conditions.
- Data collected from soil suction lysimeters positioned at different soil depths suggests that application of the polymer-coated urea compared to conventional urea delayed nitrate leaching in 2004 within the soil profile above the claypan subsoil.
- Among the drainage and irrigation treatments examined for this research, application of polymer-coated urea did not have significantly higher corn grain yields compared to conventional urea in either 2004 or 2005.
- Based on the limited data from this research, use of polymer-coated urea would only be cost-effective if an economic value is placed on reductions in environmental N losses and incentive payments or cost-share were provided for use of the product.

Materials and Methods:

A two-year field trial was started in 2004 utilizing the University of Missouri Drainage and Subirrigation (MUDS) trial at the MU Ross Jones Farm in Northeast Missouri. Treatments consisted of 150 ft long plots planted to corn containing treatments of: i) no drainage or subirrigation, ii) drainage with tile drains spaced 20 ft apart and no subirrigation, iii) drainage with tile drains spaced 20 ft apart and subirrigation, and iv) no drainage and overhead sprinkler irrigation according to the Woodruff irrigation scheduling chart . The drainage/irrigation plots were then split into N fertilizer treatments of either broadcast pre-plant-applied urea or polymer-coated urea (ESN®, Agrium, Inc.) at rates of 0, 125, and 250 lbs N/acre. Each treatment combination had 4 replications. All corn plots were chisel plowed in the fall and N treatments incorporated in the spring with a field cultivator.

Changes in soil volumetric water content and temperature due the effects of drainage and irrigation over the growing season were continuously monitored in two replicates of the field experiment using Campbell Scientific data loggers and soil moisture and temperature sensors. The sensors were installed at depths of 6 and 18 inches in the middle between drainage tile lines and in the control and high rate of urea fertilizer.

The fate of applied fertilizer N was monitored by periodic soil sampling to determine changes in soil inorganic N (NH_4^+-N and NO_3^--N) by depth, by NO_3^--N analysis of water samples collected from suction lysimeters installed at depths of 6 and 18 inches, and by measurement of nitrous oxide (N_2O) gas flux. Soil N_2O gas was collected using small sealed chambers fitted with rubber septa inserted into PVC collars in the soil. The head space gas was collected from the chambers in the different treatments and analyzed by gas chromatography (GC). Crop N recovery of applied fertilizer N due to the treatments was determined by measurement of total aboveground biomass (silage) at two different times during the season and at physiological maturity and by total N tissue analysis.

Results:

Rainfall during the 2004 cropping year was above average in the spring and consistent throughout the summer (Fig. 1A). In contrast, cumulative rainfall during the growing season in 2005 was relatively lower than in 2004 and an extended drought was experienced after the middle of June (Fig. 1B).

Due to this difference in annual rainfall, corn grain yield response to added N fertilizer and drainage and irrigation treatments varied between the two years. In 2004, grain yields averaged approximately 94 bu/acre higher than the check plots receiving no N fertilizer across all drainage and irrigation treatments (Fig. 2A). In addition, the plots in 2004 with drainage generally outyielded the non-drained plots by 23 to 31 bu/acre. Yield increases due to use of polymer-coated urea compared to conventional urea N fertilizer ranged from an average of 14 to 20 bu/acre in the plots with no drainage or supplemental irrigation, but these yield increases were not statistically significant at $P < 0.05$ (Fig. 2A).

In 2005, some yield advantage was observed with drainage, but, in general the largest response occurred when irrigation was applied (Fig. 2B and 3). Yield increases to added N fertilizer under overhead or subirrigation ranged from 72 to 165 bu/acre. No significant yield differences were observed between polymer-coated and conventional urea (Fig. 2B and 3). One possible reason for the lack of differences between the two N fertilizer sources is that all N fertilizer treatments were incorporated after application which may have reduced potential ammonia volatilization that may occur when conventional urea is surface-applied.

Nitrate-N levels contained in suction lysimeter water samples in 2004 at depths of 6 and 18 inches were highly variable and collection of samples only began 60 days after the N fertilizer was applied (DAN) since insufficient water was in the soil to enter the suction lysimeters until that date (Fig. 4). Despite the high variability in NO_3^--N contained in the water samples, the NO_3^--N was generally higher in the urea-treated plots compared to the polymer-coated urea in the beginning of the season (60, 68 and 85 DAN) and then lower later in the season (139 and 158 DAN).

Fig. 5A & B shows the relative rate of gaseous N_2O loss or efflux resulting from the different N fertilizer treatments in the overhead irrigated treatment over the 2004 and 2005 growing seasons. In general, application of the polymer-coated urea (ESN) resulted in lower N_2O efflux, especially at peak loss times. In other research at the Greenley Experiment Station, we have observed that most N_2O gas loss occurred within 40 days after N fertilizer application. However, in this research, peak N_2O gas losses often occurred between 30 to 60 days after N fertilizer application (Fig. 5A & B).

Table 1 shows a comparison of the relative N_2O gas efflux in 2004 at a June sampling date when peak activity occurred. Soil N_2O efflux was generally not significantly different among the drainage/irrigation and N fertilizer treatments. However, in the overhead irrigated plots, significantly higher N_2O efflux occurred in the urea-treated plots compared to the polymer-coated urea-treated plots. Loss of N_2O was affected by changes in soil temperature and soil water content that occurred due to rainfall and the different drainage and irrigation treatments. In general, these rates of N_2O loss in these claypan soils are much higher than those rates reported in the research literature for soils without subsoil restrictive layers.

Based on the limited data from this research, use of polymer-coated urea did not result in increased economic value over conventional urea because of higher yields. However, use of enhanced efficiency fertilizers, such as polymer-coated urea, may be cost-effective if a sufficient economic value is placed on reductions in environmental N losses. Currently, Missouri is offering incentive payments for use of some treated N fertilizer products. With funding from the Missouri Fertilizer and Aglime, we are also currently conducting research to compare other N fertilizer management practices, such as variable source application, to determine if use of polymer-coated urea can be cost-effective.

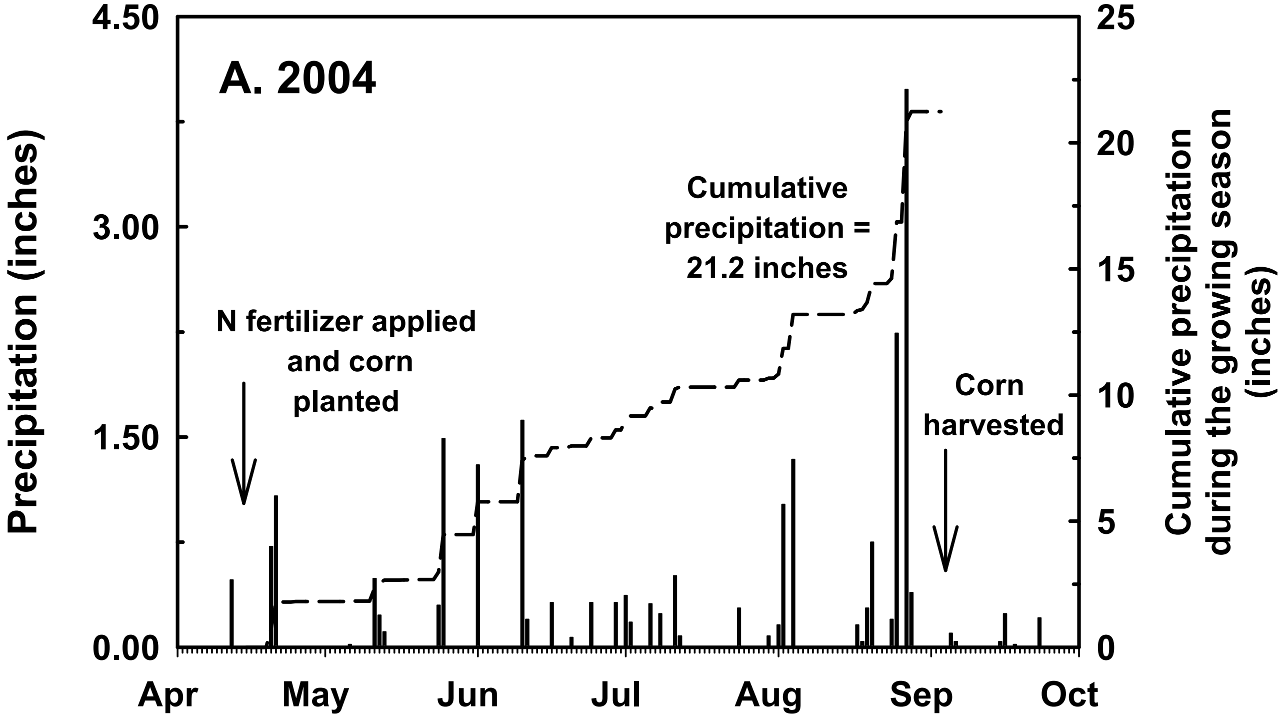
Outreach and Training:

One M.S. graduate student is receiving her training working on this project for her thesis research in soil science. The research results have been presented to Missouri growers and agricultural professionals at the 2004 and 2005 Greenley Center Field Days in Northeast Missouri and at the American Society of Agronomy National Meetings in 2005. Several workshops on drainage and irrigation practices have also been conducted at the field site.

Table 1. The effects of drainage/irrigation and N fertilizer source on soil N_2O flux on 17 June, 2004.

Fertilizer treatment	Drainage/Irrigation treatment: No drainage, No irrigation	Drainage, No irrigation	No drainage Overhead irrigation	Controlled drainage Subirrigation	$DMRT_{(0.05)}$
	---------- g N_2O-N ha^{-1} day^{-1} ----------				
Control	22.30	55.63	67.23	33.17	NS[†]
ESN[††]	162.20	106.69	223.56	68.98	NS
Urea	32.08	56.03	642.01	37.87	NS
$DMRT_{(0.05)}$	NS	NS	2.93	NS	

[†]NS = Not statistically significant
[††]N fertilizer sources were applied at 250 lb N/acre



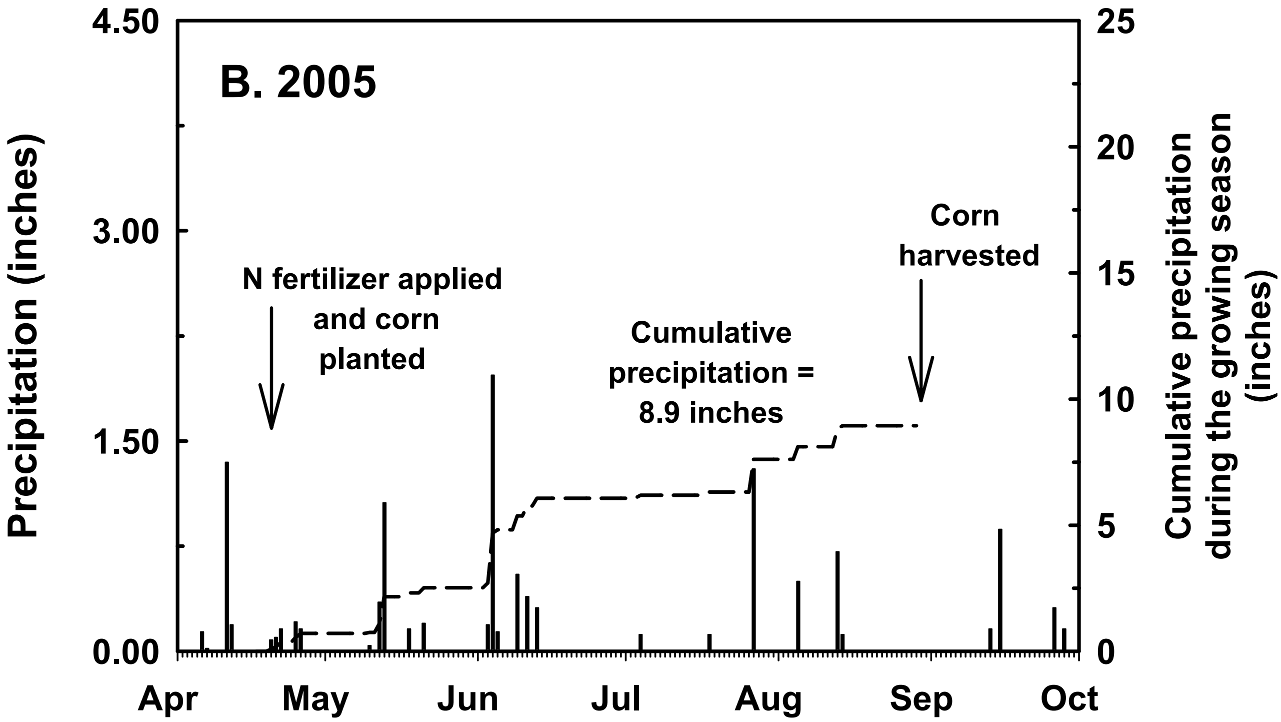


Fig. 1 A & B. Daily and cumulative rainfall at the Ross Jones Farm during the A) 2004 and B) 2005 cropping seasons.

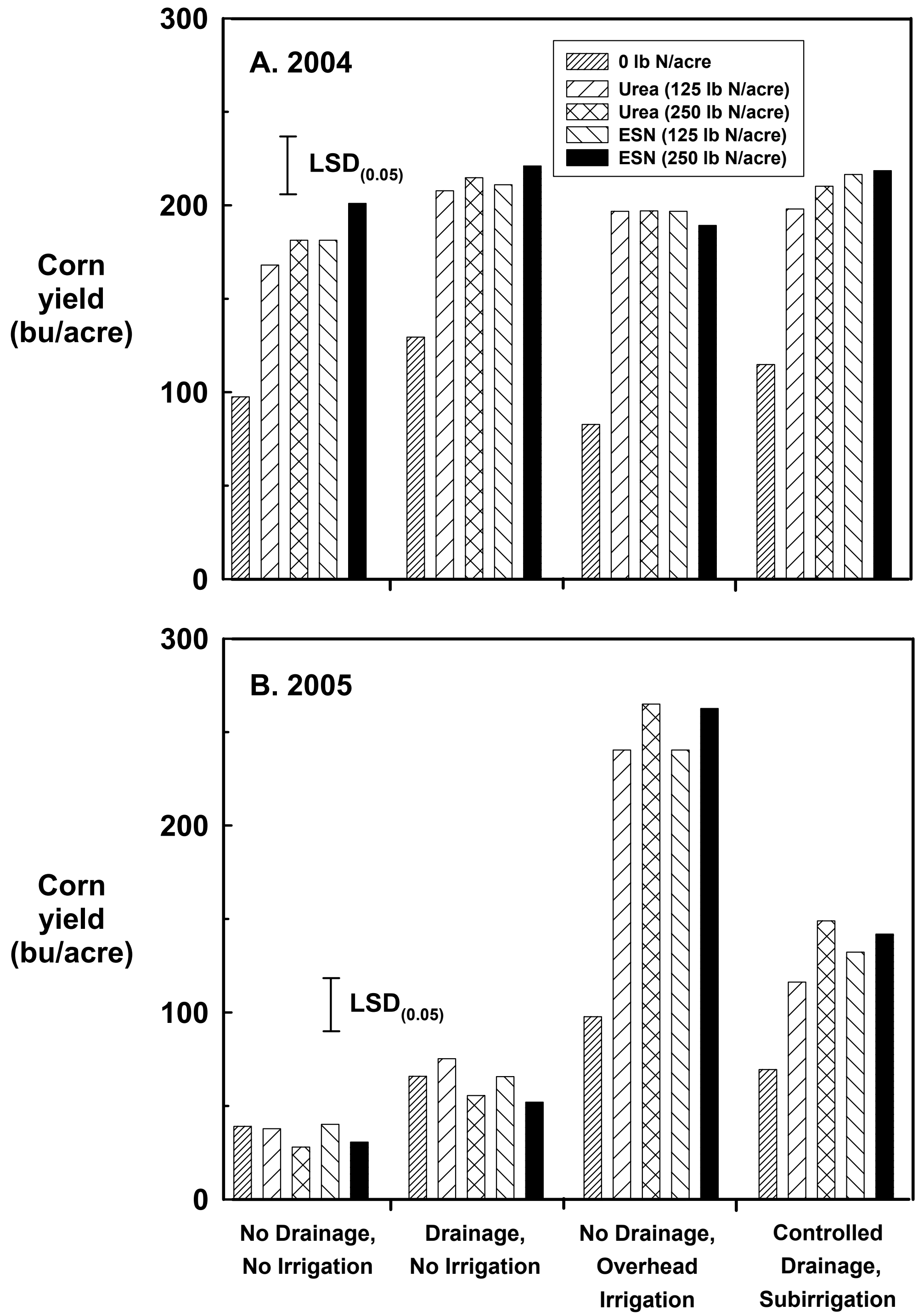


Fig. 2A & B. Corn grain yield response in A) 2004 and B) 2005 to different application rates of conventional and polymer-coated urea (ESN) under different drainage and irrigation treatments.

Fig. 3. Comparison of corn ears in 2005 to different application rates of conventional and polymer-coated urea (ESN) under different drainage and irrigation treatments.

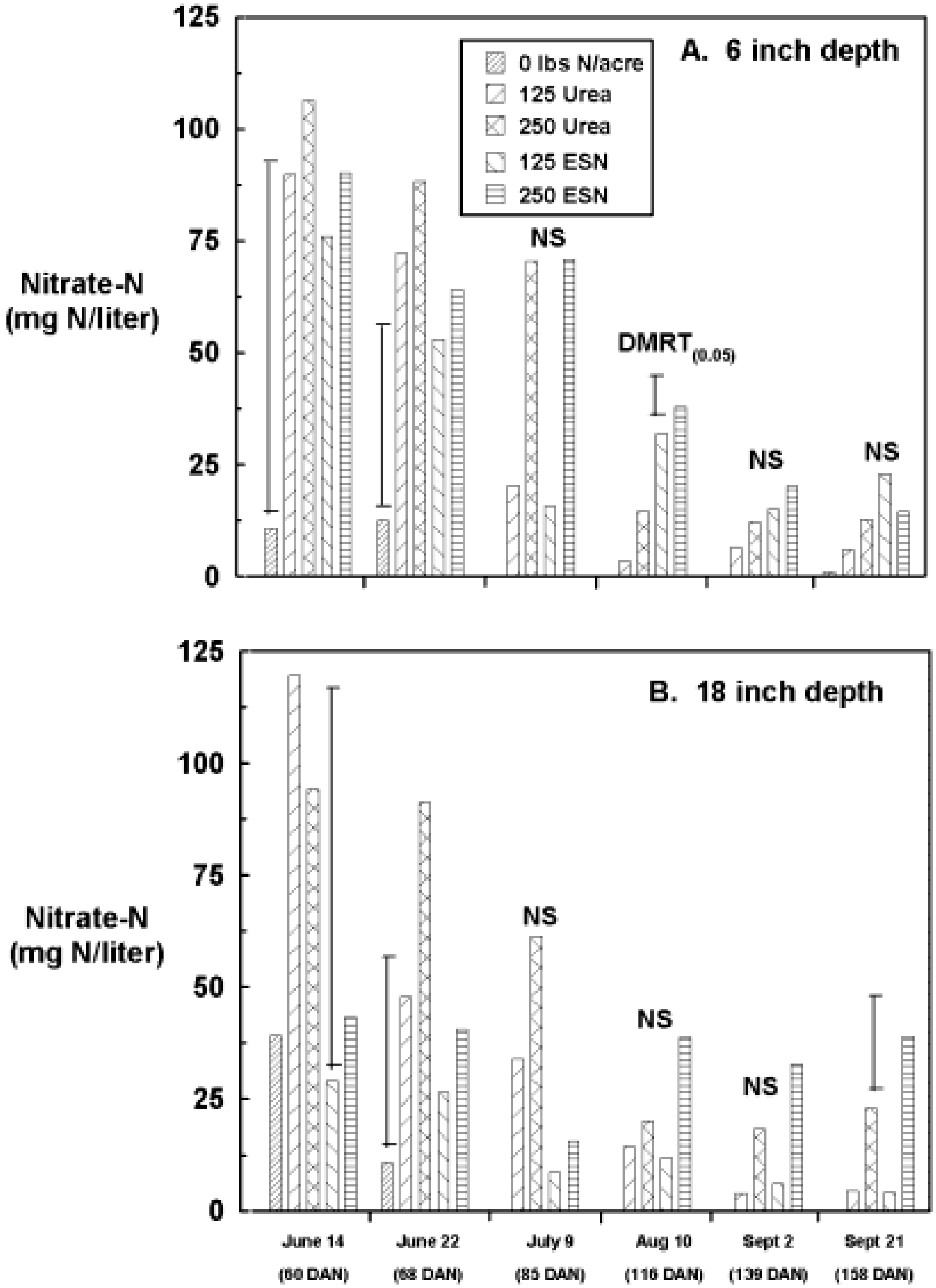


Fig. 4. Nitrate-N contained in water samples collected from suction lysimeters installed in 2004 at A) the 6 inch depth and B) the 18 inch depth in plots receiving different rates of conventional or polymer-coated urea (ESN). The values are averaged over the drainage/irrigation treatments. DAN = days after N fertilizer applied.

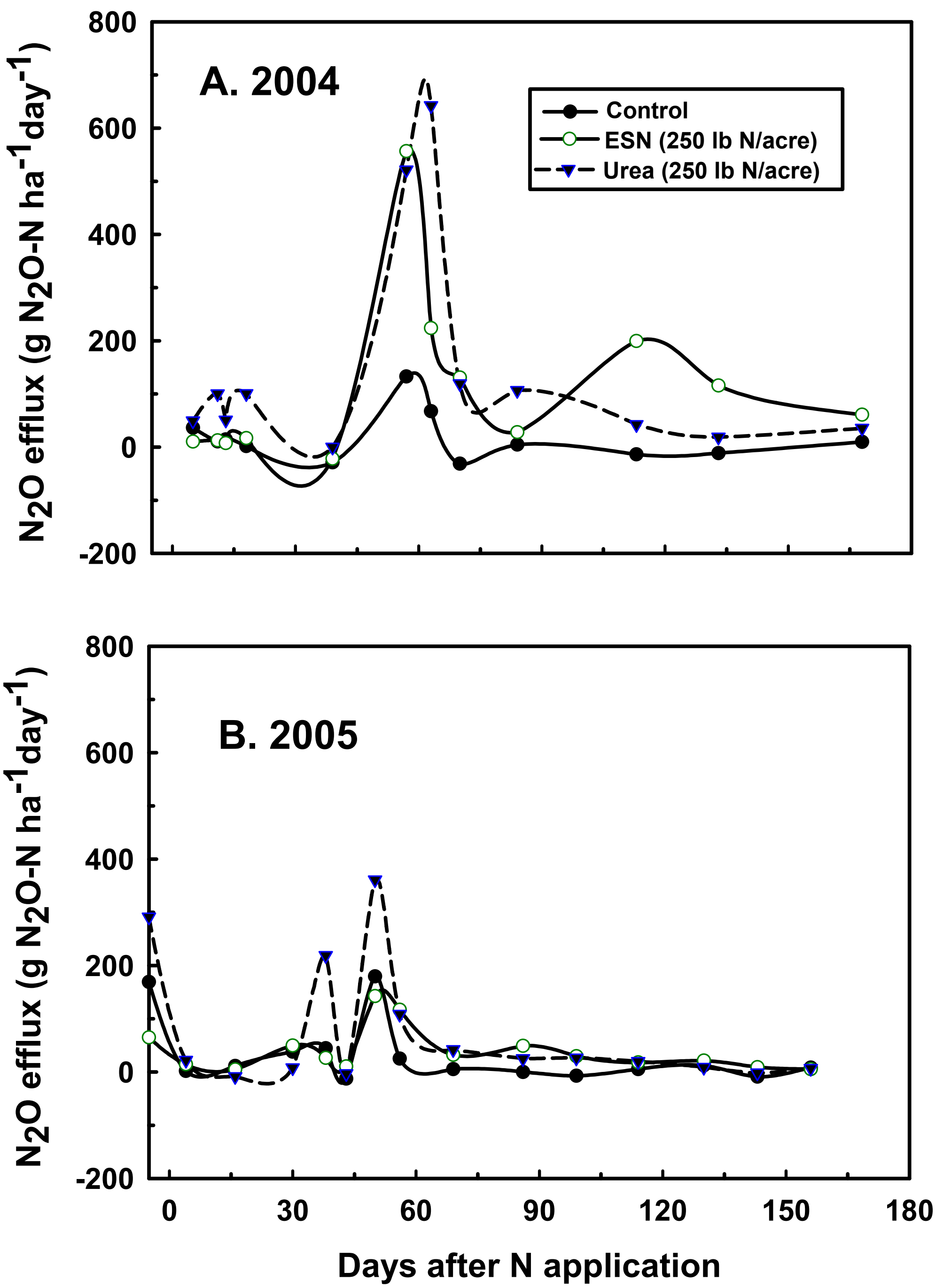


Fig. 5A & B. Nitrous oxide gas efflux in A) 2004 and B) 2005 with different N fertilizer sources at the 250 lb N/acre rate in the overhead irrigated treatment.

Effect of Crop Stand Loss and Spring Nitrogen on Wheat Yield Components

Shawn P. Conley

Objective:

- To quantify the affect of percent crop stand loss and spring nitrogen rate on soft red winter wheat yield.

Materials and Methods:

Field studies were conducted in the 2003-04 winter wheat growing season at Columbia, Lamar, and Portageville, MO. In the 2004-05 growing season only the Columbia, MO location was planted due to weather and logistical constraints. The experimental design was a randomized complete block factorial design with four replications. The main plot factors were crop stand loss treatments of 0, 15, 30, 45, and 60% and spring nitrogen treatments of 0, 30, 60, 90, and 120 lbs. N per acre. Crop stand loss treatments were established by planting a mixture of spring oat and winter wheat in the fall of each year. Achieve herbicide was applied (0.625 lbs/acre) at green up to control any spring oats that may have survived the winter. Spring N treatments were applied by hand at green up.

Truman wheat and Ogle oat seed were drilled on 7-inch centers at a seeding rate of 117 lbs/acres or 1,500,000 seeds/acre on October 7, 22, and 23, at Columbia, Lamar, and Portageville, respectfully. Wheat followed soybean at Portageville and Columbia and corn at Lamar in 2003. In 2004, wheat followed soybean at Columbia and was planted on October 8. A fall pre-plant application of 40-40-60 was applied at each location. Herbicide, insecticide, and fungicide were applied according to University of Missouri Extension recommendations. At each location tiller number per foot of row was taken at green up and jointing. Wheat head number and crop height was determined just prior to wheat harvest. Wheat grain yield, test weight, thousand kernel weight, and kernel number per head were measured at crop physiological maturity and adjusted to 13% moisture.

Results and Discussion:

There was a significant year by location by main effect interaction ($P \leq 0.001$) for grain yield, test weight, thousand kernel weight, and kernel number per head, so locations were analyzed separately. At each location the stand loss by N rate interaction was not significant ($P \geq 0.05$); therefore data were combined over main effects.

2004 Results:

Crop tiller number at green up and jointing as well as wheat head number at harvest increased as percent stand loss decreased (Tables 1, 2 and 3). The application of spring N increased wheat tiller formation at Portageville and Columbia, but not at Lamar. The application of spring N increased head number at Columbia and Lamar, but not Portageville. Crop stand loss and spring N had a variable effect on plant height depending upon location.

At Columbia and Lamar, grain yield decreased as percent crop stand loss increased (Figures 1 and 2). Grain yield also increased as spring N increased at these locations. At Portageville however spring N rate did not affect wheat yield (Figure 3). Grain test weight response to crop stand loss was variable among locations, however at each location test weight increased as spring nitrogen rate decreased (Tables 1, 2 and 3). Thousand kernel weight increased as crop stand loss decreased and spring N increased at Columbia and Lamar. In contrast, at Portageville thousand kernel weight increased as crop stand loss increased and spring N decreased. At each location kernel number per head increased as crop stand loss and spring N increased.

Variability in the crop response to stand loss and spring N among locations may be related to the residual soil N at each location. At Columbia, Lamar, and Portageville the wheat grain yield at the 0 pounds N per acre treatment were 50.1, 66.6, and 73.4 bu acre^{-1}. At Portageville wheat followed an 80 bu/acre soybean crop; whereas, at Lamar wheat followed a 141 bu/acre corn crop. Excess residual soil N may explain the lack of a wheat yield response to spring N at Portageville.

2005 Results

At Columbia crop tiller number at green up increased as percent stand loss decreased (Table 4). At jointing, crop tiller number was similar among percent stand loss treatments. Tiller response to spring N treatments was similar at green-up but varied at jointing. Spring N rate and percent crop stand loss did not affect wheat yield or crop height (Figure 4). Spring N rate also did not affect crop test weight, head number, or kernel number per head, however thousand kernel weight decreased as spring N increased (Table 4). Percent crop stand loss did not affect thousand kernel weight, however kernel number per head increased as percent crop stand loss increased.

Conclusions:

Our results indicate the importance of accurately assessing residual soil nitrate levels in order to optimize crop yield and economic gain. Our results further suggest that even at a significant crop stand loss (up to 60%) wheat yield potential may be great enough as to not automatically warrant crop replacement. By incorporating wheat yield potential, previous crop contribution to soil residual N, spring N cost, and commodity price, growers may more accurately estimate whether a wheat crop should be kept or replaced.

Table 1. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Columbia, MO in the 2003-2004 growing season.

Treatment	Tiller number at green-up (ft^{-1} row) †, ‡	Tiller number at jointing (ft^{-1} row)	Head number ($yard^{-1}$ row)	Crop height (inches)	Grain yield (bu a^{-1})	Test weight	Thousand kernel weight (g 1000^{-1} kernels)	Kernels $head^{-1}$
Crop Stand Loss (Percent)								
0	64.3 a	63.5 a	91.1 a	34.8 a	71.1 a	59.2 ab	31.6 a	39.4 d
15	62.9 a	60.3 ab	86.5 a	35.2 a	66.1 b	59.7 a	31.5 ab	42.3 c
30	57.2 a	57.5 bc	84.5 a	35.3 a	68.6 ab	59.4 ab	31.3 ab	43.0 c
45	45.2 b	52.9 c	74.7 b	34.7 a	60.9 c	59.3 ab	31.4 ab	45.8 b
60	34.2 c	44.1 d	74.1 b	34.9 a	55.39 d	58.8 b	31.2 b	50.2 a
LSD: 0.05	7.7	5.8	8.4	N.S.	4.4	0.6	0.3	2.0
Spring N Rate (pounds N a^{-1})								
0	54.2 a	45.4 c	65.6 d	32.4 d	50.1 d	60.0 a	31.9 a	41.2 c
30	51.8 a	54.5 b	79.6 c	34.6 c	60.1 c	59.9 a	31.4 bc	42.9 bc
60	51.1 a	57.0 ab	82.1 bc	35.7 b	65.4 b	59.2 b	31.7 ab	43.8 b
90	52.6 a	61.4 a	92.7 a	36.4 a	72.6 a	58.8 bc	31.1 cd	45.9 a
120	54.1 a	60.0 ab	89.9 ab	36.6 a	74.4 a	58.5 c	30.9 d	46.9 a
LSD:0.05	N.S.	5.8	8.4	0.6	4.4	0.6	0.3	2.0

†Treatment means within the same column and treatment followed by the same letter were not considered different at $P \geq 0.05$.
‡N.S., no significant differences.

Figure 1. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield at Columbia, MO in the 2003-2004 growing season.

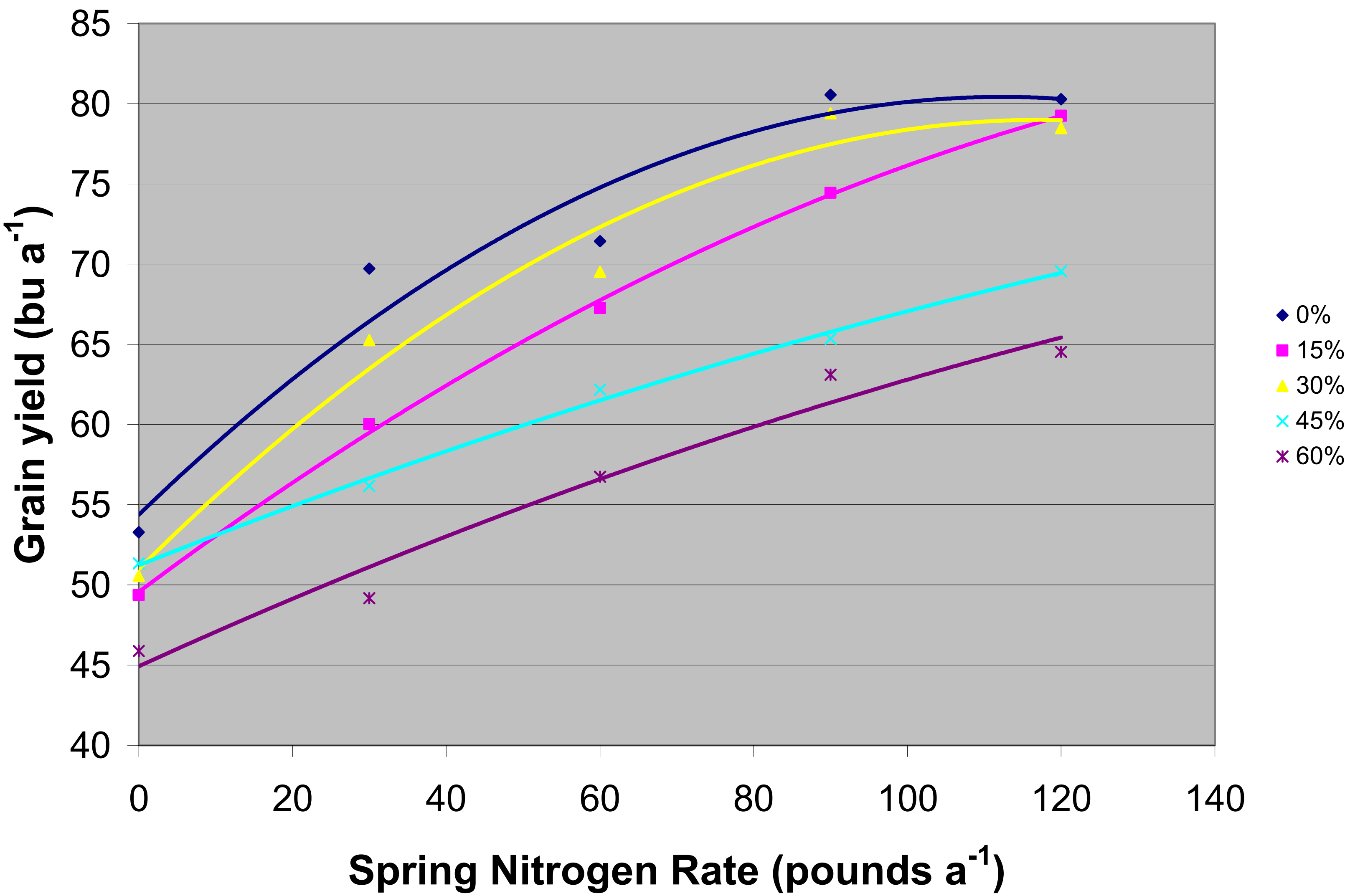


Table 2. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Lamar, MO in the 2003-2004 growing season.

Treatment	Tiller number at green-up (ft^{-1} row) †, ‡	Tiller number at jointing (ft^{-1} row)	Head number ($yard^{-1}$ row)	Crop height (inches)	Grain yield (bu a^{-1})	Test weight	Thousand kernel weight (g 1000^{-1} kernels)	Kernels $head^{-1}$
Crop Stand Loss (Percent)								
0	79.0 a	80.9 a	103.8 a	37.5 a	86.7 a	57.0 a	30.1 a	35.9 b
15	76.9 a	79.7 a	96.8 ab	37.4 ab	81.4 ab	57.0 a	29.9 ab	36.3 b
30	70.5 ab	72.4 ab	93.6 b	36.6 ab	76.8 bc	56.9 a	29.7 ab	37.5 b
45	65.7 b	69.0 b	91.6 b	36.6 ab	76.5 bc	56.6 a	29.4 bc	38.0 b
60	49.0 c	53.9 c	77.2 c	36.3 b	72.0 c	56.5 a	28.9 c	42.9 a
LSD: 0.05	9.5	9.9	9.3	1.1	5.5	N.S.	0.6	2.4
Spring N Rate (pounds N a^{-1})								
0	66.7 a	67.6 a	83.6 c	34.1 c	66.6 d	57.1 a	30.1 a	35.3 b
30	73.0 a	74.4 a	89.4 bc	36.3 b	75.4 c	57.1 a	30.1 a	38.0 a
60	67.9 a	70.7 a	93.4 ab	37.8 a	80.2 bc	57.1 a	30.0 a	38.0 a
90	67.0 a	71.8 a	96.1 ab	38.0 a	85.0 ab	56.5 b	29.1 b	39.1 a
120	66.5 a	71.3 a	100.5 a	38.1 a	86.1 a	56.3 b	28.8 b	40.0 a
LSD:0.05	N.S.	N.S.	9.3	1.1	5.5	0.5	0.6	2.4

†Treatment means within the same column and treatment followed by the same letter were not considered different at $P \geq 0.05$.
‡N.S., no significant differences.

Figure 2. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield at Lamar, MO in the 2003-2004 growing season.

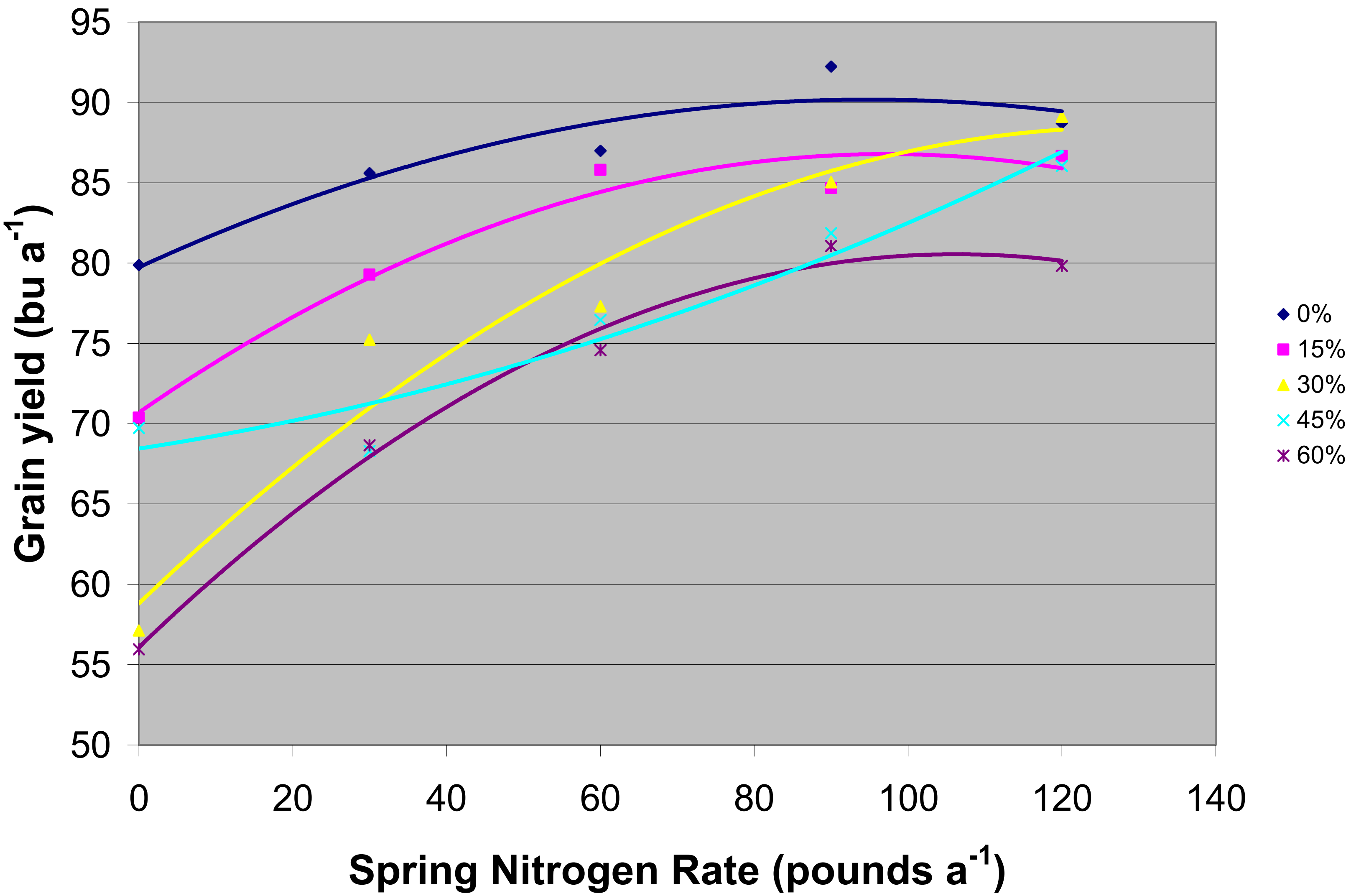


Table 3. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Portageville, MO in the 2003-2004 growing season.

Treatment	Tiller number at green-up (ft^{-1} row) †, ‡	Tiller number at jointing (ft^{-1} row)	Head number ($yard^{-1}$ row)	Crop height (inches)	Grain yield (bu a^{-1})	Test weight	Thousand kernel weight (g 1000^{-1} kernels)	Kernels $head^{-1}$
Crop Stand Loss (Percent)								
0	58.6 a	56.8 a	97.7 a	35.7 b	71.9 b	60.1 bc	26.2 c	50.0 b
15	53.5 ab	48.5 b	88.9 ab	36.9 ab	77.0 ab	59.1c	26.9 c	52.8 b
30	51.2 bc	44.7 bc	89.3 ab	37.2 a	80.6 a	59.9 bc	27.8 b	53.5 ab
45	46.1 c	42.8 c	81.6 b	36.3 ab	76.3 ab	61.2 ab	28.0 b	52.8 b
60	37.4 d	33.1 d	79.4 b	36.7 ab	73.8 b	61.5 a	28.8 a	57.0 a
LSD: 0.05	6.5	4.9	9.9	1.3	5.8	1.3	0.7	3.9
Spring N Rate (pounds N a^{-1})								
0	49.8 a	42.2 b	83.0 a	36.5 a	73.4 a	61.8 a	28.4 a	53.3 a
30	48.5 a	43.1 ab	86.3 a	36.8 a	77.2 a	59.9 b	27.8 a	54.4 a
60	50.8 a	46.9 ab	90.0 a	36.8 a	78.1 a	60.5 b	27.7 ab	53.8 a
90	50.6 a	46.2 ab	88.8 a	36.7 a	76.4 a	60.0 b	26.8 c	50.6 a
120	47.2 a	47.6 a	88.8 a	36.0 a	74.7 a	59.7 b	27.1 bc	53.9 a
LSD:0.05	N.S.	4.9	N.S.	N.S.	N.S.	1.3	0.7	N.S.

†Treatment means within the same column and treatment followed by the same letter were not considered different at $P \geq 0.05$.
‡N.S., no significant differences.

Figure 3. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield at Portageville, MO in the 2003-2004 growing season.

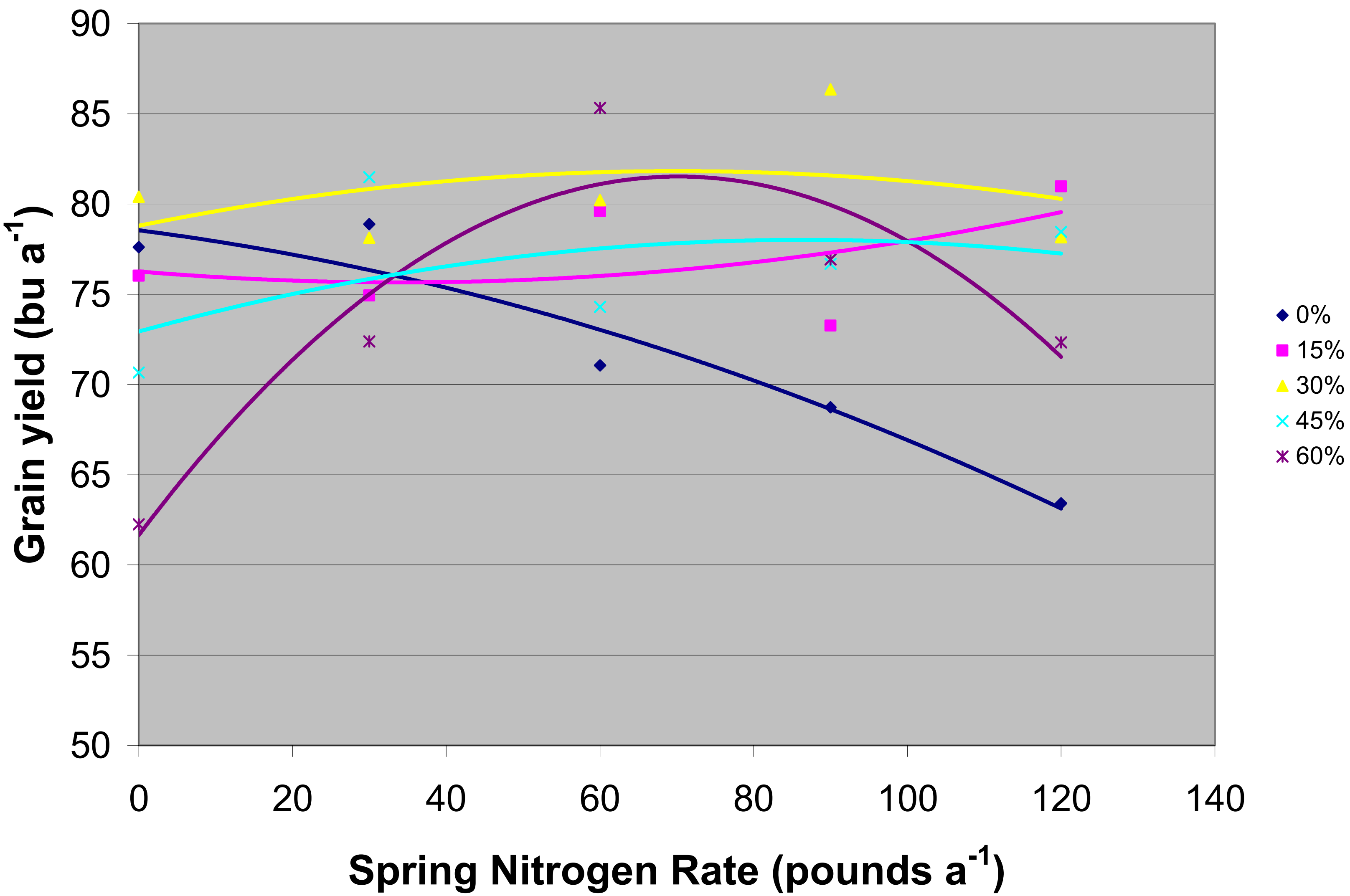
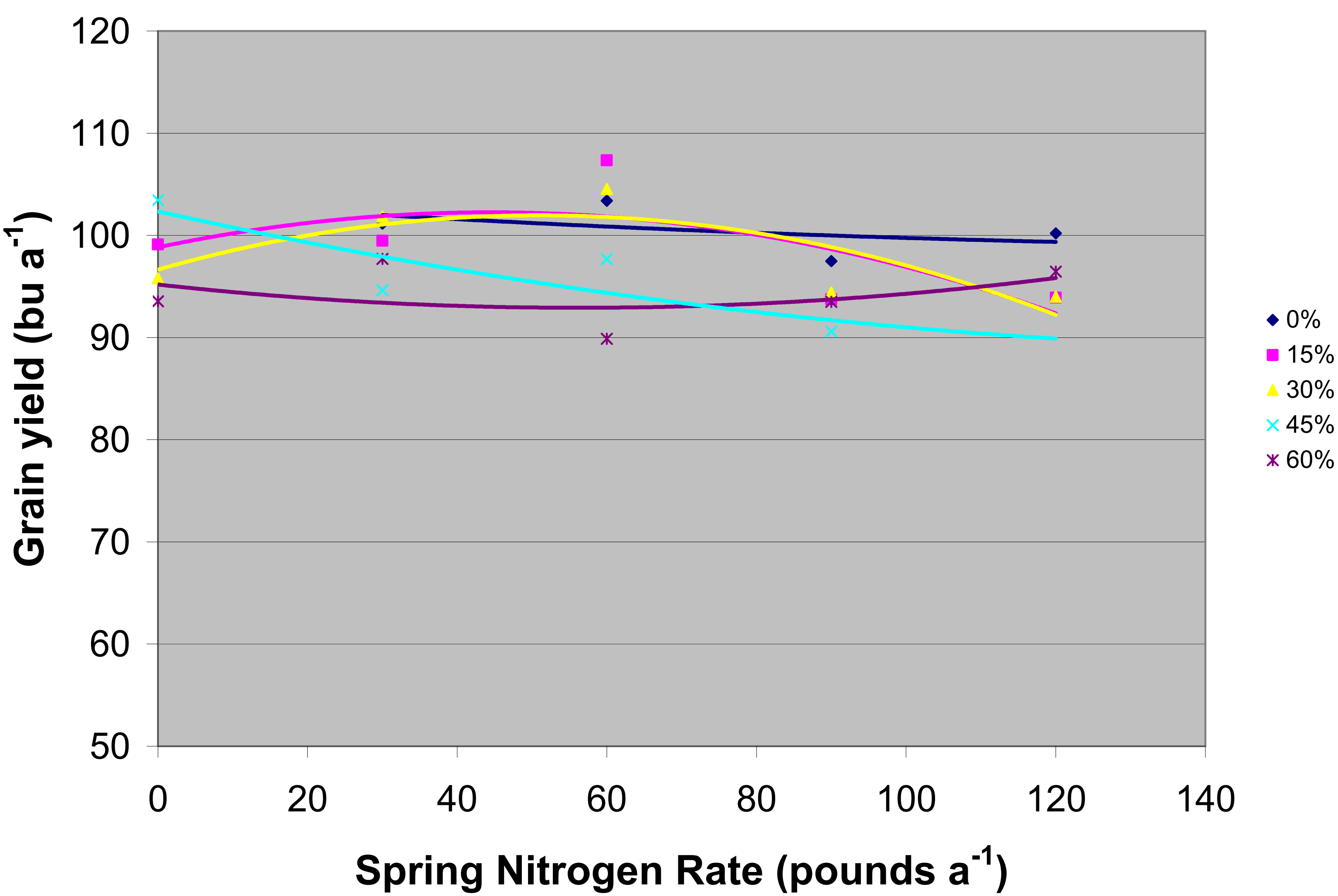


Table 4. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Columbia, MO in the 2004-2005 growing season.

Treatment	Tiller number at green-up (ft^{-1} row) †, ‡	Tiller number at jointing (ft^{-1} row)	Head number ($yard^{-1}$ row)	Crop height (inches)	Grain yield (bu a^{-1})	Test weight	Thousand kernel weight (g 1000^{-1} kernels)	Kernels $head^{-1}$
Crop Stand Loss (Percent)								
0	81.3 a	66.1 a	113.5 ab	41.3 a	100.1 a	57.4 a	32.3 a	49.1 c
15	71.5 b	65.8 a	118.0 a	41.5 a	98.7 a	51.6 b	32.6 a	50.2 c
30	58.7 c	63.8 a	105.5 b	41.3 a	98.1 a	56.2 ab	32.4 a	51.9 bc
45	45.0 d	62.4 a	109.8 ab	41.6 a	96.4 a	55.4 ab	32.2 a	54.5 ab
60	37.8 d	59.6 a	101.8 b	40.9 a	94.2 a	54.6 ab	32.2 a	56.4 a
LSD: 0.05	8.3	N.S.	12.2	0.8	N.S.	5.3	N.S.	3.2
Spring N Rate (pounds N a^{-1})								
0	59.8 a	65.7 ab	104.4 a	41.2 a	96.5 a	57.4 a	33.0 a	51.5 a
30	57.7 a	58.9 b	107.6 a	41.2 a	100.7 a	54.1 a	32.6 ab	51.6 a
60	56.4 a	59.8 b	113.5 a	41.2 a	100.0 a	52.6 a	32.3 abc	53.2 a
90	59.0 a	68.8 a	111.7 a	41.9 a	95.4 a	55.9 a	32.0 bc	54.1 a
120	61.2 a	64.4 ab	111.5 a	41.1 a	95.1 a	55.1 a	31.7 c	51.8 a
LSD:0.05	N.S.	8.4	12.2	0.8	N.S.	N.S.	0.7	N.S.

†Treatment means within the same column and treatment followed by the same letter were not considered different at P ≥ 0.05.
‡N.S., no significant differences.

Figure 4. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield at Columbia, MO in the 2004-2005 growing season.



Progress Reports

Making Urea Work in No-till

Peter Scharf, Joao Medeiros, and Larry Mueller
University of Missouri Plant Sciences Division

Objective:

- The objective of this project is to evaluate several strategies to reduce the risk of ammonia volatilization loss from urea applied to no-till corn and wheat.
    - " Strategies to be evaluated include:
      -Urea treated with Agrotain volatilization inhibitor
      -Polymer-coated urea
      -Knife-injected urea
    - Yield and economic outcomes from these strategies will be compared with
      broadcast urea and with other N sources.

Accomplishments for 2005:

- Two experiments were conducted in 2005 on Bradford Research Farm near Columbia–one in wheat and another in corn.
- Treatments were nitrogen fertilizer sources and placement.
    - All treatments were applied at rates of 140 lb N/ac for corn, 70 lb N/ac for wheat.
    - Broadcast treatments
      -Urea
      -Urea + tillage (corn only)
      -Urea with Agrotain volatilization inhibitor
      -SuperU (urea with Agrotain + DCD)
      -Polymer-coated urea
      -Gel-coated urea
      -Ammonium nitrate
      -30% urea-ammonium nitrate solution
      -30% urea-ammonium nitrate solution + Agrotain
      -30% urea-ammonium nitrate solution + Agrotain + DCD
    - Knife-injected treatments (corn only)
      -Urea
      -Anhydrous ammonia
      -Ammonium nitrate
      -30% urea-ammonium nitrate solution
    - An unfertilized check treatment was also included so that the size of the yield response to N fertilizer could be determined.
- Each treatment was replicated eight times.

Results for wheat:

- Wheat yields were good in this experiment, averaging 75 bu/acre (not including the unfertilized check treatment). For dry N applied in March, average yield was 88 bu/acre.
- Weather conditions were good for wheat this year, with a dry March and moderate spring temperatures. High temperatures reached 80 as early as late March, but only went above 85 once before June 4. This provided an extended period of warm but not hot temperatures, which is an ideal scenario for wheat. Planting was timely, and the crop looked good and was well-tillered in early March. Tiller development into heads progressed well, and head size appeared good.

- Nitrogen fertilizer treatments increased yields by up to 45 bu/acre over the unfertilized check treatment.
- High yields created a good opportunity for more efficient N sources to produce yield advantages, and clear differences between sources and timings were seen.

Table 1. Wheat yields in 2005 for different broadcast spring N fertilizer sources and application timings.

Fertilizer treatment	**Yield with treatment applied in:**		
	January	February	March
Urea	**62**	**75**	**87**
Urea + Agrotain	**71**	**75**	**92**
Urea + Agrotain + DCD (SuperU)	**67**	**78**	**90**
Polymer coated urea (ESN)	**72**	**75**	**78**
Gel coated urea	**62**	**72**	**88**
Ammonium nitrate	**70**	**79**	**91**
UAN solution*			**67**
UAN solution + Agrotain*			**68**
UAN solution + Agrotain + DCD*			**66**
Unfertilized check	**47**	**47**	**47**

Least Significant Difference (95% confidence) between yields = 5 bu/acre
*Treatments based on UAN solution were only applied in March

- A large effect of application timing was seen. Averaged over N sources, February applications produced yields 10 bu/acre higher than January applications, and March applications produced yields 10 bu/acre higher than February applications.
    - January treatments were applied to frozen ground on January 14. The greatest risk in this situation is that rain will fall while the ground is frozen, will not be able to infiltrate, and will run off carrying the fertilizer with it. This does not appear to be the reason for poor response to N applied in January, since no rain fell until February 6, and by then the soil had been thawed for three days. This should have allowed the quarter inch of rain that fell on February 6 to soak into the soil.
    - The most likely explanation is that some of the N was leached below the root zone. Although rainfall was not excessive in spring 2005, N was applied to nearly saturated soils. October through December 2004 were unusually wet, and more than 5" of precipitation had fallen in

January 2005 by the time treatments were applied on January 14. Precipitation falling on near-saturated soil will tend to either run off or move quickly through soil macropores, carrying nitrate with it.
    - Another possible explanation is that early-applied N was tied up in soil organic matter.
- Large effects of N treatments on wheat yield were also seen this year.
- All three treatments based on UAN solution yielded about 20 bu/acre less than most other treatments applied in March.
    - This agrees with previous Missouri research showing that UAN solution broadcast on residue in no-till systems performs poorly. The effect was smaller in previous research, with an average 8 bu/acre yield penalty for broadcasting UAN in no-till wheat.
- Broadcast urea produced lower yields, averaged over all three application timings, than urea + Agrotain, SuperU (urea + Agrotain + DCD), or ammonium nitrate (see Table 2 below).
    - This effect was 4 bu/acre on average.
    - The best explanation is that N was lost from the broadcast urea treatments by ammonia volatilization, which would be reduced by Agrotain and avoided with ammonium nitrate.
    - The biggest yield difference between broadcast urea and the other three treatments was with the January application (see Table 1), when the difference was more than 7 bu/acre. The January application had the longest time between application and the first rain, 23 days. Time from application to rain is known to be a major factor controlling volatilization loss of N. Volatilization is known to be much slower during cool or cold weather, but it appears that with 23 days for volatilization to occur, significant N loss can happen even during cold weather.

Table 2. Wheat yields in 2005 for different broadcast spring N fertilizer sources, averaged over application timings.

Fertilizer treatment	Yield
Urea	**76**
Urea + Agrotain	**80**
Urea + Agrotain + DCD (SuperU)	**80**
Polymer coated urea	**77**
Gel coated urea	**75**
Ammonium nitrate	**81**

Least Significant Difference (95% confidence) between yields = 4 bu/acre

- Agrotain was effective at increasing wheat yields obtained with broadcast urea.
  - This effect was 4 bu/acre on average.
  - This brought yields with urea up to being equivalent to yields with ammonium nitrate.
  - It appears that Agrotain was effective in preventing ammonia volatilization loss of N from broadcast urea.
  - There was no difference in yield between (urea + Agrotain) and (urea + Agrotain + DCD), suggesting that DCD made no contribution to reducing loss of N. Even though we found no evidence that SuperU gave higher yields than urea + Agrotain, it clearly gave the same benefits and may be preferable for some dealers since mixing is not required (as it is to coat Agrotain on urea).
- Neither polymer nor gel coatings on urea improved yields averaged over N application timings.
  - However, the polymer-coated urea (trade name ESN) improved wheat yield by 10 bu/acre relative to urea when applied in January. The coating apparently helped to reduce losses of N from January-applied urea. Although January applications of N were clearly undesirable in this experiment, producers sometimes want to apply N at this time. ESN may provide a lower-risk alternative for January N applications to wheat.
  - Balancing this effect, wheat yields with March-applied ESN were 9 bu/acre less than with normal urea. Release of N from ESN appeared to be too slow to keep up with wheat demand for N when applied in March. March ESN treatments were easy to pick out due to the lighter color of the wheat.
- Treatments were substantially different in their return to N ($/acre).
- Earlier N applications had much lower return to N because of much lower yields, coupled with good wheat prices this year.
- All three broadcast UAN solution treatments had much lower return to N than any of the other N sources, again due to m uch lower yields.
- Agrotain increased return to N by nearly $12/acre with 92% confidence.
- Amm onium nitrate gave significantly higher return to N than urea, but gave the same return as urea + Agrotain.

<u>Results for corn:</u>

- Corn yields were very low this year, actually lower than the wheat yields. Average corn yield (excluding the unfertilized check treatment) was 42 bu/acre.
  - Yields were severely drought-limited, with only 0.7 inches of rain between June 14 and August 11.
  - In some individual plots, yields were as low as 3 bu/acre due to almost complete failure of pollination, which was probably caused by late emergence of silks.
  - Plots on eroded slope positions had much lower yields than plots on summit positions.

- Treatment effects were evaluated using only the five replications with average yield above 30 bu/acre. These replications were on higher landscape positions.
    - In these five replications, average check yield was 21 bu/acre, and average yield with N was 56 bu/acre.
    - Thus yield response to N was only about 35 bu/acre, which should be easily achievable with 140 lb N/acre regardless of N source or possible N losses. We would not expect yield differences between treatments.
    - None of the N treatments gave yields significantly different than broadcast urea.
- Return to N ($/acre) was near zero on average over all treatments when using N prices from December 2005.
    - There would be a small return to N if spring 2005 prices were used.
- There were no significant differences in return to N between N sources/placem ents at the 95% confidence level, but at the 90% confidence level return to N was greater for urea than for polymer-coated urea, UAN + Agrotain, and UAN + Agrotain + DCD, largely due to the extra expense of these treatm ents.

Table 3. Corn yields in 2005 for different N fertilizer sources & placements.

Fertilizer treatment	Yield
Urea (broadcast + till)	61
Polymer-coated urea (broadcast)	60
Ammonium nitrate (broadcast)	58
UAN solution + Agrotain (broadcast)	58
Urea (broadcast)	58
Urea + Agrotain (broadcast)	57
Anhydrous ammonia (knife)	57
Gel-coated urea (broadcast)	56
SuperU (broadcast)	54
UAN solution + Agrotain + DCD (broadcast)	54
Ammonium nitrate (knife)	53
Urea (knife)	52
UAN solution (knife)	51
UAN solution (broadcast)	51
Unfertilized check	21

Least Significant Difference (95% confidence) between yields = 10 bu/acre

Summary

- Wheat yields were good, and improved by 10 bu/acre when N applications were delayed from January to February, and another 10 bu/acre when they were delayed from February to March.
- UAN solution broadcast for no-till wheat had a yield penalty of about 20 bu/acre relative to other N sources.
- Agrotain increased wheat yield by 4 bu/acre and return to N by $12/acre (on average) when coated on urea.
- Ammonium nitrate gave better wheat yield and return than urea, but the same yield and return as urea + Agrotain.
- Urea products manufactured with a physical coating (polymer or starch gel) did not increase wheat yield compared to urea.
- Corn yields were low due to drought, and there were no yield differences between N treatments.

Objectives for year 3:

- Objectives for year 3 are to repeat experiments in corn and wheat to evaluate strategies for successful urea use in no-till, including use of Agrotain, coated urea products, and knifing.
- The year 3 experiments will solidify our conclusions if we can get another year with above-average yields for both crops. We had good corn in 2004, and good wheat in 2005, but poor wheat in 2004 and poor corn in 2005 (drought), so we need another year with good yields in each crop to show consistency of treatment performance.

Budget request year 3:

Research specialist 35% 11,200 Benefits @27.5% of salary 3,025 Supplies 1,000

- **Total $15,225**

Finding alternatives to ammonium nitrate as a nitrogen source for tall fescue pastures

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Tall fescue grows on more than 12 million acres and provides forage for more than 4 million beef cattle in Missouri. About one-half of all tall fescue acres receive some nitrogen fertilizer in spring. Most of these applications are made in March or early April. Another time in which tall fescue acres are fertilized with nitrogen is in late-summer for stockpiling. Stockpiling tall fescue allows producers to extend the grazing season into winter and thereby cut winter feeding costs up to 70%.

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

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

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

The **overall objective** is to develop research-based recommendations that help industry personnel and farmers determine the best alternative to ammonium nitrate fertilizer for tall fescue pastures. Specific objectives are:

Objective 1: Compare ammonium nitrate to ammonium sulfate, urea, coated urea products, and mixtures of ammonium sulfate with urea and ammonium sulfate with ESN polymer coated urea as a source of nitrogen for tall fescue.

Objective 2: Determine the optimum rate and use efficiency for each source of N tested.

Procedures:

Treatments: Established tall fescue was fertilized with 75 lb/acre of N on 17 and 18 March 2005 at the Forage Systems Research Center near Linneus, MO and the Southwest Research and Education Center near Mount Vernon, MO. The sources of N are listed in Table 1 and include several urea based products already on the market, mixtures of some of these products, as well as untreated urea, ammonium sulfate, and ammonium nitrate as checks. The 75 lb/acre N rate was selected because it is a common fertilization rate for producers. Soil P and K levels are maintained at levels recommended by the University of Missouri Soil Testing Laboratory.

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

Fertilizer Source	For mixture treatments	
	Rate applied (lb/acre of S)	% N derived from ESN and/or Urea
Ammonium Nitrate		
Urea	-	-
Ammonium Sulfate	-	-
Urea treated with Agrotain	-	-
ESN polymer coated Urea	-	-
Nurea	-	-
Nurea with 10% NITAMIN	-	-
Ammonium Sulfate (10S)/Urea	10	88
Ammonium Sulfate (20S)/Urea	20	75
Ammonium Sulfate (40S)/Urea	40	53
Ammonium Sulfate (10S)/ESN	10	88
Ammonium Sulfate (20S)/ESN	20	75
Ammonium Sulfate (40S)/ESN	40	53
1/3 each Ammonium Sulfate + ESN + Urea	28.6	67
Unfertilized Control	-	-

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

Measurements:
Forage yield was measured in late May, late July and early October in 2005, and will be measured three times again in 2006 and 2007. Forage yield was determined by clipping a 4-ft. x 25-ft. strip in each plot using a Hege sickle bar harvester. At each date, sub-samples of forage harvested from each plot were retained for forage quality analyses {crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF), and indigestible NDF (iNDF)}. Samples were dried at 122° F in a forced-air oven before being ground to pass a 1-mm screen. Crude protein, ADF, NDF, and iNDF will be measured using near infrared reflectance spectroscopy. None of this data is available at present, but will be included in future reports.

Preliminary Results:
Our preliminary data indicate that only the spring harvests responded to N applied in March. This fact was true for both locations (Tables 2 and 3). We hypothesized that the "coated urea" products might have yielded greater in the summer and perhaps fall because of their slow N release activity. But this was not the case. Additionally, no one product was overwhelmingly consistent in producing high yields.

We noted that ammonium sulfate ranked in the top producing group at nearly all harvests and locations and its performance is perhaps the most surprising data from this experiment. Conventional thinking is that we do not get a response to fertilizing tall fescue with sulfur in Missouri. Another somewhat surprising result was that ammonium nitrate provided no better yields than urea in this first year. We acknowledge that each location received nearly 1.0 inch of rain within 5 days of the fertilizer application. Most likely, this precipitation was sufficient to get urea into the soil solution. An extended dry period after application of these products may have resulted in more volitization of urea and thus better performance of the "coated urea" products.

The total yield of the unfertilized control was the least at SWC while at FSRC, it was the same as 11 other products. This discrepancy is likely attributable to a pure tall fescue stand at SWC while at FSRC, the pasture contained approximately 30% red clover. Thus, the rhizobia of red clover were fixing atmospheric N and supplying plant available N to the system. At the SWC, 75 lbs N/acre produced on average 3600 lb/acre of forage. This high ratio of dry matter to N input was well worth the cost and would be ideal for producers focused on their haymaking enterprise.

Table 2. Yield from the 26 May, 29 July, and 11 October 2005 harvests of tall fescue fertilized with different nitrogen sources at the Southwest Research and Education Center near Mount Vernon, MO. Nitrogen was applied at 75 lb/acre for each fertilizer source.

Fertilizer Source	5/26/2005	7/29/2005	10/11/2005	Total yield
	---------------------------- lb/acre ----------------------------			
Ammonium Nitrate	8081	928	1224	10232
Urea	7780	759	1244	9784
Ammonium Sulfate	8834	892	1067	10793
Urea treated with Agrotain	8300	858	1359	10518
ESN polymer coated Urea	7134	772	1077	8983
Nurea	8142	867	1096	10104
Nurea with 10% NITAMIN	7368	891	1117	9376
Ammonium Sulfate (10S)/Urea	7927	969	1091	9987
Ammonium Sulfate (20S)/Urea	7574	999	1076	9649
Ammonium Sulfate (40S)/Urea	7810	886	1236	9931
Ammonium Sulfate (10S)/ESN	7044	780	1032	8856
Ammonium Sulfate (20S)/ESN	6675	746	1091	8513
Ammonium Sulfate (40S)/ESN	7613	867	1013	9492
AS + ESN + Urea at 1/3 each	7500	861	1253	9613
Unfertilized Control	4231	591	1121	5943
LSD $_{(0.05)}$	916	NS	NS	1228

Table 3. Yield from the 27 May, 27 July, and 12 October 2005 harvests of tall fescue fertilized with different nitrogen sources at the Forage Systems Research Center near Linneus, MO. Nitrogen was applied at 75 lb/acre for each fertilizer source.

Fertilizer source	5/27/2005	7/27/2005	10/12/2005	Total yield
	---------------------------- lb/acre ----------------------------			
Ammonium Nitrate	3723	1864	2304	7892
Urea	4157	1958	2310	8425
Ammonium Sulfate	5217	2733	2361	10580
Urea treated with Agrotain	3916	2333	2095	8611
ESN polymer coated Urea	4271	2413	2002	8685
Nurea	3846	2106	2055	8135
Nurea with 10% NITAMIN	3692	2152	2101	7945
Ammonium Sulfate (10S)/Urea	5190	2605	2120	9915
Ammonium Sulfate (20S)/Urea	3750	1757	1989	7395
Ammonium Sulfate (40S)/Urea	3754	1768	1954	7476
Ammonium Sulfate (10S)/ESN	3617	1691	2397	7692
Ammonium Sulfate (20S)/ESN	4232	1947	2200	8380
Ammonium Sulfate (40S)/ESN	4854	2401	2055	9310
AS + ESN + Urea at 1/3 each	4835	2416	1957	9208
Unfertilized Control	2997	2305	1967	7269
LSD $_{(0.05)}$	1154	NS	NS	NS

Budget for Year 2

Salary and Benefits	
Research Specialist (25% of $38,850)	$ 9,713
Benefits for Research Specialist	$ 3,059
Student labor for grinding, etc	$ 1,000
Benefits for student labor	$ 100
Total Salary and Benefits	$13,872
Operating Expenses	
Fertilizer, bags, repair parts for harvester and other field supplies	$ 1,000
NIR charges for forage quality (255 samples @ $10 each)	$ 2,550
Soil N analysis (510 samples @ $8 each)	$ 4,080
Travel to FSRC and SWC (mileage, lodging, and meals)	$ 1,700
Total Operating Expenses	$ 9,330
Total Proposal Request for Year #2	$23,202

Variable Source N Fertilizer Applications to Optimize Crop N Use Efficiency

Peter Motavalli, Kelly Nelson, Newell Kitchen, Steve Anderson, and Peter Scharf

Accomplishments for First Year:

Research was initiated in 2005 to determine methods to delineate and map areas in fields which are more vulnerable to N loss due to wet conditions, to examine the use of a *variable-source* strategy to optimize crop N fertilizer use efficiency and, to calculate the cost-effectiveness of using this *variable-source* strategy compared to uniform applications of conventional or other N fertilizer sources.

Two field trials were initiated in 2005 at the MU Greenley Experiment Station and in a farmer's field in Centralia (Fig. 1A&B). Both sites were mapped for elevation and apparent electrical conductivity (EC_a) using a EM-38 sensor (Fig. 1A&B). Measurement of soil EC_a gives an indication of relative depth to the claypan subsoil layer (Kitchen et al., 1999). Soil gravimetric water content was determined on 6 in depth soil samples collected in a 10 by 25 ft grid over the Greenley site on March 31st in order to compare the effects of spatial distribution of elevation and EC_a on the distribution of soil water content.

At the Greenley site, N fertilizer treatments included a control and 150 lb N/acre of either urea, polymer-coated urea (ESN, Agrium, Inc.), a 50% urea/50% polymer-coated urea mixture, or anhydrous ammonia were injected or broadcast-applied and incorporated in 10 m by 1500 ft strips across three landscape positions representing shallow, deep and low-lying areas (Fig. 1A). At the Centralia site, N fertilizer treatments of 150 lb N/acre of either urea or polymer-coated urea (ESN, Agrium, Inc.) were broadcast surface-applied in 15 by 1470 ft strips across landscape positions representing shallow and deep areas (Fig. 1B).

Corn (*Zea mays.* L.) silage and grain yields were determined at each site. Site harvest locations are shown in Fig. 1A&B. Total aboveground biomass tissue samples at harvest and periodically during the growing season were taken and are currently being analyzed for total N content in order to determine fertilizer N use efficiency.

The rate of soil N_2O gas loss or efflux was also measured periodically over the growing season at the Greenley site for each N fertilizer treatment and landscape position. Soil N_2O gas was collected using small sealed chambers fitted with rubber septa inserted into PVC collars in the soil. The head space gas was collected from the chambers in the different treatments and analyzed by gas chromatography (GC).

Rainfall during the 2005 cropping year was relatively low during the growing season at both field sites with a long period of drought after the middle of July (Fig. 2 A&B). Despite similar cumulative rainfall (an average of 342 mm or approximately 13.4 in) at both sites, the Greenley site (Fig. 2A) had better rainfall distribution than the Centralia site (Fig. 2B), and, therefore, crop growth and crop N fertilizer response was greater at the Greenley site compared to that of Centralia.

Measurement of the spatial distribution of soil water content in the top 6 in depth at the Greenley site was undertaken prior to planting to evaluate whether measurements of elevation and EC_a would assist in predicting spatial differences in soil water content that might affect the fate of applied N fertilizer. Initial evaluation of the distribution of surface soil water content (Fig. 3), suggests that elevation may be a better predictor of spatial patterns of surface soil water content. However, this analysis did not take into account the possible effect of differences in soil water availability deeper in the soil profile on the fate of applied N fertilizer. In claypan soils, the amount of available water in the soil profile is probably affected by the depth to the claypan

layer which is a property related to soil EC_a.

At the Greenley site, visual symptoms of plant N deficiency were observed both in control plots and in low-lying areas, possibly due to water collecting in those areas from spring and early summer rainfall. However, lack of sufficient water for crop growth after the middle of June also affected corn growth response to added N fertilizer at both field sites. Grain yields at Greenley increased 19.9 to 46.2 bu/acre with added N fertilizer at the summit (shallow) and low-lying landscape positions (Table 1). The polymer-coated urea (ESN) and anhydrous ammonia had grain yields that were 24.4 and 23.5 bu/acre greater than urea in the low-lying area and had the highest yields of all the N sources in the low-lying area (Table 1).

Silage yields observed at the Centralia site were highest in the footslope (deep) area and no effects of the different N fertilizer sources were observed (Table 2). Relatively higher amounts of available water in the deeper soil profile during the drought period may account for the landscape response and lack of N response at the Centralia site.

Summary:

Both polymer-coated urea and anhydrous ammonia had higher grain yields compared to urea in the low-lying area at Greenley. However, there were no differences among these fertilizer sources at the other landscape positions, which suggests that response to N fertilizer source may vary across fields depending on landscape position.

Yield response at Centralia was apparently due to relative differences in soil water storage between soils with different depths to the claypan layer and not due to applied N sources. Surface application of the N sources at Centralia versus incorporation of N sources at Greenley may also have been a factor.

This first year of research indicates that the concept of variable source application may have some validity for N fertilizer management. However, further research is required under wetter climatic conditions when risk of N loss is higher.

Outreach and Training:

An undergraduate student majoring in soil science has been involved in working on this project as part of their training. The first year research results were presented at the 2005 American Society of Agronomy National Meetings and to growers and agricultural professionals at the 2005 Greenley Center Field Day in Northeast Missouri.

Objectives for Year 2:

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

1. To determine methods to delineate and map areas in fields which are more vulnerable to N loss due to wet conditions.
2. To examine the use of a *variable-source* strategy to optimize crop N fertilizer use efficiency.
3. To calculate the cost-effectiveness of using this *variable-source* strategy compared to uniform applications of conventional or other N fertilizer sources.

The field studies will be repeated for a second year to assess variation in climate on crop performance and N use efficiency in response to the differences between the two sites, the N fertilizer sources and the landscape positions that represent different elevations and depths to the claypan layer. In addition, we will be testing whether elevation and soil EC_a are useful predictors of differences in soil water in the field to allow for variable source applications of different N sources. An economic analysis will be also conducted to determine whether use of this strategy would be cost-effective for Missouri farmers.

Table 1. Effects of N fertilizer source and landscape position on corn grain yields at the Greenley site

N Fertilizer Treatment	Landscape Position: Summit	Sideslope	Low-lying	$LSD_{(0.05)}$
	--- bu/acre ---			
Control	73.6	72.3	71.0	NS
Urea	93.5	79.1	92.8	NS
ESN	94.0	73.9	117.2	29.5
ESN/Urea	95.1	77.2	104.2	NS
Anhydrous	100.6	88.7	116.3	24.1
$LSD_{(0.05)}$	8.7	NS*	19.6	

*NS = not significant

Table 2. Effects of N fertilizer source and landscape position on silage yields at the Centralia site.

N Fertilizer Treatment	Landscape Position: Summit (Shallow)	Footslope (Deep)	$LSD_{(0.05)}$
	--- tons/acre ---		
Urea	4.71	8.19	1.04
ESN	4.38	8.38	1.46
$LSD_{(0.05)}$	NS	NS	

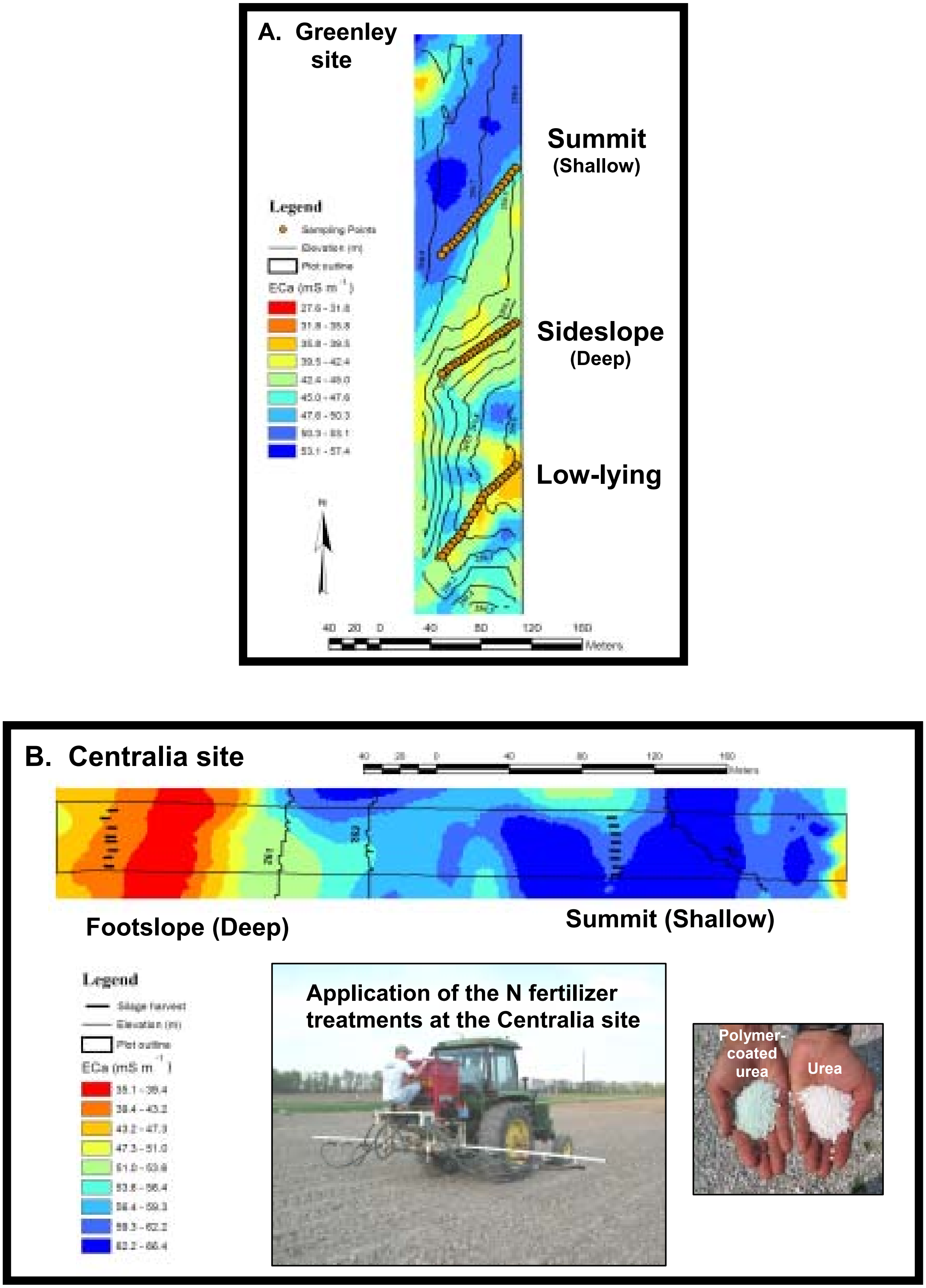

Fig. 1 A & B. Maps showing the spatial distribution of elevation and EC_a at the A) Greenley and B) Centralia farm sites. Circles in the Greenley site map show the location of the sampling collars for soil N_2O gas loss and the approximate location for the grain and silage harvests. The lines in the Centralia map show the location of the silage harvest.

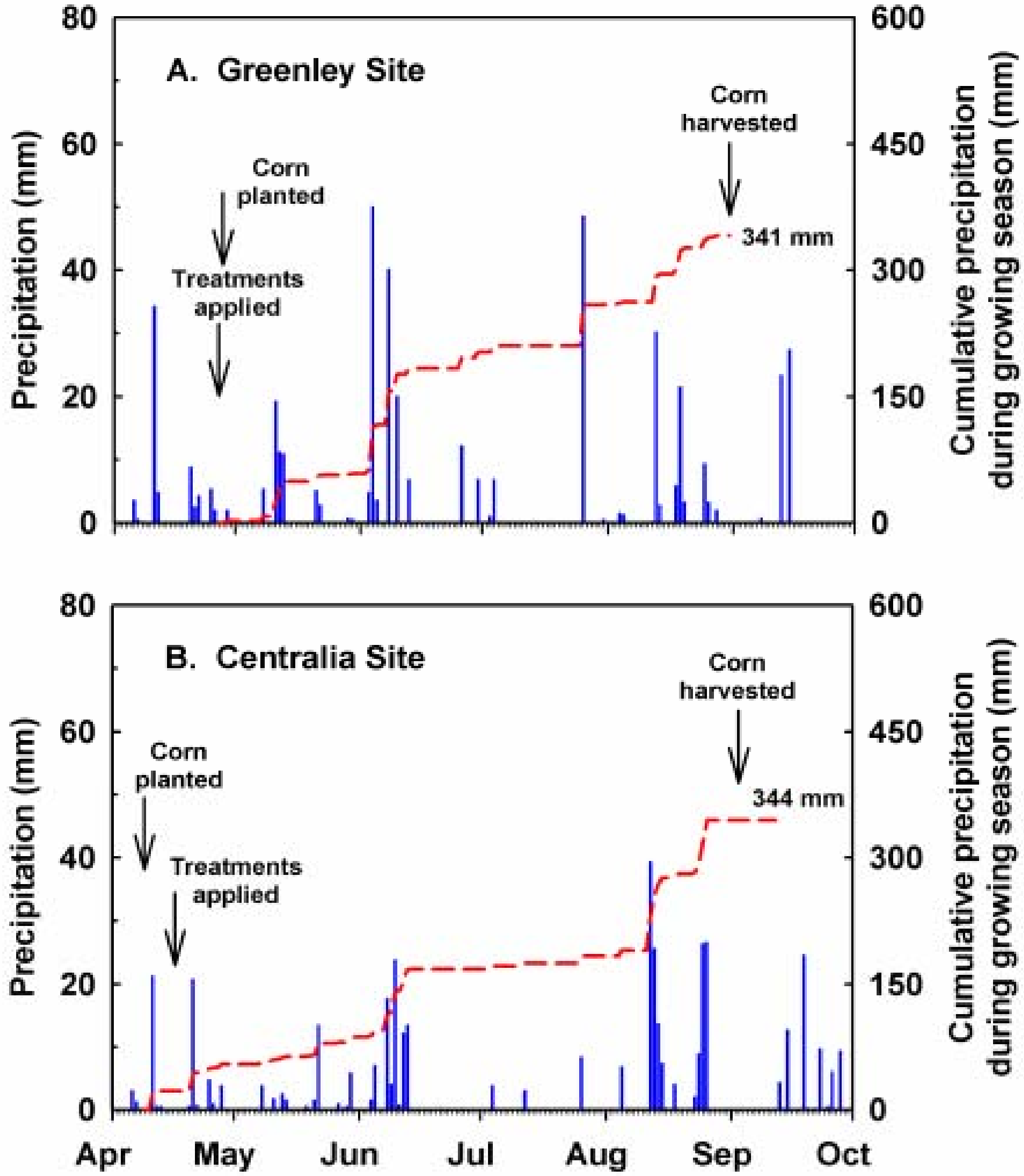

Fig. 2 A & B. Daily and cumulative precipitation at the A) Greenley and B) Centralia sites. Figures also show the times of important cropping events in relation to rainfall.

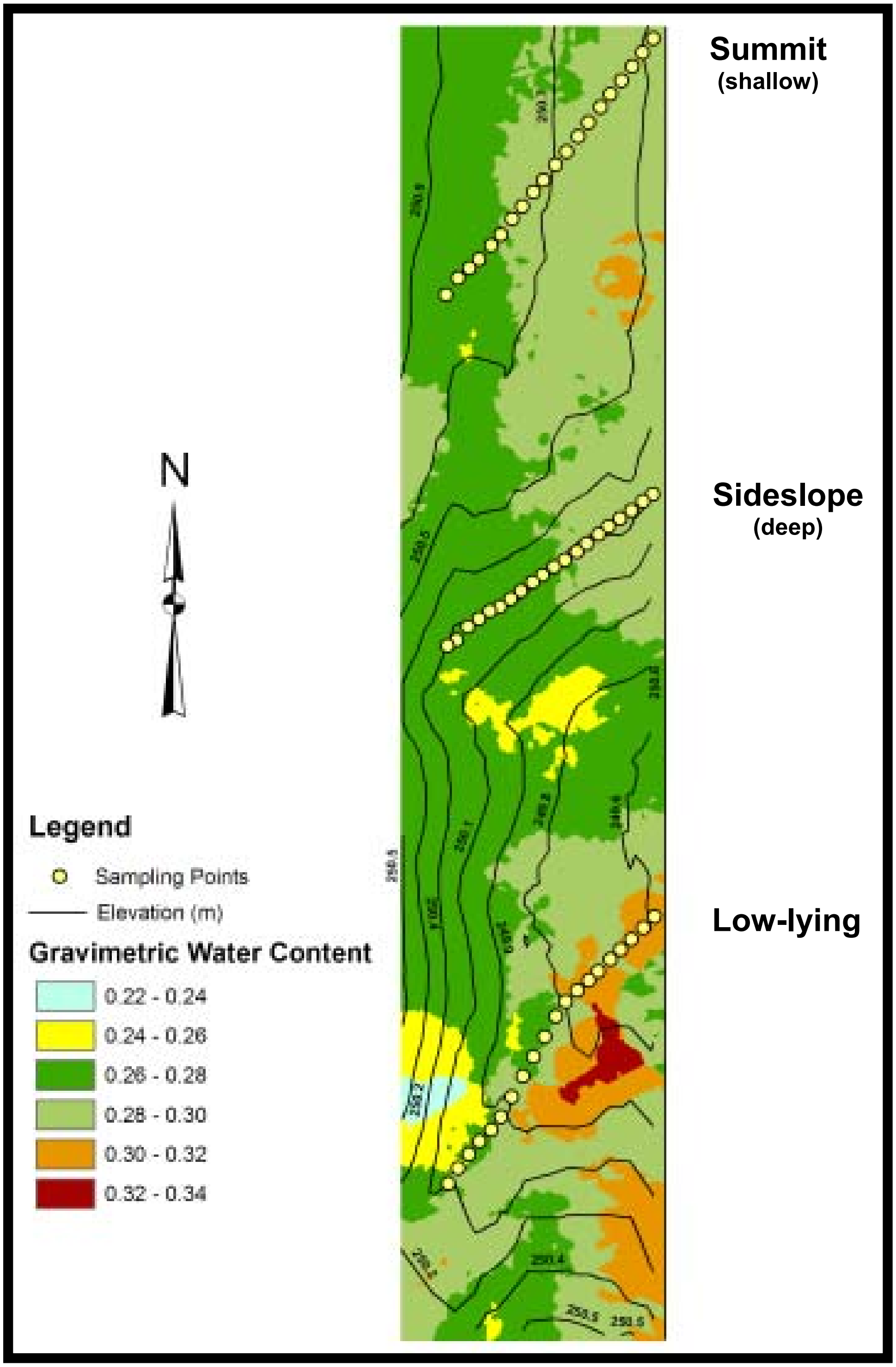

Fig. 3. Spatial distribution of soil gravimetric water content at the Greenley site on March 31st.

Proposed Budget for Year 2:

CATEGORIES	YEAR TWO
A. Salaries Research Technician (50%)	$13,390
B. Fringe Benefits Fringe for research specialist	$3,922
TOTAL SALARIES AND FRINGE BENEFITS	$17,312
C. Travel Travel to field site Travel to professional meeting	 $375 $300
TOTAL TRAVEL COSTS	$675
D. Equipment	$0
TOTAL EQUIPMENT COSTS	$0
E. Other Direct Costs Laboratory reagents and supplies Field supplies Publications/Documentation	 $2,000 $1,500 $500
TOTAL OTHER DIRECT COSTS	$4,000
TOTAL REQUEST	$21,987

Justification:
Salaries and Fringe Benefits: Funds are requested for support of a research technician (50% time@ $26,000/year the first year). Fringe benefits for the technician are 28.26% for the first year and 29.29% the second year.

Travel: Covers cost of travel to the Greenley Research Center and the two field sites at a rate of 37.5 ¢/mile. In the second year, $300 is requested to cover cost of travel and board for one researcher to attend a professional conference for presentation of results.

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

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

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

Rice Nitrogen Management- Rates and Timing of Urea Fertilizer

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

Managing nitrogen fertilization in rice fields can be challenging for producers. In drill-seeded rice, urea fertilizer is usually broadcast immediately before flooding. Depending on irrigation well pump capacity, field size, and weather conditions, urea can be lost by volatilization while a field is being flooded. Optimum N rates vary by rice variety, soil texture, and previous crop rotations. Nitrogen can also be lost by denitrification if the urea is converted to nitrate in the soil.

For many years, rice agronomists have tried to develop an accurate method of determining whether supplemental nitrogen is needed at internode elongation growth stage. The Plant Area Board has shown good correlation to rice yield response to mid-season N in experiments. However, few growers use it because it is time consuming and requires tedious calculations. Likewise, Minolta SPAD chlorophyll meters have been used successfully in N rice research projects but are too expensive for most growers and consultants.

Accomplishments in Year 1

Yardstick N test

In 2004, we developed and tested a new inexpensive method using an ordinary, wooden yardstick for monitoring rice plant N. The objective of the experiments was to develop critical threshold values using simple yardstick measurements that farmers can use to determine whether midseason N is needed on a rice field. Field tests were conducted at Glennonville, Missouri on a Crowley silt loam soil and Portageville, Missouri on a Sharkey clay soil. At each location, plots were drill seeded (7.5-in row spacing) with Francis and Cheniere varieties. A split-plot design was used with varieties in main plots and N treatments in subplots. Five pre-flood urea nitrogen rates were applied at 0, 35, 70, 105 and 140 lb N/acre. One half of the subplot treatments received mid-season N and one half did not receive additional N. Subplots with mid-season N received 30 lb urea N/acre at internode elongation plus 30 lb urea N/acre one week later. Plots were mechanically harvested with a combine. Rice yields for each pre-flood N rate subplot without midseason N were subtracted from yields in pre-flood N rate subplots with midseason N.

Visual observations with a yardstick were made at green ring growth stage. Two center rows from each plot were selected. A wooden yardstick was placed halfway between the rice rows on the surface of floodwater. (The yardstick was positioned parallel to the rows.) Standing between adjacent rows and leaning over the sampling rows, we counted the inch numbers showing on the yardstick (not hidden by rice leaves) out of the 36 places possible. Two digit inch numbers were counted as one place. When a rice leaf obstructed the view of either of two digit numbers, we did not count that place.

<u>**Rice Yields**</u> **Averaged across varieties, soils, and years; rice yields were highest when 140 lb N/acre was applied before flooding with no midseason N applications (Table 1). In seven out of eight (2 varieties X 2 soils X 2 years) field observations, midseason N reduced rice yields in main plots with 140 lb N/acre applied preflood. The one exception occurred on the Sharkey clay soil in 2004 when midseason N increased Francis rice yields at all preflood N rates. The greatest yield reduction (-61 bu/acre) occurred when midseason N was applied following the highest preflood N rate on freshly graded Sharkey clay in 2005. Poor harvesting efficiency from plant lodging contributed to the yield loss. Winds from the aftermath of Hurricane Katrina caused lodging in some plots at both locations. On the fresh cut field, lodging in plots with mid-season N following 140 lb urea N/acre preflood was 62%**

compared with only 3% in plots without mid-season N (Figure 1). For all environments, rice yield increases from midseason N applications following 0 and 30 lb urea N/acre pre-flood ranged with +9 to 23 bu/acre. In the mid-range of preflood N rates tested, rice yield responses from midseason N following 70 and 105 lb N/acre pre-flood varied by environment. Midseason N yield response in these treatments ranged from –37 to +16 bu/acre.

Yardstick. Yield response to mid-season N was correlated with yardstick observations made at green ring (Figures 1 and 2). In 2004 and 2005, 12 numbers showing on a yardstick was the critical level for applying midseason to Cheniere on Crowley silt loam soil (only 2005 results shown). In other words, when fewer than 12 digits were showing little or no positive yield response to midseason was found. Twelve was also the critical midseason yardstick value for Francis in 2004. However, since Francis grew taller than Cheniere, it was more prone to lodge from the 2005 winds resulting from hurricanes. In 2005 on the Crowley silt loam soil, Francis plot yields were increased from midseason only when greater than 18 numbers were showing on a yardstick. In 2005 on the freshly graded Sharkey clay soil, Francis and Cheniere yields were increased only when greater than 23 numbers were showing on a yardstick. Disturbing the Sharkey clay soil during the land grading process in the previous year, may have promoted above average N mineralization from soil organic matter in 2005 on the Sharkey clay, which would explain the lodging and lack of positive yield response to midseason N.

Summary One application of 140 lb urea N/acre applied before flooding produced the highest rice yields in this study. If a rice farmer suspects that significant preflood N has been loss in his field by urea volatilization, denitification, or water loss from a leaky levee, visually counting the numbers showing on a yardstick placed between rice rows at green ring may be helpful for making midseason N decisions. We found that the most consistent critical yardstick value for making midseason N decision was twelve. Zero or negative rice yield responses were found from midseason when fewer numbers were showing. However, if rice is grown on a freshly graded field or a field with a history of lodging, midseason N may not be beneficial to rice yields unless fewer than 18 to 23 digits are showing at green ring.

Low population N test

A field test was conducted at the Missouri Rice Research Farm in Glennonville, Missouri on a Crowley silt loam soil and the University of Missouri-Delta Center in Portageville, Missouri on a Sharkey clay soil and. The objective was to evaluate the yardstick method in sub-optimum rice plant densities in fields. The field was graded in the spring of 2004 and planted in soybeans. In 2005, rice plots were drill seeded (7.5-in row spacing) with Wells cultivar at seeding rates of 5, 15, 25, and 35 seeds ft^2. Three pre-flood nitrogen treatments were applied at 45, 90, and 135 lb urea N/acre. One half of the treatments received mid-season N while the other half received no mid-season applications. Plots with mid-season applications received 30 lb urea N/acre at internode elongation plus an additional 30 lb N/acre one week later. Plots were mechanically harvested with a combine.

Two methods of measuring leaf canopy were tested. For the first method, we used a macro developed at University of Arkansas for Sigma Scan™ image software to evaluate digital pictures based on the percentage of green leaf material in a given area. Digital photos were taken from each plot during the GR growth stage. A digital camera was positioned on 5-ft rod held at a 45-degree angle above the plot. Photos were taken at a downward angle over the rice rows. Photos were analyzed using Sigma Scan to determine the percentage of pixels in each picture that appeared green in color (near 510 nm in wavelength). For the second method, visual observations with a yardstick were also made at GR growth stage. The same procedure was used as in the “yardstick test” above.

Rice yields. Crop yield response to mid-season N decreased as pre-flood N rates increased. Averaged across seeding rates, midseason N increased yields 23 bu/acre at 45 lb N/acre pre-flood rates. However, at 135 lb N/ acre pre-flood, midseason N caused yields to decrease 10 bu/ acre. At the 5 seeds ft^2 seeding rate, plots with 45 lb N/acre pre-flood yielded significantly less than the 90 and 135 lb N/acre pre-flood N rates. At the 35 seeds ft^2 rate, no significant difference in yields was found between pre-flood nitrogen treatments. Also, no significant interaction between mid-season nitrogen applications and seeding rates was found. At the 90 and 135 lb N/acre preflood N application rates, lodging increased as seeding rates increased. Lodging was 25% at the 135 lb N/acre pre-flood compared to 7% at 90 lb N/ acre and 0% at 35 lb N/ acre.

Yardstick. In rice plots, numbers showing on the yardstick and leaf area percentages measured with digital photos processed in Sigma Scan were strongly correlated (R^2 = 0.998). This validated that the yardstick method was an accurate indicator of rice leaf canopy development at green ring growth stage. Averaged across N treatments, at the lowest seeding rate (5 seeds ft^2) percent leaf canopy at GR from digital photos was 40%. At higher seeding rates, percent canopy at GR was 65 to 80 %. The highest rice yields that we measured were when percent leaf canopy and yardstick numbers showing at GR were 60% and 15, respectively.

Objectives for Year 2

We will continue the rice nitrogen experiments in 2006 at the University of Missouri-Lee Farm and Missouri Rice Research Farm. In 2006, we will also study slow release urea N in rice-after-rice fields.

Table 1. Rice yields as affected by urea preflood and midseason nitrogen rates at the University of Missouri-Lee Farm at Portageville, Missouri on a Sharkey clay soil.

		Francis				Cheniere			
Nitrogen applications		2004		2005		2004		2005	
Preflood	Mid-season	total	change	total	change	total	change	total	change
-----lb N acre^{-1}-----		---------------------------------bu acre^{-1}---------------------------------							
0	0	113	+12	169	+11	110	+20	175	7
0	30+30	125		180		130		182	
35	0	110	+9	191	+7	129	+19	194	-7
35	30+30	119		199		148		187	
70	0	118	+10	212	-12	134	+11	200	-19
70	30+30	128		200		145		181	
105	0	125	+12	208	-24	138	+5	205	-37
105	30+30	137		184		143		168	
140	0	138	+5	202	-18	145	-15	185	-61
140	30+30	143		184		130		124	

Table 2. Rice yields as affected by urea preflood and midseason nitrogen rates at the Missouri Rice Research Farm at Glennonville, Missouri on a Crowley silt loam soil.

		Francis				Cheniere			
Nitrogen applications		2004		2005		2004		2005	
Preflood	Mid-season	total	change	total	change	total	change	total	change
-----lb N acre^{-1}-----		---------------------------------bu acre^{-1}---------------------------------							
0	0	142	+22	125	+26	141	+23	134	+29
0	30+30	164		150		164		163	
35	0	172	+19	148	+24	151	+22	146	+35
35	30+30	191		172		173		181	
70	0	185	+16	172	+25	175	+4	165	+24
70	30+30	201		197		179		190	
105	0	202	+2	186	-12	182	-7	169	+29
105	30+30	204		174		175		198	
140	0	211	-17	207	-4	175	-13	194	-17
140	30+30	194		203		162		177	

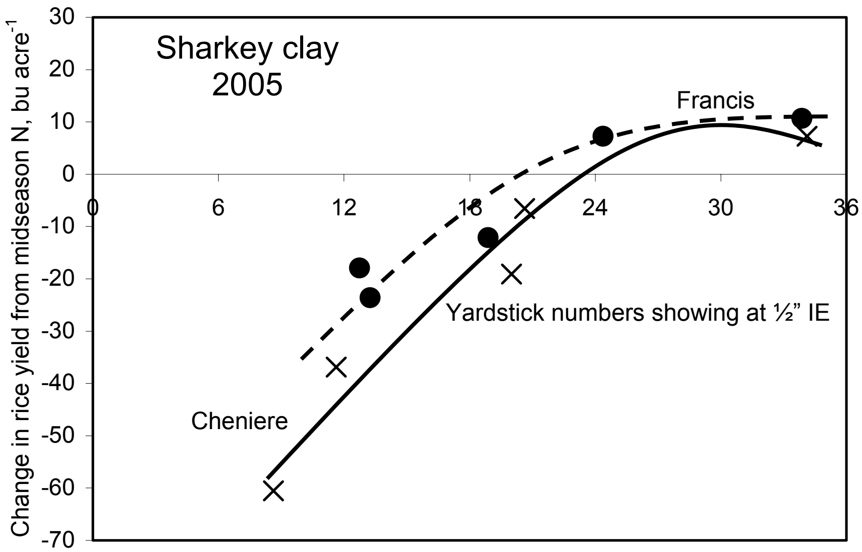

Figure 1. Change in rice yields (+ and -) from applying 30 lb N acre^{-1} at IE followed by 30 lb N acre^{-1} one week later as correlated to numbers visible on a yardstick placed between drill rows at green ring on a Sharkey clay loam soil in 2005 at Portageville, Missouri. Significant lodging was observed at high N rates and average rice yields were 186 bu acre^{-1}.

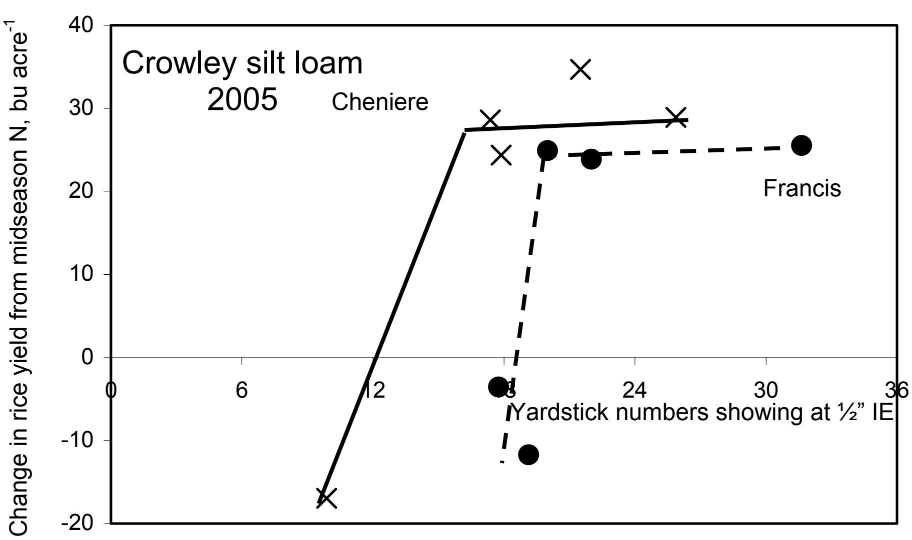

Figure 2. Change in rice yields (+ and -) from applying 30 lb N acre^{-1} at IE followed by 30 lb N acre^{-1} one week later as correlated to numbers visible on a yardstick placed between drill rows at green ring on a Crowley silt loam soil in 2005 at Glennonville, Missouri. No lodging was observed and average rice yields were 172 bu acre^{-1}.

Table 3. Effect of rice seeding rate, preflood N and mid-season on lodging, leaf canopy at green ring growth stage and rice yields at the MU Delta Research Center in 2005.

	Mid-	Plant			Green ring		
Preflood	season	seed	Lodging	Ht	Yardstick	Leaf	Bu/a
lb N/acre	applied	#/ft^2	%	in	showing	Canopy[1]	
45	no	5	0	24	27	36%	119
45	yes	5	0	24	29	30%	130
90	no	5	0	24	21	41%	155
90	yes	5	0	26	20	42%	157
135	no	5	0	24	26	44%	151
135	yes	5	0	24	25	37%	134
45	no	15	0	25	23	51%	172
45	yes	15	0	26	19	66%	180
90	no	15	0	26	17	67%	171
90	yes	15	3	26	14	69%	175
135	no	15	31	28	14	73%	153
135	yes	15	60	27	11	73%	130
45	no	25	0	24	24	62%	143
45	yes	25	0	26	18	64%	187
90	no	25	0	26	18	64%	168
90	yes	25	3	27	14	72%	190
135	no	25	61	29	8	83%	149
135	yes	25	46	28	9	79%	152
45	no	35	0	26	19	68%	166
45	yes	35	0	26	16	74%	196
90	no	35	13	26	11	84%	169
90	yes	35	38	28	8	83%	175
135	no	35	5	29	12	84%	169
135	yes	35	3	27	10	80%	166

Measured from digital photo and analyzed with Sigma Scan software.

Table 4. Effect of rice seeding rate, preflood N and mid-season on lodging, leaf canopy at green ring growth stage and rice yields at the Missouri Rice Research Farm in 2005.

Preflood	Mid-season	Plant seed	Ht	Green ring yardstick	Yield
lb N/acre	applied	#/ft^2	in	showing	bu/acre
45	no	5	23	36	15
45	yes	5	23	35	21
90	no	5	24	35	28
90	yes	5	18	36	29
135	no	5	24	36	25
135	yes	5	24	36	34
45	no	15	26	25	148
45	yes	15	28	21	200
90	no	15	30	21	163
90	yes	15	27	20	229
135	no	15	31	19	207
135	yes	15	28	21	216
45	no	25	28	24	192
45	yes	25	28	22	208
90	no	25	32	9	215
90	yes	25	32	10	245
135	no	25	32	13	248
135	yes	25	33	12	239
45	no	35	28	15	201
45	yes	35	29	18	222
90	no	35	31	15	221
90	yes	35	31	18	237
135	no	35	34	13	227
135	yes	35	32	11	245

Proposed budget:

Expenses	2005	2006	2007
Res. Specialist salary (0.4)	$11,200	$11,648	$12,114
Fringe benefits	$2,800	$2,912	$3,028
Supplies	$1,500	$1,560	$1,622
Travel	$2,000	$2,080	$2,163
Total	$17,500	$18,200	$18,928

Phosphorus Management

Enhancing Macronutrient Concentrations in Stockpiled Tall Fescue with Phosphorus Fertilization

Dale Blevins and Will McClain
Division of Plant Sciences
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Abstract

Tall fescue (*Festuca arundinacea*) is a popular cool season grass used for beef production. Stockpiling tall fescue pasture is recommended for extending the grazing season and reducing winter-feeding costs. Our previous work indicated that stockpiled tall fescue leaves had low concentrations (< 0.2%) of P and magnesium (Mg) in late winter even after applications of 25 lbs P/acre. The objective of this study was to determine if high rates of P fertilization would maintain leaf P and Mg concentrations above the target 0.2% required by lactating beef cows throughout the stockpiling period. Leaf concentrations of P, Mg, and calcium (Ca) were higher with P fertilization than those of the untreated controls. The 200 lbs P/acre treatment maintained leaf P and Mg concentrations at or above the target 0.2% level during the first year of the experiment. The leaf concentrations of P, Mg, and potassium (K) declined from October to February with all treatments. The decrease in leaf concentrations of phloem mobile elements like P, Mg, and K may be the result of nutrient remobilization from leaves to roots during the late fall and early winter as strategy to provide support for next springs growth.

Introduction

Tall Fescue (*Festuca arundinacea*) is a popular cool season grass used for beef production. Stockpiling tall fescue is recommended for extending the grazing season and reducing winter-feeding costs. The hardy nature of tall fescue and its ability to maintain growth with the onset of cooler temperatures as well as its wide range of adaptability for soil types and climatic conditions make it excellent forage for stockpiled systems (19,18,13).

Tall fescue persists with little or no management owing to its adaptability, nevertheless on many soils yields can be enhanced by fertilization. Gerrish et al. (8) increased yields of stockpiled tall fescue up to 35% with nitrogen (N) fertilization. Although Archer and Decker (1,2) stimulated growth and crude protein (CP) of tall fescue with N fertilization, overall forage quality was not affected. More recently, Singer et al. (17) found that a late season application of N increased the quality and quantity of stockpiled tall fescue. These researchers pointed out, however, that harvests delayed beyond October could incur losses to quality as well as yield.

In Missouri, the majority of pasture soils are low in plant available phosphorus (P) (9). Forage production on such soils may impact the nutrient concentrations of stockpiled tall fescue leaves. Studies in Tennessee and West Virginia found that nutrient concentrations in tall fescue leaves declined through the winter months (4,14,15,6,7). Previous work by Reinbott and Blevins (12,13) indicated that P fertilization improved nutrient concentrations in tall fescue leaves in southwest Missouri. However there are no reports of fertilization on improvement of nutrient quality of stockpiled tall fescue.

Currently beef producers compensate for nutrient deficiencies in forages by supplementing the diets of livestock grazing in winter and early spring. Managing pastures in a practical and cost effective manner that improves the nutrient concentrations in tall fescue leaves would benefit beef producers in regions with low soil P. Therefore the objective of this research is to improve the nutrient concentrations of stockpiled tall fescue during winter and early spring with P fertilization.

Setting Up a Stockpiled Tall Fescue Field Study

The two-year study was conducted on an established tall fescue pasture at the University of Missouri Southwest Research Center near Mt. Vernon, Missouri (37º 04'N 93º 53'W elevation 1150 ft) on a Creldon silty clay loam (fine, mixed,

active, mesic, Oxyaquic, Fragiudalf). The site was typical of southwest Missouri in that the soil is low in plant available P, 7 lbs/acre Bray I, and had the following test results: pH 5.3; O.M.2.8 %; Ca 2748 lbs/acre; Mg 280 lbs/acre; and K 446 lbs/acre.

Treatments. In August the forage was removed from the pasture and 10' x 25' plots with 5' alleys were laid out in six replicate blocks. Treatments consisted of 0, 50, 100, and 200 lbs P/acre in the form of triple super phosphate (46% P_2O_5). Each treatment was randomly applied to plots in all six blocks and the entire area received 100 lbs N/acre in the form of ammonium nitrate. In August of the second year of the experiment, the forage was again removed and a 100 lbs N was applied. At the end of each year, soil samples were taken to determine the changes in soil P.

Harvests and Mineral Analyses. Beginning in mid-October through April of both years, twenty of the most recently collared leaves were harvested from each plot. All samples were oven dried, ground, and digested in nitric acid with a microwave accelerated digestion system (5). Digested samples were filtered, diluted, and analyzed for nutrient content. Potassium was determined by flame ionization, Ca and Mg by atomic absorption, and P by colorimetric analysis. In November of the first year ten of the most recently collared leaves were measured for each plot.

Statistical Analysis. The experiment was a completely randomized blocks design analyzed as a split-split plot in time model with repeated measures. This model was used to test for statistical significance of P treatment effects as well as interactions with month using PROC MIXED in SAS version 9.1 (16). Main plot consisted of P treatment; harvest date was considered the split plot and year the split-split plot. Fertilization treatment was a fixed effect factor and year, month, and block were treated as random factors.

Macronutrients in Stockpiled Tall Fescue Leaves

Leaf Growth in Response to P Fertilization. In fall of the first year of this study, P fertilization produced remarkable tall fescue leaf growth (Fig. 1). Leaf growth exhibited an increasing response to all P treatments, with the leaves from the 200 lb P treatment being twice as long as those from the untreated control plots (Fig. 2). It is possible that the Creldon soil in this pasture, with high concentrations of aluminum, manganese, and iron may be influenced by high rates of P fertilization, in that P could ameliorate the toxic effects of these metals.

Phosphorus. Across all months of fall, winter and spring, leaf P concentrations were higher with P fertilization treatments compared to the untreated controls (Fig.3). With all treatments, leaf P levels decreased from October to February in the first year of the study. This trend is also seen in the second year of the study, except the decline lasted until March. The drop in leaf P concentrations in late winter and early spring may be the result of remobilization of P for utilization the following spring.

Leaves from untreated control plots had P concentrations that were well below the 0.2% required by grazing lactating beef cows (10). During the first year both the 100 and 200 lb P treatments produced leaf P concentrations above the 0.2% critical level each month. However, in the second year all P treatments were at or below this level in mid February and March. Insufficient forage P could result in reduced milk production and in turn lower calf weaning weights. This is an important consideration for producers in areas were soil P levels are low.

Magnesium. Magnesium concentrations of tall fescue leaves were higher with P fertilization treatments compared to control plots and the leaf Mg declined from October to March for both years (Fig.4). In the second year, there was a slight increase in Mg concentrations from December to February for all treatments. Control plots had leaf Mg levels below the 0.2% value required for the diets of lactating beef cows for winter months of both years (10). Again, as with leaf P concentrations, the two highest P treatments maintained Mg levels at or above the critical 0.2% level for the first year. During the second year both of the highest P treatments had two months were the leaf Mg values fell below this level (December and March). Perhaps one of the more notable findings from these data is that leaf Mg concentrations of stockpiled tall fescue can be improved through P fertilization. While the effects of high P treatments did not carryover to the second year, producers would only have to worry about supplementation for one or two months as opposed to several in the late winter and early spring. Therefore, beef producers might be able to reduce incidences of grass tetany by improving the amount of available P in their soils.

Calcium. Tall fescue leaf concentrations of Ca were lower in this study than in previous studies conducted in this area (McClain and Blevins, unpublished). However, the P fertilization treatments produced higher leaf Ca concentrations than those of untreated controls (Fig. 5). Both the 50 lb P treatments and the controls had leaf Ca concentrations below the 0.3% required by grazing lactating beef cows (10). While most efforts for alleviating the incidence of grass tetany have focused on improving Mg in the forage, it should be noted that leaf Ca concentrations are also important and might be a larger factor in occurrence grass tetany in southwest Missouri. Also, Ca deficient forage can lead to “milk fever” in grazing cattle. Although this metabolic disorder is less common in beef cows, it should still be considered in managing a beef herd’s health.

Potassium. Leaf K concentrations decreased from October to February in plots from all treatments (Fig. 6). During the first year, leaf K concentrations were higher with P fertilization treatments compared to control plots, however in the second year there was no difference across P treatments. For all P treatments the leaf K concentrations remained below 0.3% from December through April. Cases of grass tetany have been associated with high K concentrations of the forage (21). Therefore, the second year’s data would suggest a reduced risk of grass tetany based on the leaf K concentrations.

Soil Test Results. Soil samples taken after the first year, indicated that much of the P fertilizer added to plots was “sorbed” most likely by aluminum, iron, and manganese present in this Creldon soil (Table 1). The build up in Bray II levels is a good indication of how important P is in forage production in this area. While the higher P treatments did improve the Bray I soil P it is most likely that over time these levels will return to normal. Improving soil P might help producers alleviate several nutrient disorders seen in livestock as well as improving forage yield and quality.

Conclusions

Phosphorus fertilization improved the nutrient concentrations in stockpiled tall fescue leaves compared to controls. The higher rates of P fertilization maintained P and Mg leaf concentrations at or above the requirements for lactating beef cows in late winter and early spring. The results show a decline in nutrient concentrations in tall fescue leaves in late fall and winter, and an increase as spring growth begins. The drop in leaf nutrient concentrations between October and February may result from nutrient remobilization from leaves to rhizomes and roots during late fall and winter as a storage mechanism. Leaching of nutrients from leaves is another possibility. In alfalfa it is well established that N stored as amino acids and soluble proteins in tap roots is used to support early spring growth (3,20). Remobilizing nutrients to the underground structures of the plant is a strategy tall fescue might employ to have nutrient pools available for spring growth when nutrient acquisition is slow.

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Figures

Figure 1. Experimental plots of stockpiled tall fescue in 0 and 200lbs P/acre.

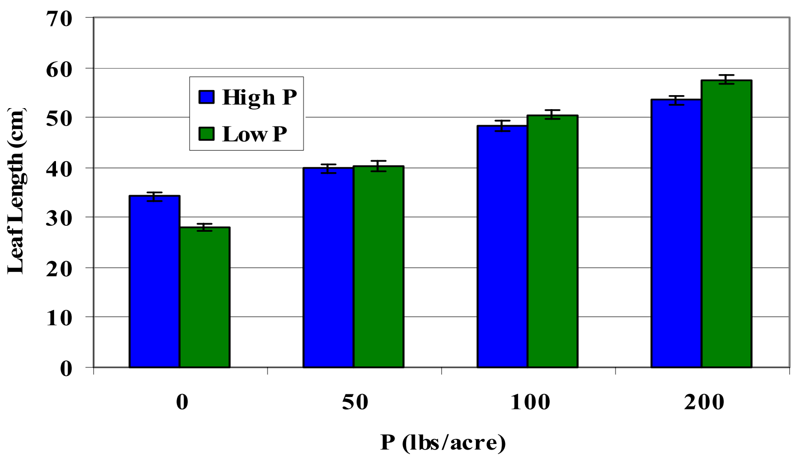

Figure 2. Leaf length (cm) of the most recently collared tall fescue leaves in November 2003 following P fertilization. Means± S.E. (n = 10) for each plot.

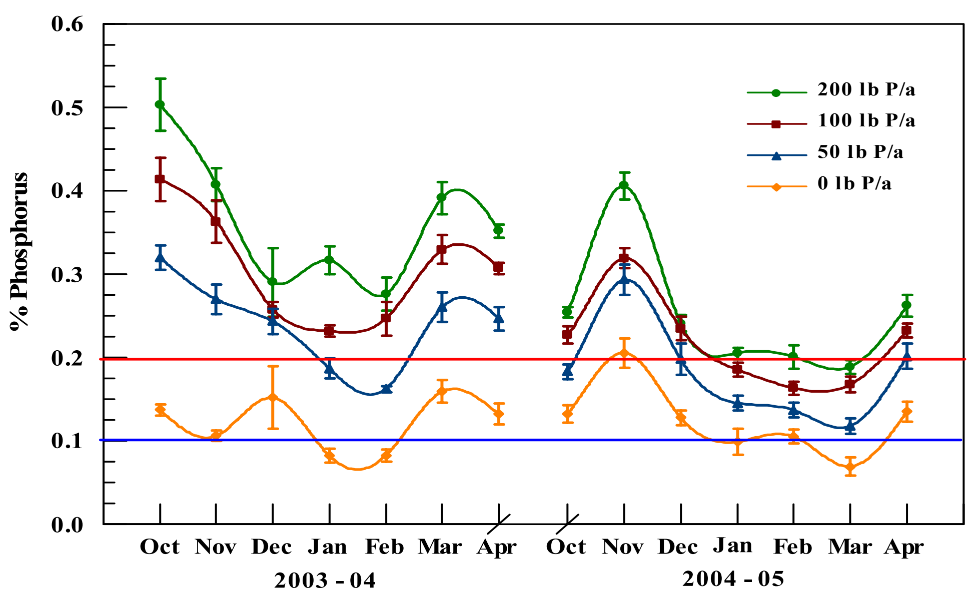

Figure 3. Phosphorus concentrations of stockpiled tall fescue leaves treated with 0, 50, 100, or 200 lbs P/acre. Means ± S.E. (n = 6) for each month.

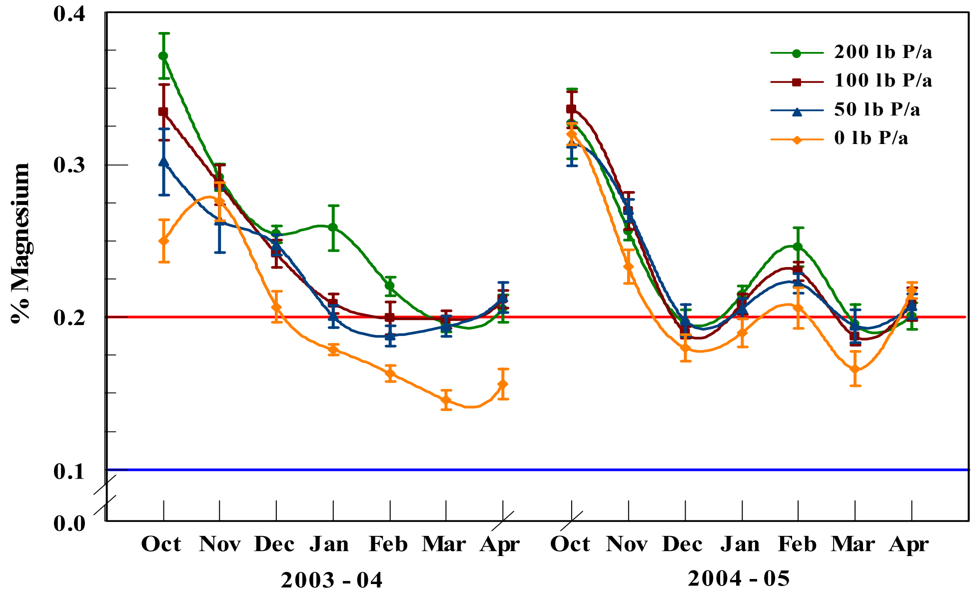

Figure 4. Magnesium concentrations of stockpiled tall fescue leaves treated with 0, 50, 100, or 200 lbs P/acre. Means ± S.E. (n = 6) for each month.

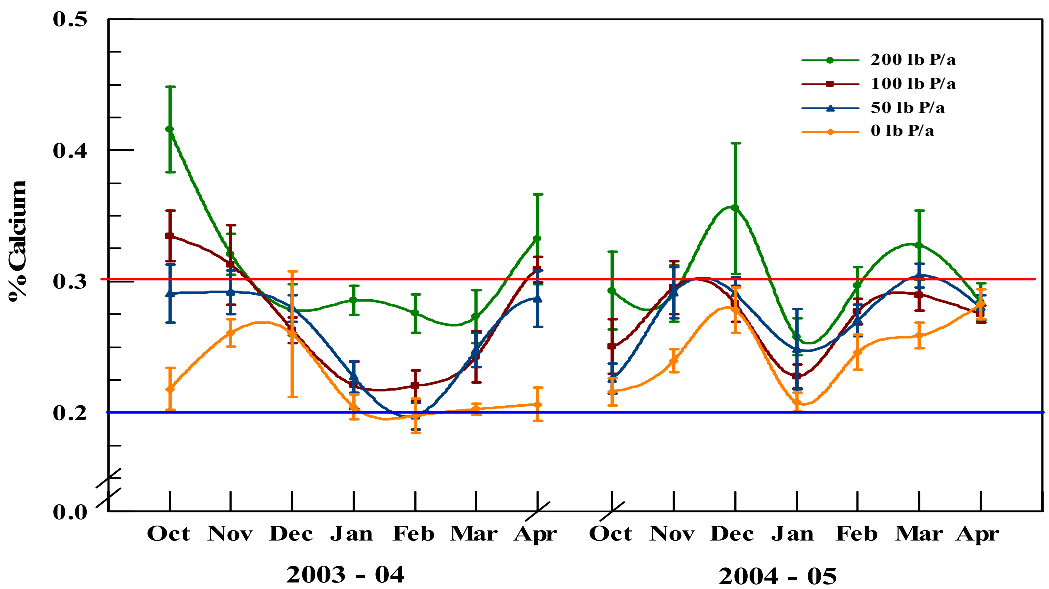

Figure 5. Calcium concentrations of stockpiled tall fescue leaves treated with 0, 50, 100, or 200 lbs P/acre. Means ± S.E. (n = 6) for each month.

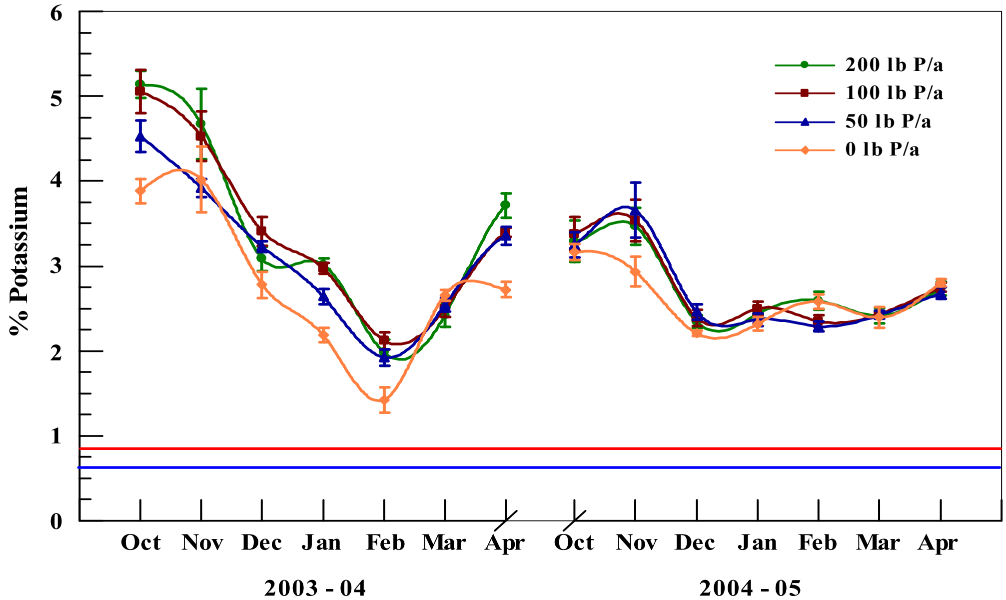

Figure 6. Potassium concentrations of stockpiled tall fescue leaves treated with 0, 50, 100, or 200 lbs P/acre. Means ± S.E. (n = 6) for each month.

Table 1. Soil test results following completion of the first year. Means (n = 6) for all plots.

P (lbs/Ac)	pHs	N.A. (meq/100g)	% O.M.	Bray I P (lbs/Ac)	Bray II P (lbs/Ac)	Ca (lbs/Ac)	Mg (lbs/Ac)	K (lbs/Ac)	CEC (meq/100 g)
0	5.55	1.92	2.87	7.17	22.83	1743.2	259	330.3	7.78
50	5.28	2.58	3.00	16.33	42.33	1810.5	245	292.0	8.50
100	5.33	2.67	2.97	23.50	61.33	1932.5	257	297.3	8.93
200	5.23	2.92	2.92	68.83	175.50	1857.0	264	277.8	9.02

Phosphorus Fertilization of Tall Fescue Pastures ImprovesRate of Gain and Weaning Weight of Beef Calves in Missouri

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Objectives: To increase the rate of gain and weaning weight of nursing beef calves in Missouri.

Procedure: Several large tall fescue (K31, endophyte infested) pastures were selected at the Forage Systems Research Center near Linneus in March, 2005. Pasture selection was based on low to moderately low soil Bray I phosphorus analysis (Table 1). Pastures were also selected and organized into treatments groups that would be located close together for convenient pasture rotation (Figure 1). Treatments were 0 or 50 lbs P/acre, 100 lbs N/acre/yr and K was added as recommended by the soil test results. All pastures were supplied with salt blocks containing only NaCl. At least four replicated pastures were selected for each treatment and pastures size averaged about 15 acres. In the original proposal, I stated that each pasture will be supplied with at least six beef cow/calf pairs (crossbred cows with Red Angus calves). But we decided that it would be easier and cost much less for fencing and management to use most of the FSRC herd in this study, consequently, we used 150 cow/calf pairs Therefore, each replicate treatment had 25 cow/calf pairs and at least four different pastures. Calving of this herd actually began around February 15 and ended around March 15. About 90% of the calves were siblings from the same (AI) red Angus bull. Cows were preconditioned on the same large stockpiled tall fescue pasture for at least four weeks prior to the beginning of this experiment. On April 14, 2005, cows and calves were weighed and placed the appropriate pastures. Stocking rates were adjusted to produce similar grazing pressures on the various pastures. The amount of forage available was determined by using 50 different measurements with an Elinbank Rising Plate meter. The forage meter readings were calibrated with monthly forage harvests taken with a flail-type forage harvester. Using the forage harvester, we harvested, weighed and sub-sampled forage from ten 32” x 15’ cuts from one pre-grazed pasture and one post-grazed pasture in each replicate set of pastures. Sub-samples grabbed from each of the 10 harvested samples harvested were pooled, dried, and stored for determination of quality components and mineral elements. The cows and calves were to be weighed monthly for six months or at least that was the plan. The study was terminated after four months because of drought conditions. Even though we had included extra pastures in the study, the severe dry weather resulted in almost no available forage for grazing in August. Therefore we had to terminate the study after four months, instead of the proposed six months.

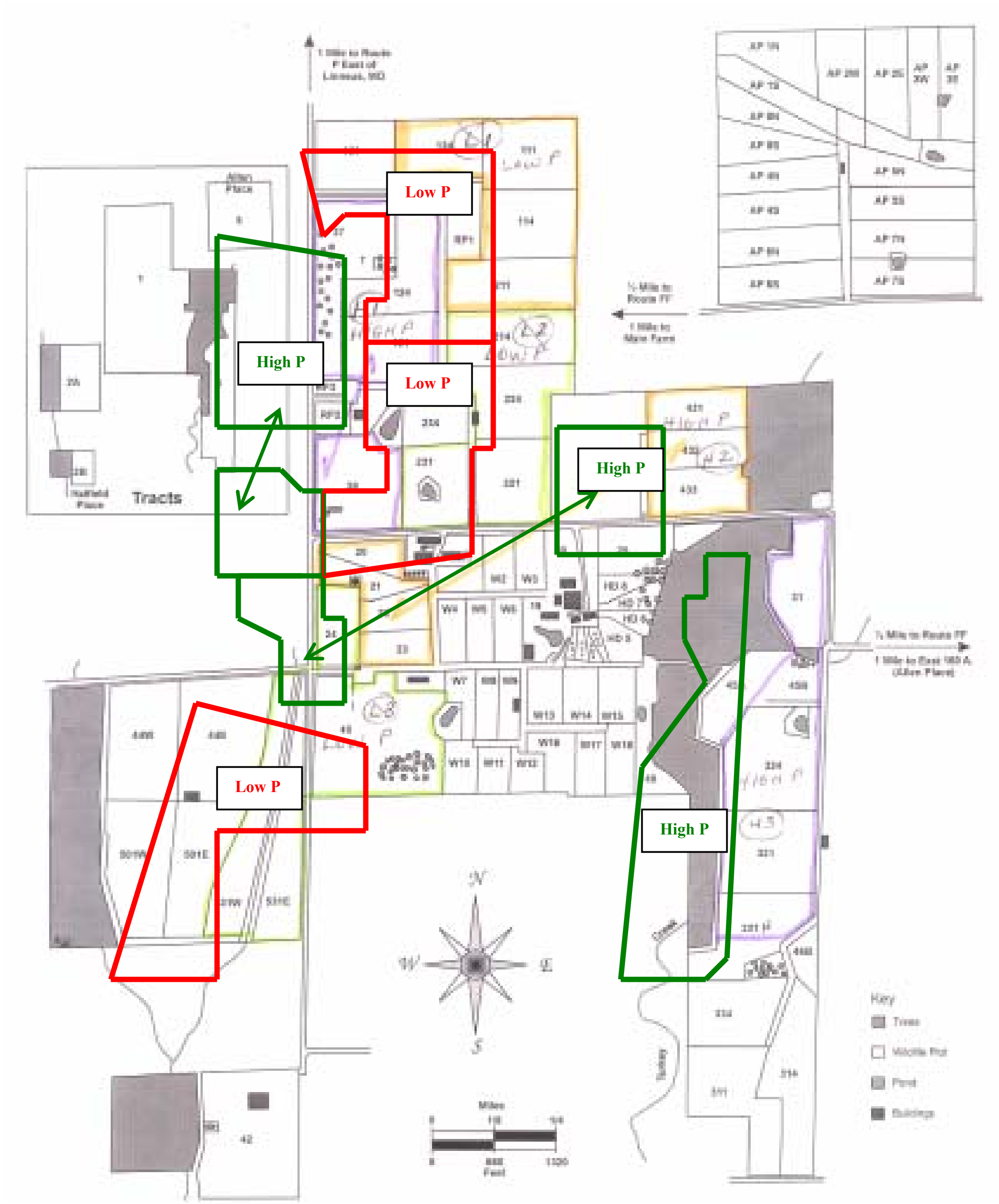

Figure 1. Plot map of the 2005 cow/calf phosphorus study at the Forage Systems Research Center near Linneus, Missouri.

Results

The Forage Systems Research Center is an excellent site for this type of research. We were able to locate adequate number of low P pastures on the farm to accommodate this large scale study (Figure 1). This farm has a great cow herd and the genetics of the calves is top-notch, plus the facilities are readily available for weighing the cows and calves frequently. Also, agronomists and animal scientists are available for helping collect forage samples, for rotating pastures, and for weighing and caring for the cattle. One difference between this study and the preliminary study that we had conducted at the SW Center near Mt. Vernon, was the cows in this current study calved earlier, therefore calves went into the P study when they were over one month of age. At the SW Center calves were actually born around the day the experiment began. The major problem with the study this year was the lack of rainfall. The lack of precipitation may have nullified the usefulness of the P fertilization, and by July, had lowered the soil test K levels in many of the pastures (Table 2). There were no P treatment differences in rate of gain or final weight of the calves cows on this year (Tables 2 & 3). We are currently analyzing the most recent soil test data to re-evaluate each pasture in the study to make sure that pastures in the low P treatments are really low enough for the study. We are also calculating total NPK needs for each pasture for the second year. Another 50 lbs of P will be added to the high P pastures, but we are trying to determine how much K to add to pastures in order to make them equivalent in K levels.

Table 1. March 27, 2005 soil test data from pastures used in the phosphorus cow/calf study at the Forage Systems Research Center. Each value is the mean of data from all of the pastures within a particular treatment group, usually at least four different pastures.

P Treatment	**pH**	**Bray I P lbs/acre**	**Bray II P lbs/acre**	**Ca lbs/acre**	**Mg lbs/acre**	**K lbs/acre**
Low 1	5.50	19	78	4012	468	268
Low 2	5.53	23	144	4259	518	276
Low 3	5.90	25	172	3339	329	291
High 1	5.78	33	199	3706	420	331
High 2	5.55	50	225	3599	408	315
High 3	6.35	26	215	4016	388	315

Table 2. July 27, 2005 soil test data from the pastures used in the phosphorus cow/calf study at the Forage Systems Research Center. Note that soil K levels are markedly lower in most of the pastures as a result of the drought. Each value is the mean of data from all of the pastures within a particle treatment group, usually at least four different pastures.

P Treatment	**pH**	**Bray I P lbs/acre**	**Bray II P lbs/acre**	**Ca lbs/acre**	**Mg lbs/acre**	**K lbs/acre**
Low 1	5.35	12	67	3701	382	124
Low 2	5.38	15	129	4147	445	138
Low 3	5.90	33	192	3541	330	255
High 1	5.65	37	237	3870	418	339
High 2	5.45	54	274	3709	380	237
High 3	6.30	48	297	4139	365	253

Table 3. The 2005 calf performance on high and low phosphorus pastures at the Forage Systems Research Center. Start weight was on April 14, Period 1 weight was on May 12, Period 2 was on June 9 and Period 3 was on July 5 and Period 4 weights were taken on August 9 and again on August 10. At the end of the experiment, the calves and cows were weighed on two consecutive days. Values are means of weight from 75 calves in the treatment.

		Period 1			**Period 2**			**Period 3**			**Period 4**		
Treatment	**Start Wt lbs**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**
Low P	201	293	92	3.30	366	73	2.61	436	69	2.47	514	78	2.34
High P	202	286	86	3.07	364	78	2.77	425	61	2.18	502	74	2.47

Table 4. The 2005 cow performance on high and low phosphorus pastures at the Forage Systems Research Center. Periods 1, 2, 3 and 4 are the same as those described in the legend of Figure 3. Values are means of weight from 75 cow in the treatment.

		Period 1			**Period 2**			**Period 3**			**Period 4**		
Treatment	**Start Wt lbs**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**	**Wt lbs**	**Wt Gain lbs**	**ADG lbs/ day**
Low P	1099	1275	176	6.28	1304	28.3	1.01	1267	-37	-1.31	1302	36	1.27
High P	1118	1290	172	6.14	1328	38.2	1.36	1293	-36	-1.28	1331	38	1.37

Potassium Management

Selection of Foliar-Applied Potassium Fertilizer Sources and Rates of Application to Optimize Soybean Response and Weed Control with Glyphosate in a "Weed and Feed" Management System

Peter Motavalli, Kelly Nelson, Gene Stevens, Andy Kendig, Manjula Nathan, and David Dunn

__Summary:__

An increased incidence of K deficiency in soybeans and the potential for lowering application costs by mixing foliar nutrient sources with herbicides or other agrochemicals may make foliar K fertilization more cost-effective. This research was conducted in 2004 and 2005 to determine the effects of foliar-applied K fertilizer sources and refine the product application rate on glyphosate-resistant soybean response and weed control. Field trials were established in Northeast (Novelty) and Southeast Missouri (Portageville) on soils with low and high soil test K and with a diverse, high population of weeds to evaluate weed control. Among the findings of these studies were:

- **Leaf injury resulting from foliar application of up to 19.2 lb K_2O/acre from several K fertilizer sources (i.e. potassium chloride, potassium thiosulfate, and 3-18-18) was generally less than 10%.**
- **K fertilizer sources such as 3-18-18 at 2.4 and 9.6 lb/a, 5-0-20-13 at 2.4 lb/a, and 0-0-62 at 9.6 and 19.2 lb/a tank mixed with glyphosate controlled weeds greater than 90% and had grain yields similar to DAS while providing additional K fertilizer to the soybean plant in a single-pass weed management system in Northern Missouri. However, the two-pass weed management system in Southern Missouri provided excellent weed control for all additives and grain yields were greater than or similar to glyphosate plus DAS.**
- **The results of this study indicate that foliar K applications can be mixed with glyphosate with minimal crop damage and reduction in weed control, but yield response can be inconsistent. Further research is needed to understand the factors and develop methods to assess when foliar K response may occur.**

__Objectives__

1. Determine soybean yield response and salt injury from different foliar-applied potassium (K) fertilizer sources and rates of application.
2. Determine the impact of K fertilizer source and rate of application on weed control when mixed with a glyphosate-based herbicide.
3. Evaluate the cost-effectiveness of applying K fertilization with glyphosate-based herbicides for no-till glyphosate-resistant soybean production.

__Relevance__

Soybeans were produced on over 5 million acres in Missouri and 83% of the soybean varieties were Roundup Ready® or contained another form of transgenic herbicide resistance in 2003 (MASS, 2003). Roundup Ready® varieties allow farmers to apply glyphosate-based products for broad spectrum post-emergence weed control. The incidence of K deficiency has increased in recent years due to reduced K availability under drought and areas with soil compaction, reduced applications for soybean due to low commodity prices, and higher corn grain yields and increased soybean acreage in rotation with corn increasing K fertilizer requirements (Fixen, 2000; Reetz and Murrell, 1998). Soil test K data from the University of Missouri Soil and Plant Testing Lab indicates that over 50% of the soil samples tested in the low to medium range for K (Fixen, 2002). This situation indicates that nearly 2.5 million soybean acres in Missouri could be at risk or are currently experiencing yield loss due to inadequate K soil test levels.

Several studies have evaluated response of soybean to foliar fertilizer mixtures (Garcia and Hanway, 1976; Haq and Mallarino, 1998; Parker and Boswell, 1980); however, no research has evaluated the interaction between macronutrient foliar fertilizers and weed control with postemergence herbicides. Potassium is an essential nutrient that increases drought tolerance, stem strength, and improves plant growth. Uptake of K is primarily by diffusion through roots and under drought conditions limited uptake may occur.

Previous research on a farm field in Northeast Missouri on crop response to a foliar application of K sulfate at the V4, R1-R2, or R3-R4 stages of development demonstrated that soybean grain yield increased over 10 bu/acre when compared to a non-treated or $MgSO_4$ control (Nelson et al., 2005).

The calculated increase in profit due to this yield increase from foliar K applications was approximately $50/acre. However, possible limitations for the use of K sulfate combined with a post-emergence herbicide application are the large carrier volume required for an optimum foliar K application and the possible incompatibility that the K fertilizer source may have when mixed with a glyphosate-based herbicide. In addition, the K source/herbicide mix must result in minimal crop injury and not affect weed control.

Materials and Methods:

Research was conducted in 2003 and 2004 at the University of Missouri Greenley Center near Novelty on a Putnam silt loam with a high soil test K and the Delta Center near Portageville on a Portageville sandy loam in locations with a high and low soil test K. Plots were 7.5 by 25 ft to 10 by 35 ft. Soybean were planted in 15 in. rows at Novelty and 30 in. rows at Portageville. All treatments were applied with a CO_2 propelled hand sprayer calibrated to deliver 15 and 20 GPA at Novelty and Portageville, respectively. Treatments were applied at four rates (0, 2.4, 9.6, and 19.2 lb K_2O/acre) of foliar K fertilizer sources (potassium chloride, potassium thiosulfate, potassium phosphate, Trisert K+) and diammonium sulfate (2.6 lb/acre) either sprayed separately on plots maintained weed-free or sprayed as a mixture with a glyphosate at 0.75 lb ae/acre on plots with weeds.

Foliar salt injury and weed control was rated on a scale of 0 (no effect) to 100 (complete crop or weed death). Weed control for individual weed species was visually evaluated at both locations. Leaf samples were collected at initial bloom to determine crop K status in treated and non-treated plants. A biomass harvest of soybean and weeds was collected 28 days after application to determine total weed control at Novelty. Percent dry weight reduction was calculated as 100[1-(total weed dry weight/untreated weed dry weight)]. Grain was harvested and moisture adjusted to 13% prior to analysis.

All data were subjected to analysis of variance using PROC ANOVA (SAS Inst., 1999) and subjected to an *F Max* test for homogeneity (Kuehl 1994). Data were combined over years and locations when variances were homogenous. Injury and weed control data were transformed to the arc sine prior ANOVA. This transformation did not affect conclusions; therefore, original means were reported. Means were separated using Fisher's Protected LSD at p=0.01.

Results:

- Soybean injury was less than 10% 3 days after treatment at Novelty (Table 1). Similarly, all treatments except 5-0-20-13 at 19.2 lbs/a injured soybean less than 10% 22 days after treatment at Portageville (Table 2).
- Glyphosate plus 3-18-18 at 2.4 and 9.6 lb/a, 5-0-20-13 at 2.4 lb/a, and 0-0-62 at 9.6 and 19.2 lb/a controlled weeds greater than 90% at Novelty 28 days after treatment (Table 1). All treatments except glyphosate plus DAS controlled palmer amaranth, morningglory spp., and large crabgrass greater than 90%

21 days after treatment at Portageville (Table 2).

- K concentration in leaves at Novelty in the non-treated, weedy check was similar to all glyphosate tank mixtures except glyphosate plus 0-0-25-17 at 9.6 and 19.2 lb/a (Table 1). Leaf K concentration 14 days after application was similar among K treatments at the low soil test K site at Portageville, and no grain yield differences were detected at this site (Table 3).
- No grain yield increases over the weed-free control was observed at Novelty (Table 1). Glyphosate plus 0-0-62 at 19.2 lb/a reduced grain yield 5 bu/a when compared to 0-0-62 applied in the weed-free check in 2004. K fertilizer additives applied alone to weed-free checks had grain yields 5 to 14 bu/a greater than a single application of glyphosate plus the fertilizer additive in 2005 due primarily to reduced weed control. Soybean grain yield was reduced 6 bu/a when glyphosate was tank mixed with 5-0-20-13 at 19.2 lb/a when compared to glyphosate plus NIS in 2005. Similarly, 0-0-25-17 at 9.6 and 19.2 lb/a reduced grain yields 7 and 6 bu/a, respectively.
- All weed-free treatments had grain yields similar to tank mixtures with glyphosate at Portageville (Table 2). All K additives increased soybean grain yield compared to glyphosate plus DAS except 5-0-20-13 at 9.6 and 19.2 lb/a and KTS at 19.2 lb/a. This was probably due to increased soybean injury caused by these treatments.
- K-based fertilizer sources such as 3-18-18 at 2.4 and 9.6 lb/a, 5-0-20-13 at 2.4 lb/a, and 0-0-62 at 9.6 and 19.2 lb/a tank mixed with glyphosate controlled weeds greater than 90% and had grain yields similar to DAS while providing additional K fertilizer to the soybean plant in a single-pass weed management system in Northern Missouri. However, the two-pass weed management system in Southern Missouri provided excellent weed control for all additives and grain yields were greater than or similar to glyphosate plus DAS.

Outreach and Training:

One M.S. graduate student is receiving his training working on this project for his thesis research in soil science. The research results have been presented to Missouri growers and agricultural professionals at the 2004 and 2005 Greenley Center Field Days in Northeast Missouri and at the American Society of Agronomy National Meetings in 2005. Additional presentations have been made and published in proceedings at the Fluid Forum in 2005, in the 2004 Missouri Crop Management Conference, in the 2004 North Central Extension-Industry Soil Fertility Conference, in the 2004 North Central Weed Science Society of America Conference, and in the 2005 Southern Plant Nutrition Management Conference. The research has also appeared in several popular farm media, including the Fluid Journal.

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Table 1. The effect of fertilizer additive on soybean injury, leaf tissue nutrient levels 14 days after application, total weed dry weight reduction and grain yield applied alone as a weed-free treatment and tank mixed with glyphosate in 2004 and 2005 at Novelty.[a]

		Injury 3 DAT		Tissue K		Total weed[b] dry weight reduction	Yield 2004		Yield 2005	
Fertilizer additive[c]	Fertilizer rate	Weed-free	Glyphosate tank mixture	Weed-free	Glyphosate tank mixture	Glyphosate tank mixture	Weed-free	Glyphosate tank mixture	Weed-free	Glyphosate tank mixture
	lb K_2O/a	----------- % -----------		---------- % ------------		-- % --	---------------------------- bu/a ----------------------------			
Non-treated		0		2.61		0	9.6		15.9	
Weed-free		0	—[d]	2.75	—	100	66.3	—	47.6	—
NIS		—	1	—	2.67	93	—	68.1	—	42.5
NIS + DAS		—	1	—	2.57	93	—	69.9	—	40.9
3-18-18	2.4	0	0	2.90	2.75	96	66.7	67.1	47.5	41.5
3-18-18	9.6	1	3	2.72	2.60	96	70.4	66.8	46.5	40.1
3-18-18	19.2	4	3	2.76	2.60	88	66.8	68.9	46.7	38.5
0-0-25-17 KTS	2.4	1	1	2.69	2.53	88	68.6	65.1	48.1	39.1
0-0-25-17 KTS	9.6	3	5	2.77	2.50	86	68.2	65.1	48.7	35.1
0-0-25-17 KTS	19.2	5	6	2.72	2.77	84	66.6	66.0	47.5	36.6
5-0-20-13	2.4	0	1	2.71	2.77	96	67.7	66.4	47.2	40.5
5-0-20-13	9.6	4	6	2.77	2.58	87	70.2	66.6	46.9	40.7
5-0-20-13	19.2	6	4	2.83	2.66	85	65.1	67.3	46.8	36.9
0-0-62	2.4	0	1	2.73	2.66	88	70.3	67.1	46.3	41.2
0-0-62	9.6	2	3	2.68	2.57	91	67.5	67.7	47.5	40.3
0-0-62	19.2	6	6	2.79	2.59	90	69.4	64.1	49.4	38.9
LSD (p=0.01)		—— 1 ——		—— 0.15 ——		— 11 —	—— 4.9 ——		—— 4.7 ——	

[a]Abbreviations: DAS, diammonium sulfate; DAT, days after treatment; KTS, potassium thiosulfate; NIS, non-ionic surfactant.

[b]Weeds included common lambsquarters in 2004, common ragweed in 2005, common waterhemp in 2004 and 2005, and giant foxtail in 2004 and 2005. Total dry weight reduction was calculated as 100[1-(total weed dry weight/untreated weed dry weight)].

[c]Fertilizer additives included 3-18-18, K phosphate + urea (NA-CHURS/ALPINE); 0-0-25-17, K thiosulfate; 5-0-20-13, K thiosulfate + urea-triazone (Trisert-K+, Tessenderlo Kerley); and 0-0-62, potassium chloride. All tank mixtures with glyphosate included non-ionic surfactant unless stated otherwise.

[d]Treatment was not included.

Table 2. Soybean injury 22 days after treatment (DAT), palmer amaranth control, ivyleaf and entireleaf morning glory control, large crabgrass control, and soybean yield at Portageville in 2004 and 2005.[a]

		Injury 22 DAT								
		2004		2005					Yield	
Fertilizer additive[b]	Rate	Weed-free[c]	Glyphosate tank mixture	Weed-free[c]	Glyphosate tank mixture	Palmer amaranth	Ivyleaf and entireleaf morningglory	Large crabgrass	Weed-free	Glyphosate tank mixture
		%							bu/a	
Non-treated		0		0		0	0	0	17.2	
NIS		—[c]	0	—	2	95	95	94	—	43.8
NIS + DAS		—	0	—	1	91	85	90	—	31.4
0-0-62	2.4	5	6	0	0	95	95	96	39.3	45.3
	9.6	5	5	2	0	94	96	95	38.2	48.8
	19.2	5	10	5	10	95	96	96	38.6	41.6
5-0-20-13	2.4	4	5	3	2	95	94	96	37.1	44.8
	9.6	3	10	1	3	95	94	92	38.1	40.0
	19.2	5	0	18	10	95	96	96	35.0	37.6
3-18-18	2.4	5	10	1	3	96	97	97	44.4	41.9
	9.6	0	4	1	1	96	96	97	41.5	41.3
	19.2	4	3	4	2	96	96	95	38.8	45.6
0-0-25-17 KTS	2.4	3	5	1	0	96	96	96	40.8	46.2
	9.6	0	3	7	3	95	96	95	38.8	43.0
	19.2	3	0	8	10	93	95	93	42.7	40.6
LSD (p=0.01)		8		7		5	5	6	10	

[a]Abbreviations: DAS, diammonium sulfate; DAT, days after treatment; KTS, potassium thiosulfate; NIS, non-ionic surfactant.
[b]Fertilizer additives included 3-18-18, K phosphate + urea (NA-CHURS/ALPINE); 0-0-25-17, K thiosulfate; 5-0-20-13, K thiosulfate + urea-triazone (Trisert-K, Tessenderlo Kerley); and 0-0-62, potassium chloride. All tank mixtures with glyphosate included non-ionic surfactant unless stated otherwise.
[c]Treatment was not included.

Table 3. Leaf tissue K and grain yield at Portageville with a low soil test K in 2004 and 2005.[a]

Fertilizer additive[b]	Rate	Tissue K Weed-free	Tissue K Glyphosate tank mixture	Yield Weed-free	Yield Glyphosate tank mixture
	lb K_2O/acre	-------- % --------		-------- bu/a --------	
Non-treated		1.7		48.0	
Weed-free		1.7	—[c]	54.4	—
NIS		—	1.8	—	49.9
NIS + DAS		—	1.7	—	53.1
3-18-18	2.4	1.6	1.8	44.5	52.1
3-18-18	9.6	1.7	1.7	53.3	57.5
3-18-18	19.2	1.8	1.7	54.4	54.9
0-0-25-17 KTS	2.4	1.8	1.6	51.2	51.1
0-0-25-17 KTS	9.6	1.6	1.8	50.3	53.5
0-0-25-17 KTS	19.2	1.7	1.8	52.7	55.8
5-0-20-13	2.4	1.8	1.8	51.8	52.1
5-0-20-13	9.6	1.9	1.7	54.3	47.9
5-0-20-13	19.2	1.8	1.6	53.4	53.0
0-0-62	2.4	1.6	1.7	53.7	55.8
0-0-62	9.6	1.6	1.7	59.7	52.1
0-0-62	19.2	1.8	1.7	51.8	53.9
LSD (p=0.01)		NS[d]		NS	

[a]Abbreviations: DAS, diammonium sulfate; KTS, potassium thiosulfate; NIS, non-ionic surfactant.
[b]Fertilizer additives included 3-18-18, K phosphate + urea (NA-CHURS/ALPINE); 0-0-25-17, K thiosulfate; 5-0-20-13, K thiosulfate + urea-triazone (Trisert-K, Tessenderlo Kerley); and 0-0-62, potassium chloride. All tank mixtures with glyphosate included non-ionic surfactant unless stated otherwise.
[c]Treatment was not included.
[d]NS = not statistically significant.

Plant Mapping Potassium in Rice Tissue: What Part to Sample When?

Final report

David Dunn and Gene Stevens
University of Missouri-Delta Center

Objectives

(1) Develop critical levels of K concentrations within rice plants during the growing season.
(2) Define which plant parts are most appropriate for plant tissue K analysis.
(3) Evaluate current University of Missouri soil test recommendations for K fertilization of rice.

Introduction

Proper potassium (K) nutrition is critical for maximizing rice grain yields. K is very mobile within the rice plant. Older leaves are scavenged for the K needed by younger leaves. Recent studies at the Missouri Rice Research Farm have shown that supplemental K can be supplied to the rice plant as late as Internode Elongation (IE) and still increase rice grain yields. In this same study whole plant K analysis at IE was better correlated to yield than flag leaf analysis at early boot. Profitable rice production hinges on accurate, reliable, and relevant information about plant-soil interactions. A review of the available literature shows that no consistent methodology has been developed correlating K determinations in rice plants to rice grain yields. This study will attempt to determine which part of the rice plant and at which growth stage tissue samples should be collected.

Research Methods:

Reference plots for potassium fertilization were established at the Missouri Rice Research Farm at Qulin, MO on a soil testing low in available K. These plots received one of three levels of K fertilization, deficient (0 lb K/a), adequate (50 lb K/a), and excessive (200 lb K/a). Plant tissue samples were collected from each plot every two weeks during the growing season beginning at first tiller and continuing through harvest. These samples were then divided into plant components i.e. upper leaf, lower leaf, stalk, and whole plant. These tissue samples were analyzed for K%. Each plot was mechanically harvested for yield and the grain milled for quality determination. Correlation will be made between yield and plant tissue K levels.

An additional study was conducted in 2005. In this study additional plots received one of three levels of pre-plant K fertilization 0 , 50, or 200 lb K_2O/a. This produced three levels of soil test K which were measured at pre-flood (90, 145 and 275 lbs K/a) At one of four times during the growing season (pre-flood, inter-node elongation, boot, or 10 % heading) these plots were split in to two sub-plots and the sub-plots received either 0 lb K/a or 50 lb K/a as KCl. Each plot was mechanically harvested for yield and the grain milled for quality determination.

Statistical analyses of the data were preformed with SAS (1990) using General Linear Modeling procedures. Fisher's Protected Least Significant Difference (LSD) was calculated at the 0.05 probability level for making treatment mean comparisons. Regression and correlation analysis were performed in accordance with procedures outlined by the SAS Institute (SAS, 1997)

Project Accomplishments:

Information collected during this study was used to justify increasing the University of Missouri soil test recommendation K critical level from 5 X CEC to 125 + 5 X CEC in lbs K/a. Additionally critical levels for rice tissue K have been developed for drill seeded rice grown in Missouri. Data collected during this study is presented in Tables 1, 2, 3, 4, 5, and Figure 1. In 2003 and 2004 grain yields were significantly increased by both levels of K fertilization (Table1). In 2005 however, only the 200 lbs K/a rate significantly increased yields. In 2003 and 2004 grain yields for the 50 and 200 lbs K/a treatments were statistically equivalent. This indicted that the University of Missouri's revised soil test recommendations for K on rice is appropriate. Flag leaf K levels were greater than lower leaf levels (Table 2). This difference was greater at 10% heading than at internode elongation. Potassium fertilization effected both dry matter accumulation and K uptake by rice plants (Table 3). In all three years tissue K levels of lower leaf were better correlated to yield than flag leaf tissue K levels (Table 4). This was true for both the internode elongation and 10% head sampling time. In 2003 and 2004 whole plant samples collected at pre-flood were well correlated to yield.

Table 5 shows the effect of K fertilization at various mid-season growth stages on rice yields at varying pre-flood soil test K levels. Rice grain yields were numerically but not statistically increased by in-season potassium in plots that tested 89 lbs K/a at pre-flood. Rice yields of plots testing 145 lbs K at pre-flood that received 50 lbs K at any time during the growing season were statistical equivalent to the plots that tested 275 lbs K at pre-flood. Plots that tested 275 lbs K at pre-flood did not respond to K fertilizers applied at any growth stage. Numerically the yields for the 89 and 145 lbs K plots were lower for application made later in the season. These results show the importance of proper K nutrition at early stages of rice growth.

In 2003 & 2004 this data was presented at the Rice Farm Field Day held in Qulin, MO and the Delta Center Field Day held 9-2-04 in Portageville MO. Results were also presented in 2003, 2004, & 2005 at the Southern Plant Nutrition Conference in Olive Branch, MS. Additionally research papers were presented at the 2004 Rice Technical Working Group Conference in New Orleans, LA and the 2005 World Rice Research Conference in Tokyo, Japan. Data from this project was used in Certified Crop Advisor Continuing Education presentations in 2003, 2004, & 2005. Data from this project has been used to prepare three peer reviewed papers have accepted for publication. These publications are available via the Internet at the following locations:

Dunn, D. J., Wrather, J. A., Stevens, W. E., Kenty, M. M., Beighley, D. H., and Aide, M. T. 2004. Measuring K^+ in rice basal stem sap with a Cardy meter. Online. Crop Management doi:10.1094/CM-2004-1006-01-RS.
http://www.plantmanagementnetwork.org/pub/cm/research/2004/meter

Slaton, N.A., D.J. Dunn, and B. Pugh. 2004. Potassium nutrition of flood-irrigated rice. Better Crops Vol 88-3, pp 20-22.
http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/92A39CB2801C484888256ED2005BD75E/$file/04-3p20.pdf

Dunn, D.J., and W.E. Stevens. 2005. Potassium research for rice in Missouri. Better Crops Vol 89-1, pp15-17.
http://www.ppi-ppic.org/ppiweb/bcrops.nsf/$webindex/45B5E4D6A23DAC9585256F9E0020B63E/$file/05-1p15.pdf

Table 1. Average rice grain yield, moisture %, and milling quality for K treatments 2003, 2004, & 2005.

Treatment	Yield (bu/a)			Moisture %			Milling Head%/Whole%		
	2003	2004	2005	2003	2004	2005	2003	2004	2005
O lbs K/a	95a	168a	112a	14.0a	14.3a	17.7a	57a/65a	58a/65a	54a/62a
50 lbs K/a	112b	190b	121a	13.5a	14.6a	17.2a	57a/66a	57a/66a	56a/66a
200 lbsK/a	117b	192b	141b	13.3a	15.0a	16.6a	56a/66a	56a/65a	56a/65a

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Table 2. Average tissue K levels for rice plant parts at growth stages for K treatments, 2002, 2003, & 2004.

Growth Stage	Plant Part	Tissue K %								
		0 lbs K/a			50 lbs K/a			200 lbs K/a		
		2002	2003	2004	2002	2003	2004	2002	2003	2004
Pre-flood	Whole	1.89	2.93	2.53	2.57	3.15	2.99	2.56	3.43	2.62
Inter node elongation	Whole	1.37	2.17	2.19	1.36	2.24	2.27	1.56	2.42	2.82
Inter node elongation	Flag leaf	1.34	1.78	1.85	1.33	2.08	2.34	1.51	2.25	2.37
Inter node elongation	Lowest leaf	1.20	1.49	1.62	1.35	1.80	1.99	1.56	1.94	2.24
Inter node elongation	Stem	1.31	2.40	2.77	1.44	2.92	2.88	1.62	3.25	3.20
10% Heading	Whole	1.13	1.36	1.50	1.39	1.39	1.71	1.57	1.44	1.74
10% Heading	Flag leaf	1.30	1.43	1.60	1.34	1.85	1.56	1.70	1.93	1.73
10% Heading	Lowest leaf	1.01	1.26	1.45	1.24	1.43	1.39	1.57	1.44	1.37
10% Heading	Stem	1.10	0.88	1.47	1.49	1.57	1.28	1.85	1.64	1.49
10% Heading	Head	1.28	0.95	0.92	1.38	1.11	0.91	1.85	0.69	0.86

Table 3. Dry matter and K uptake for K treatments at three rice growth stages, 2004 & 2005.

Growth stage	Pre-plant K treatment (lbs K/a)							Pre-plant K treatment (lbs K/a)					
	0		50		200			0		50		200	
	…………Dry matter (lbs/a)…………							…………K uptake (lbs K/a)…………					
	2004	2005	2004	2005	2004	2005		2004	2005	2004	2005	2004	2005
First tiller	131	68	154	155	220	172		3.5	1.9	4.5	4.1	5.7	4.6
Inter-node elongation	1770	1153	2070	1295	1853	1486		33.1	13.3	44.7	20.2	52.8	34.3
100% heading	6734	4218	7055	5697	7660	7810		101	51	120	75	131	109

Table 4. Correlation of plant tissue K levels with grain yields, 2002, 2003, & 2004.

Growth Stage	Plant Part	R^2 value		
		2002	2003	2004
First tiller	Whole	0.22	0.54	0.34
Internode elongation	Whole	0.27	0.37	0.22
Internode elongation	Flag leaf	0.07	0.23	0.02
Internode elongation	Lowest leaf	0.38	0.39	0.38
Internode elongation	Stem	0.07	0.30	0.24
10% Heading	Whole	0.25	0.32	0.24
10% Heading	Flag leaf	0.06	0.07	0.05
10% Heading	Lowest leaf	0.45	0.39	0.53
10% Heading	Stem	0.11	0.41	0.13
10% Heading	Head	0.0001	0.003	0.001

Table 5. Average rice yields for midseason K treatments, 2005.

Soil test K pre-flood (lbs K/a)	0 lbs K	50 lbs K Pre-Flood	50 lbs K Inter-node elongation	50 lbs Boot	50 lbs K 10% head
89	112b	118b	120b	117b	115b
145	121b	139a	136ab	134ab	133ab
275	141a	141a	141a	140a	142a

Numbers followed by the same letter in each column are not significantly different at the alpha = 0.05 level.

Micronutrient Studies

Using High Boron Application Rates to Control Weevils and Leafhoppers in Alfalfa

Dale G. Blevins, Professor and Wayne Bailey, Associate Professor,
Division of Plant Sciences, University of Missouri
(1.5 years into the study)

Objective: to determine if high application rates of boron (B) will control weevils, leafhoppers and grass invasion into alfalfa stands, in order to reduce pesticide and herbicide utilization.

Alfalfa establishment: A site was selected at the University of Missouri South Farm in the summer of 2004. This site is near the University of Missouri's Entomology Building at South Farm, and is ideally located for the labor intensive insect counting that will be required. Soil samples were collected from this site and analyzed at the University of Missouri Soil Testing Laboratory in summer 2004. Mean values from the soil test results are listed in Table 1.

Table 1. Initial Soil Test Results from the South Farm Alfalfa Site.

pH	O.M. %	Bray I P lb/A	Ca lb/A	Mg lb/A	K lb/A	CEC meq/100g
6.6	2.7	46	4308	446	163	13.9

We selected two different alfalfa cultivars for this study, Pioneer 54V46 (leafhopper susceptible) and Pioneer 54H91 (leaf hopper resistant). Seeds from both cultivars were Nitragen Plus (they were supplied already inoculated with rhizobia). Alfalfa planting date was Sept 18, 2004, after removal of the forage sorghum crop. The forage sorghum had been planted in June, 2004 to draw down soil nitrogen. Alfalfa was planted with a Tye Pasture Placer 80 inch No-till drill. A 52 Vicon PS 103 Spreader was used on Oct 5 to apply 0-50-300 P_20_5 and K_20 fertilizer onto plots, based on the soil test results in Table 1. Plots were 20'x30' with 14' alleys and each treatment was replicated four times. The treatments were 0, 2.5, 5.0, 10.0 lbs/acre B treatments, with one set of plots allocated for insecticide (w/o B) treatments and with the two different cultivars.

The alfalfa emerged quickly, the stand was excellent and the plants showed good fall growth. However, during late fall of 2004, we had heavy rainfall, which resulted in water standing on the plots. By spring 2005, it was obvious that most of the alfalfa plants had died over winter. Therefore the alfalfa was re-planted on March 30, 2005 and again we got an excellent stand. On April 1, 2005, turf-type tall fescue was planted into the borders of the plots, and on April 2, 2005 plots were sprayed with Paraquat to remove spring weeds. On March 16, 2005, the first application of 2.5lbs B (as Solubor, a gift from U.S. Borax) was applied to each B treatment plot. The Solubor was mixed with fine sand and broadcast. On June 1, the second 2.5 lbs B was applied to plots that were to receive 5.0 or more lbs of B/acre. The 10 and 20 lbs B/acre plots were treated with boron again on June 16, this put the B up to 7.5 lbs B/acre on the 10 and 20 lbs B/acre plots. On July 5 and September 7, 2005, 10 insect sweeps were made on each plot. The insects were collected in plastic bags and frozen. Insect identification and counts will be made this winter, using the frozen material. Immediately after the insect samples were taken, the forage was sampled for hay yield determination, and all forage was harvested from the plots. Therefore, the maximum B applied for the insect counts and hay yields in 2005 was a total of 7.5 lbs B/acre. On October 5, another 2.5 lbs B/acre was applied completing the 10 lbs B/acre application. On October 8 and 26, B was applied to the 20 lbs B/acre plots, raising the total applied to 15 lbs B/acre. On the plots that were to receive a total of 20 lbs B/acre, we started noticing some leaf damage after the application of 15 lbs B/acre. Therefore for these high B treatment plots, we have not yet added the final 5 lbs B/acre. These final B applications will be completed in spring of 2006.

Hay yields were increased with B applications to alfalfa cultivar 54H91, which is leafhopper resistant, however there was no clear response for cultivar 54V46, which is leafhopper susceptible (Figures 1,2 & 3). The lack of response of cultivar 54V46 may be a result of the higher population of large weed species in control plots of this cultivar, as seen in Figure 4 on the right side. Yields were very good for the first and second cuttings in July and September, 2005, respectively. Total hay production was also very good for first year alfalfa. At the first cutting date, the alfalfa plots had quiet a few weeds, and in addition, one could clearly see the superiority of the leaf hopper resistant cultivar (Figure 4, left side). The leaf hopper resistant cultivar clearly responded to B applications up to 5 lbs B/acre (Figures 1, 2 and 3). The B applications to this resistant cultivar increased hay yields by 1500 lbs/acre total. This 1500 lbs/acre yield increase when comparing 0 B to 5 lbs B/acre rates, came from a 1000 lbs/acre increase at the July harvest and a 500 lbs/acre increase at the September harvest (Figures 1 and 2).

In summary, the 5 lbs B/acre application to the leafhopper resistant cultivar, Pioneer 54H91, increased hay yield by ¾ of a ton/acre (Figure 3). This could be worth about $90/acre and could easily pay for the seed, the B and provide extra profit!

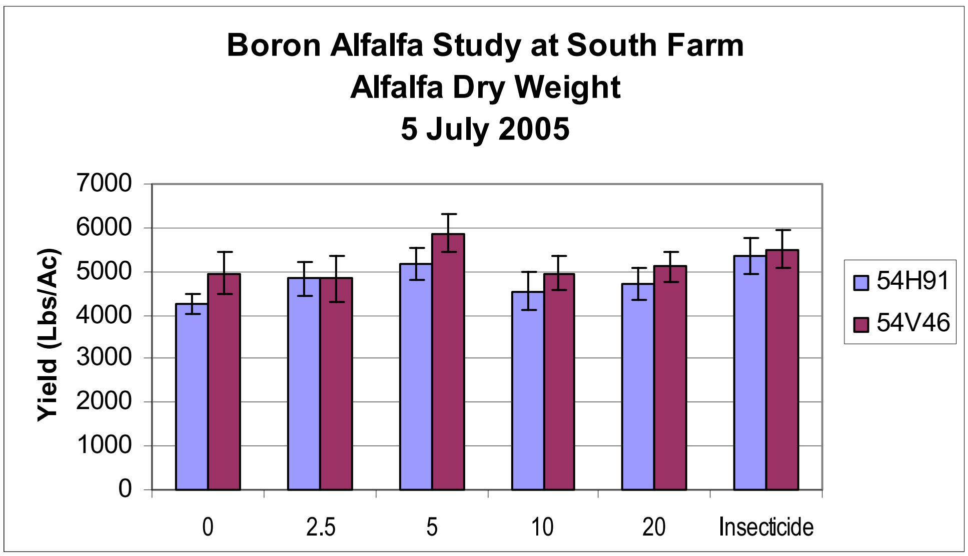


Figure 1. First cutting hay yields in 2005 after boron treatments of leaf hopper resistant (54H91) and leafhopper susceptible (54V46) alfalfa. Even the 10 and 20 lbs B/acre applications are listed on the Figure, only a total of 7.5 lbs B/acre had been applied to these plots by harvest time. Boron was only applied at a rate of 2.5 lbs B/acre at each application to prevent leaf burn, and a subsequent application was made only after a rainfall event.

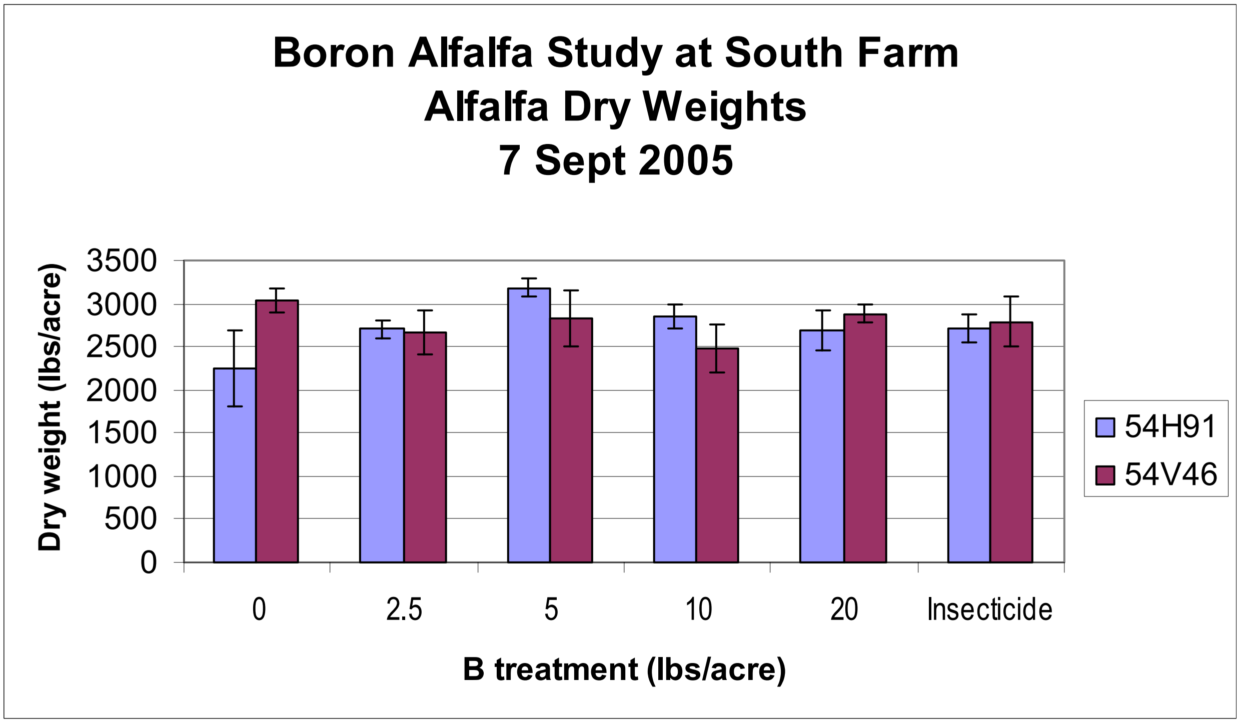


Figure 2. Second cutting hay yields in 2005 after boron treatments of leaf hopper resistant (54H91) and leafhopper susceptible (54V46) alfalfa. Even the 10 and 20 lbs B/acre applications are listed on the Figure, only a total of 7.5 lbs B/acre had been applied to these plots by harvest time. Boron was only applied at a rate of 2.5 lbs B/acre at each application to prevent leaf burn, and a subsequent application was made only after a rainfall event.

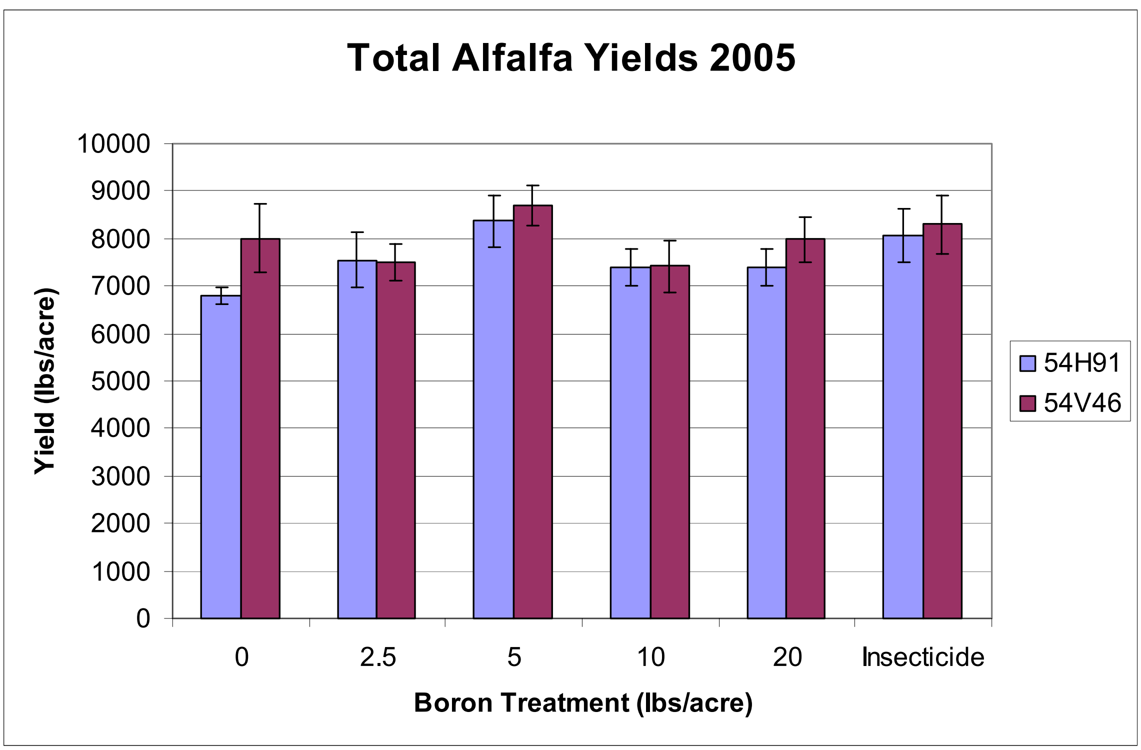


Figure 3. Total hay yields from summer 2005 after boron treatments of leaf hopper resistant (54H91) and leafhopper susceptible (54V46) alfalfa. Even the 10 and 20 lbs B/acre applications are listed on the Figure, only a total of 7.5 lbs B/acre had been applied to these plots by harvest time. Boron was only applied at a rate of 2.5 lbs B/acre at each application to prevent leaf burn, and a subsequent application was made only after a rainfall event.

Figure 4. Leaf hopper resistant (Pioneer 54H91) on the left and leaf hopper susceptible (Pioneer 54V46) alfalfa on the right in early July prior to the first hay harvest.

Miscellaneous Tests

Evaluating Mehlich III Extractant for Extracting Available Nutrients for Missouri Soils using inductively Coupled Plasma Spectrometry

Manjula Nathan, Peter Scharf, Yichang Sun, Division of Plant Sciences
David Dunn, Delta Regional Soil Testing Lab

Objectives:

1. To determine the relationship between the Ammonium acetate and Mehlich III extractable K, Ca, Mg, Na for Missouri soils using Inductively Coupled Plasma (ICP) Spectrometry and Atomic Absorption (AA) Spectrometry.

2. To determine the relationship between the Bray I and Mehlich III extractable P using ICP and the colorimetric methods for Missouri soils.

3. To determine the relationship between the DTPA and Mehlich extractable Zn, Fe, Cu and Mn for Missouri soils using ICP and AA.

4. To relate the nutrient extracted by above methods with greenhouse yield response.

Procedures:

- Soil samples (162) received by the soil testing labs collected through out the state of Missouri were be used in this study. Samples collected from Sanborn field from the manured and non-manured plots as well from the farmer fields were also analyzed. The soil samples were analyzed for P, K, Ca, Mg. Ca, Zn, Fe, Cu and Mn by the current MU soil test analytical procedures (colorimetry or AA) and by ICP.

- Soil samples were analyzed for plant available K, Ca, Mg and Na by the Ammonium Acetate extraction (routine method used by MU Soil Testing Labs) and Mehlich III extractant using ICP and AA. Soil samples were also analyzed for extractable P by Bray I extraction and Mehlich III extraction using ICP and colorimetric methods.

- Soil samples were analyzed for plant available Zn, Fe, Cu and Mn by the DTPA extraction (routine method used by MU Soil Testing Labs) and Mehlich III extractant using ICP and AA.

- The relationship between the plant available nutrients estimated by Mehlich III extraction and the standard soil test procedures used by MU Soil Testing labs were studied.

- The nutrient extracted by both procedures will be also related to the yield response using the yield data collected by Drs. John Lory's and Peter Scharf's (CO-PI) greenhouse study on "Soil Specific Phosphorus and Potassium Recommendations – Critical Values".

Current Status and Importance of Research:

Mehlich III is being increasingly used by soil testing labs for rapid nutrient analysis using ICP technology. The universal extractant Mehlich III, which extracts multiple elements simultaneously, has the potential to replace one or more of the standard extractants currently used by the MU labs.

Current status of research project: 162 samples have been collected from all parts of the state to represent agricultural soils and research soil samples used in Co PI's greenhouse studies. The samples have been analyzed in duplicate using the University of Missouri recommended soil test procedures. We have been working on the Mehlich extractable nutrients measurements using ICP since 2004.

Results from year 2004 and 2005 analysis on Comparison of Mehlich 3 Extractable Nutrients vs. the Standard Soil Testing Methods used by MU Soil Testing Labs are presented in figures 1 to 9.

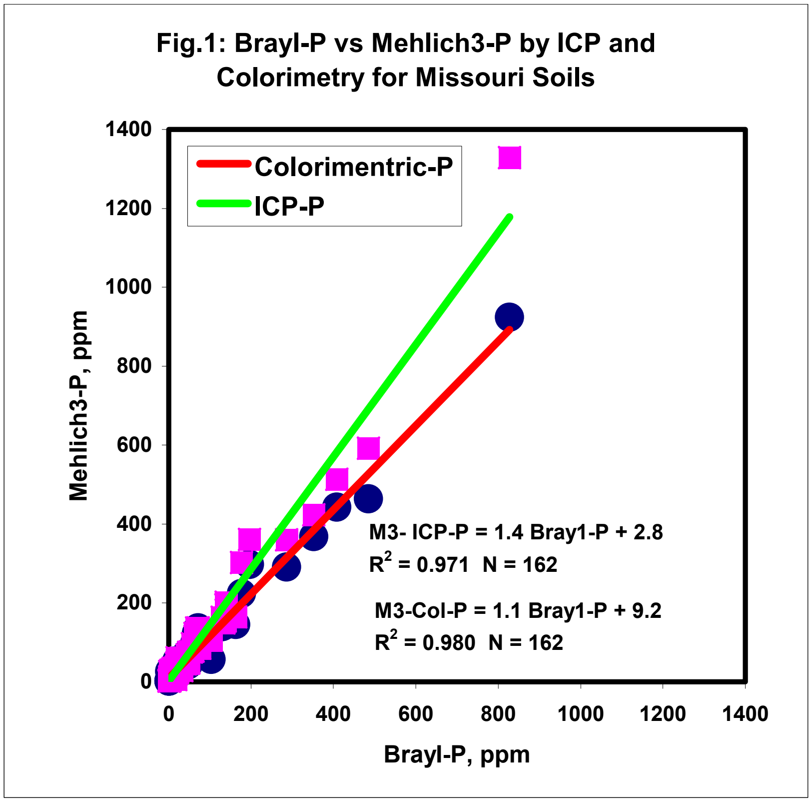


Fig. 2: Ammonium Acetate-K by AA vs Mehlich3-K by ICP

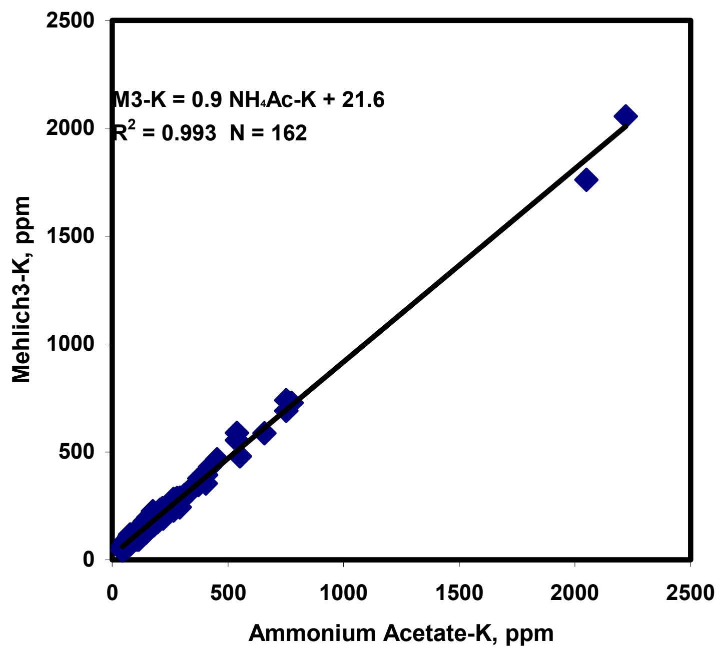
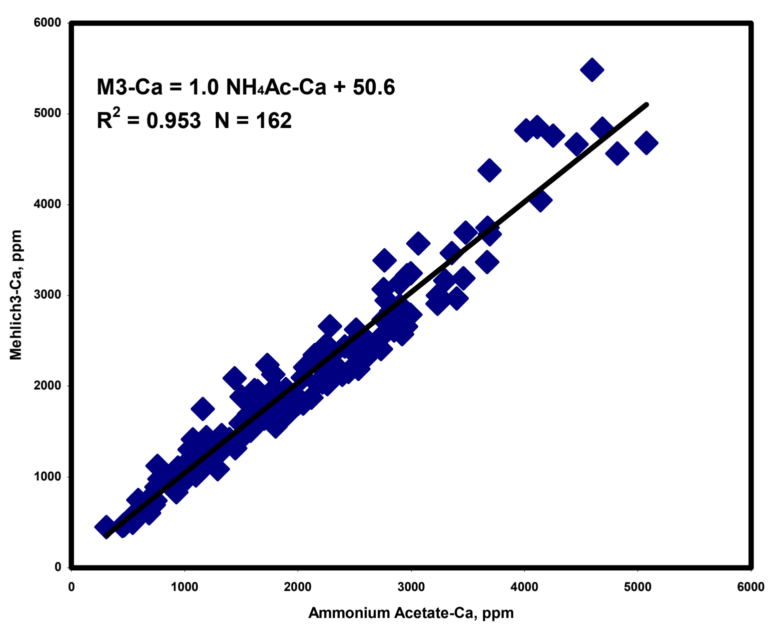


Fig. 3: Ammonium Acetate-Ca by AA vs Mehlich3-Ca by ICP



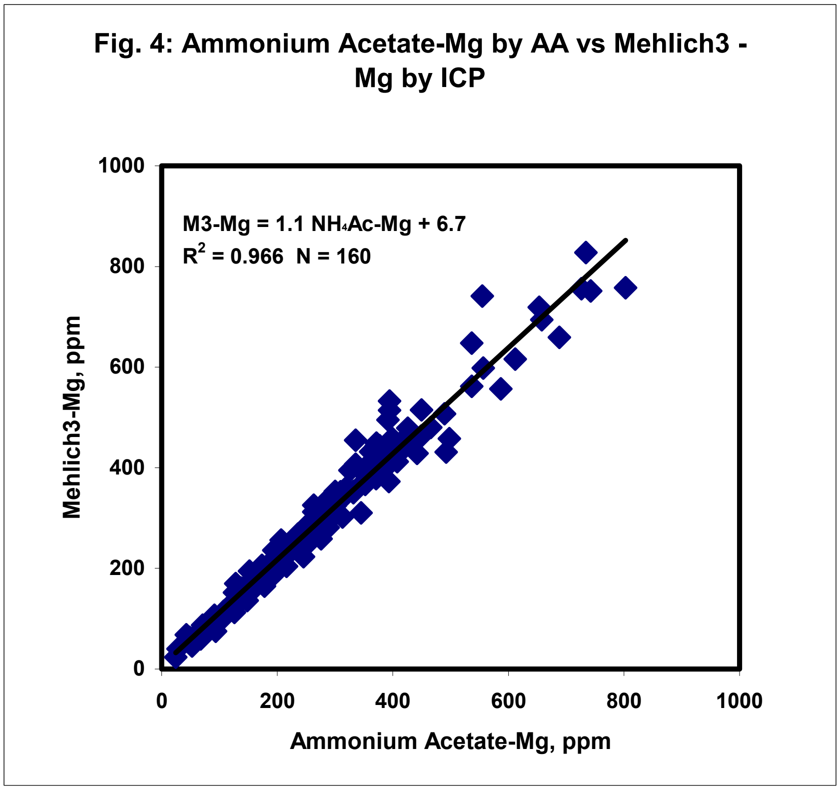


Fig. 4: Ammonium Acetate-Mg by AA vs Mehlich3 - Mg by ICP
M3-Mg = 1.1 NH4Ac-Mg + 6.7
R2 = 0.966 N = 160
Mehlich3-Mg, ppm
Ammonium Acetate-Mg, ppm
0
200
400
600
800
1000

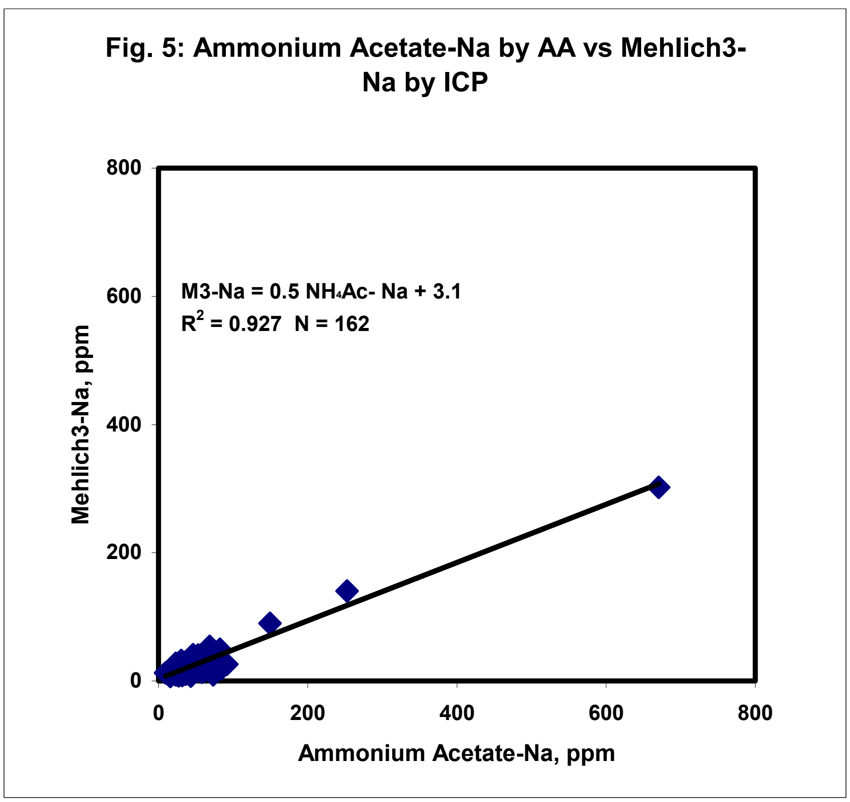


Fig. 5: Ammonium Acetate-Na by AA vs Mehlich3-Na by ICP
M3-Na = 0.5 NH4Ac- Na + 3.1
R2 = 0.927 N = 162
Mehlich3-Na, ppm
Ammonium Acetate-Na, ppm
0
200
400
600
800

Fig. 6: DTPA-Zn by AA vs Mehlich3-Zn by ICP

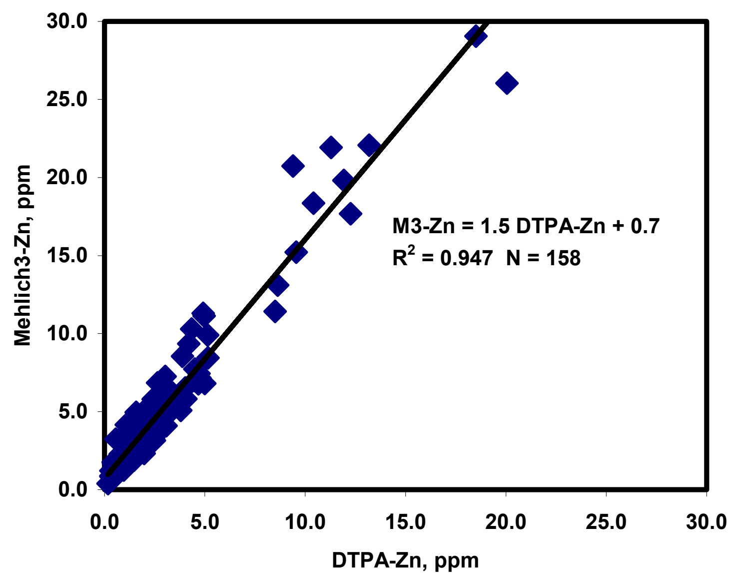


Fig. 8: DTPA-Fe by AA vs Mehlich3-Fe by ICP

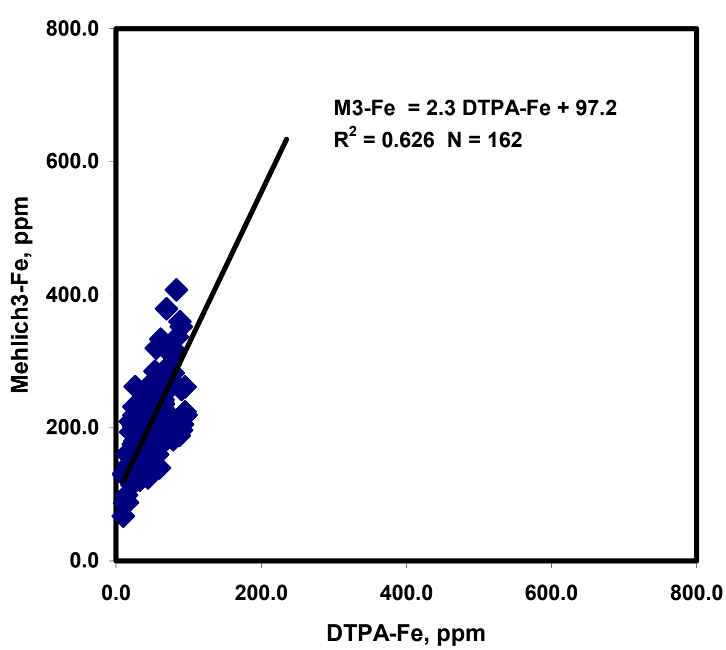


Fig. 9: DTPA-Cu by AA vs Mehlich3-Cu by ICP

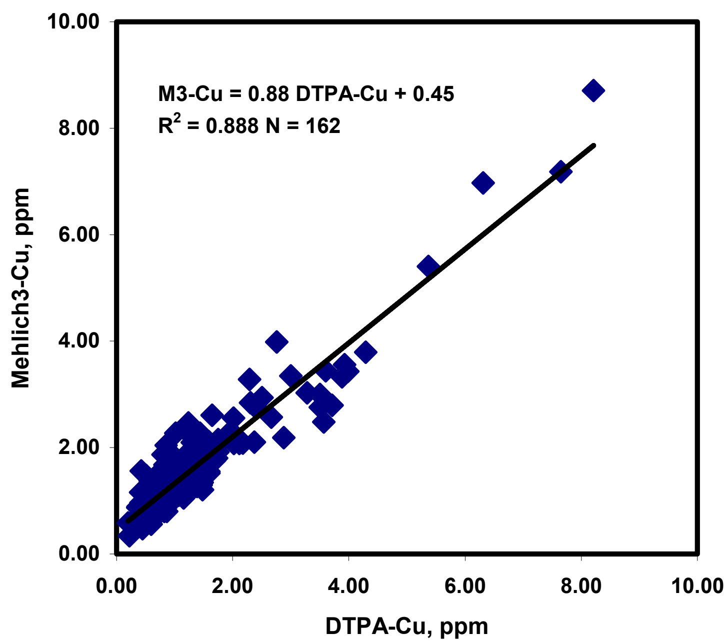


Fig. 7: DTPA-Mn by AA vs Mehlich3-Mn by ICP

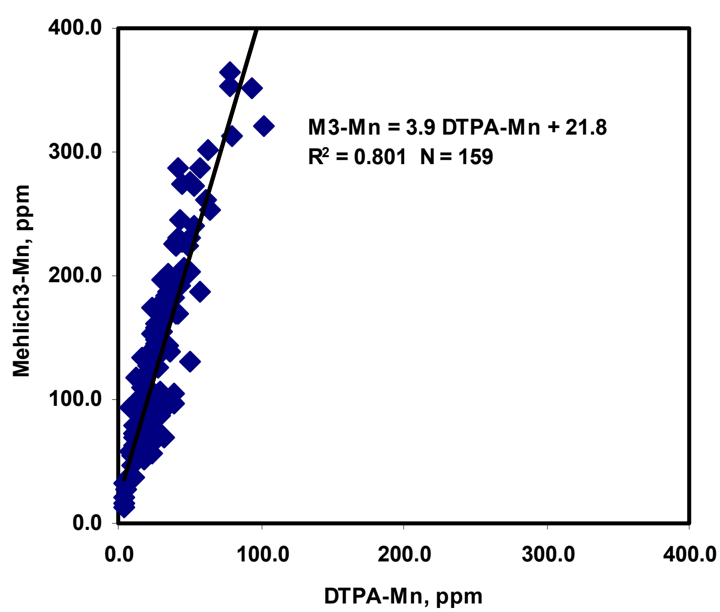


Table 1: Relationship between Mehlich 3 Extractable Nutrients and Standard University of Missouri Soil Tests

Regression Equations	R^2	
M3-ICP- P = 1.4 Bray 1 - P + 2.8	0.097	n=162
M3-Col- P = 1.1 Bray 1 - P + 9.2	0.980	n=162
M3- K = 0.9 NH_4OAc K + 21.8	0.993	n=162
M3-Ca = 1.1 NH_4OAc Ca + 50.6	0.953	n=162
M3-Mg = 1.1 NH_4OAc Mg + 6.7	0.966	n=162
M3- Zn = 1.5 DTPA Zn + 0.7	0.947	n=162
M3- Mn = 3.5 DTPA Mn + 21.58	0.801	n=162
M3- Fe = 2.3 DTPA Fe + 97.2	0.626	n=162
M3- Cu = 0.88 DTPA Cu + 0.45	0.888	n=162

Conclusions:

Mehlich 3 and Bray P1 extracted similar quantities of P when measured by colorimetry (Fig. 1; M3-Col P= 1.1 Bray 1 P + 9.2, R2= 0.980). However, more P was measured by ICP on Mehlich extracts (about 30% more) than colorimetric measurements (Fig. 1; M3- ICP P= 1.4 Bray 1-P +2.8, R^2= 0.971). The same was observed in manured and non-manured soils.

Mehlich 3 extracted approximately same amount of K as NH_4OAc (Fig 2; M3-K= 0.9 NH_4OAc-K +21.6, R^2= 0.953). ICP measurements were slightly less than AA measurements.

The Mehlich 3 extractable Ca, Mg and Na measurements by ICP correlated well with the NH_4OAc extractable Ca, Mg, and Na measured by AA (Fig. 3 to Fig. 5).

Mehlich 3 extracted more Zn, Fe and Mn than DTPA (Fig. 6 to Fig. 8) with the exception of Cu (Fig. 9).

Although ICP measurements varied relative to standard methods, the correlation between the methods was great enough to suggest that the fertilizer recommendations could be adapted to Mehlich 3 extractant using simple linear relationships for most measured nutrients. (Table 1).

The results suggest the Mehlich 3 extractant can be adapted to determining plant available nutrients in Missouri soils. The liner equations obtained from this study to relate the standard MU soil testing procedures to Mehlich 3 extractable nutrients by ICP could be used in converting the Mehlich 3 numbers to the standard MU soil tests values to provide MU Fertilizer and lime recommendations. The equations on relationship between the testing methods could be used to develop fertilizer recommendation based on the Mehlich III extractant. These findings would help in improving the use of MU soil test recommendations by producers using commercial soil testing labs that are using Mehlich III extractant. This in turn would improve the quality of soil test based fertilizer recommendations used in Missouri.

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Comparison of Woodruff Buffer and Modified Mehlich Buffer Tests for Determining Lime Requirement in Missouri Soils

Report for First Year (2005)

Manjula Nathan, Peter Scharf, and Yichang Sun
Division of Plant Sciences, University of Missouri

Objective:

1. To compare the Modified Woodruff Buffer test method with the Modified Mehlich Buffer test for determining the lime requirement for Missouri soils.
2. To determine if the Modified Mehlich Buffer is an effective alternative to the Modified Woodruff Buffer test for Missouri soils.

Current Status and Importance of Research:

In Missouri, the Modified Woodruff Buffer test is used to determine the lime requirement in soils. Though this method has proven to work for Missouri soils it uses para-nitrophenol as one of the reagents which is a hazardous substance. Para-nitrophenol can cause serious health effects on humans when breathed in or when absorbed by skin. Thus the waste produced by the Woodruff buffer test needs to be treated as a hazardous waste. Also, since Missouri is the only state in the nation which uses the Woodruff Buffer test, it is better to evaluate the other buffer tests used so that data and lime recommendations developed for Missouri can be compared with similar information from the other states.

The SMP buffer test is commonly used throughout the U.S. for determining lime requirement. This is the method listed as the recommended procedure for lime requirement in the publication: *Recommended Chemical Soil Test Procedures by the North Central Region*. This method too uses para-nitrophenol. Even though the SMP buffer test is commonly used throughout the U.S. for determining lime requirement, the SMP buffer solution contains potassium chromate, a carcinogen, and poses a health risk to laboratory technicians who perform this test. Additionally, all waste generated by the test must be collected for proper disposal. An alternative to the SMP test is the Mehlich Buffer test. Although the Mehlich buffer contains barium chloride, another toxic and regulated compound, calcium chloride ($CaCl_2$) has been shown to be an effective and safe substitute (Hoskins, 2005).

A recent study carried out at Pennsylvania State University by Wolf and Beegle (2004) in comparing SMP buffer with Modified Mehlich buffer test ($CaCl_2$ substituted for $BaCl_2$) revealed that the Mehlich buffer is a better predictor of lime requirement on PA soils than the SMP buffer and, additionally, does not contain any hazardous components. They also reported that the Mehlich buffer calibration on PA soils was similar to Mehlich buffer calibrations in North Carolina and Maine. They concluded that the Mehlich buffer test is a feasible alternative to the SMP buffer test for determining lime requirement on acid soils of the Northeast and other regions of the U.S.

Conducting this research at this time is very timely, as parallel studies are being conducted in comparing Mehlich extractable nutrients with the standard procedures used by University Missouri soil testing labs, and in developing fertilizer recommendation based on the Mehlich III extractant.

Research Conducted in 2005

- Twenty soil samples collected from different soil regions in Missouri that represent major agricultural areas were used in the soil incubation study. Lime requirement in the soils selected for incubation study was estimated by the Modified Woodruff Buffer test (method currently used) and the Modified Mehlich Buffer test method.

- *Incubation Study*:
  Soils were amended with reagent grade $CaCO_3$ at rates of 0, 1/3, 2/3, 1 and 1 1/3 and 2 times the estimated lime requirement from the Modified Woodruff method to raise the soil pH for target levels 6.5 and 7.0 and incubated in the dark for 3 weeks with the following wetting and drying cycle for a total duration of three months.
    a. Add water to each soil to bring to field capacity.
    b. Cover with lid and incubate at room temperature (20 degree +/- 5 degree ^{0} C) in the dark for three weeks.
    c. Remove lid and incubate in dark for 1 week.
    d. Mix soil by hand and return to the cups.
    e. Repeat steps 1 to 4 for a total of three times

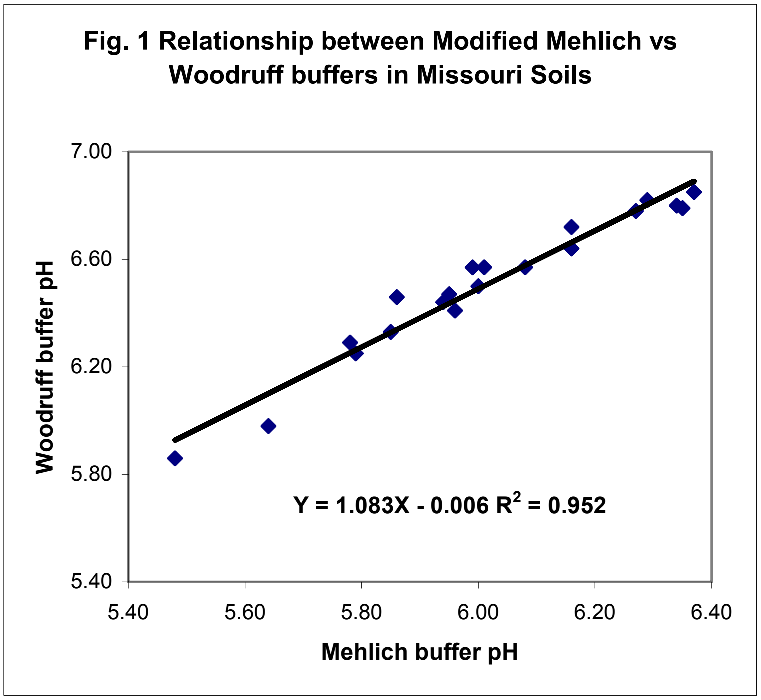
.

Soil pH was regressed with $CaCO_3$ added to all 20 soils, and the actual lime requirement was estimated for each soil to raise the soil pH to target levels of 6.5 and 7.0. Woodruff and Mehlich buffer pHs were regressed against actual lime requirement for all 20 soils to evaluate effectiveness of each test for estimating the lime requirement in Missouri soils. Soil characteristics of the soils used in this study are presented in Table 1.

Table 1. Soil Characteristics

ID	County	Location	Soil Series	Soil pH	Woodruff pH	Mehlich pH	OM %
1	Boone	Bradford Farm	Mexico silt loam	4.6	6.3	5.8	2.7
2	Boone	South farm	Mexico silt loam	5.9	6.6	6.2	4.1
3	Knox	Novelty	Kilwinning silt loam	5.4	6.6	6.1	3.2
4	Holt	Corning	Salix silty clay loam	5.1	6.5	5.9	3.4
5	Linn	Linneus	Lagonda silty clay loam	5.4	6.6	6.0	5.2
6	Lawrence	Mount Vernon	Creldon silt loam	4.7	6.4	6.0	2.1
7	Webster	Springfield	Tonti silt loam	4.2	5.9	5.5	3.7
8	Gentry	Albany	Grundy silt loam	5.4	6.5	6.0	4.0
9	Saline	Marshall	Higginsville silt loam	6.0	6.8	6.3	3.2
10	Mississippi	Hwy K	Commerce silt loam	5.1	6.7	6.2	1.8
11	Oregon	Alton	Fanchon silt loam	4.5	6.4	5.9	2.6
12	Pemiscot	Portageville	Tiptonville silt loam	4.2	6.3	5.8	2.4
13	Dunklin	Qulin	Crowley silt loam	5.9	6.9	6.4	1.5
14	Barton	Lamar	Parson's silt loam	4.5	6.5	6.0	1.7
15	Pemiscot	Portageville	Tiptonville silt loam	5.9	6.8	6.3	1.9
16	New Madrid	Morehouse	Sharkey clay	5.4	6.6	6.0	3.7
17	Osage	Linn	Union silt loam	6.0	6.8	6.4	1.9
19	Pike	Annada	Tice silt loam	6.0	6.8	6.3	2.1
20	Ray	Camden	Colo Silt loam	5.0	6.3	5.9	3.0

A preliminary research findings on "Comparison of Modified Woodruff Buffer in Missouri Soils" revealed a good correlation (R^2=0.952) between the modified Woodruff and Mehlich buffers for Missouri soils. Fig.1.



Relationship between the buffer pH and lime requirement for both buffer tests (Woodruff and Mehlich) after incubating the soil with different $CaCO_3$ treatments to achieve target pH of 6.5 and 7.0 are presented in Fig 2 and 3. The modified Mehlich and Woodruff buffer pHs were well correlated with lime requirement estimates to raise the soil pH to 6.5 (Fig.2) and 7.0 (Fig.3).

Lime requirement regression equations for both buffer tests are presented in Table 2.

Table 2: Lime Requirement Regressions using Buffer pH in meq/100 g of soil

Buffer Test	Target pH	Regression Equation	R^2
Modified Woodruff	6.5	L. R = 33.9 – 4.9 WB pH	0.935
Modified Mehlich	6.5	L. R = 34.5 – 5.4 MB pH	0.922
Modified Woodruff	7.0	L. R = 39.6 – 5.6 WB pH	0.954
Modified Mehlich	7.0	L. R = 40.1 – 6.2 MB pH	0.935

Fig. 2 Relationship between buffer pH and lime requirement for target pH of 6.5

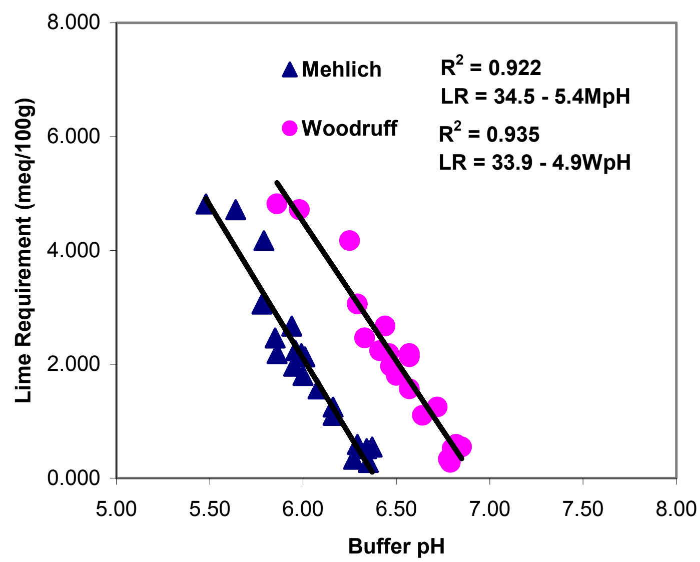
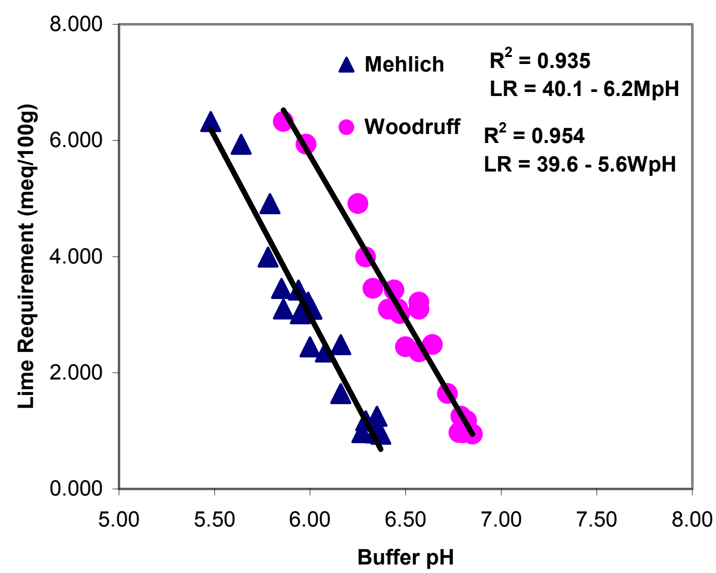


Fig. 3 Relationship between buffer pH and lime requirement for target pH of 7.0



Both buffers (Mehlich and Woodruff) are found to be equally good in predicting the lime requirement in Missouri soils. (Fig 2 and 3). Based on our findings, Modified Mehlich buffer seems to be a viable alternative to Woodruff buffer in determining the lime requirement in Missouri soils. However, an additional incubation study to obtain the lime requirement equation for target pH to 5.5 – 6.0 is needed to come up with the complete set of lime recommendation equations for Modified Mehlich Buffer test in Missouri soils. In addition, bulk comparison of soil samples received by both the MU soil testing labs, using Modified Mehlich buffer and Woodruff buffers; and lime requirement estimations by both buffers in these soils is required before this new buffer test could be adopted and implemented in Missouri.

Continuing this research now is very timely, and essential to implement the changes based on additional research. Also parallel studies have being conducted to compare Mehlich extractable nutrients with the standard procedures used by University of Missouri soil testing labs, and conversion factors have been developed for providing fertilizer recommendation based on the Mehlich III extractant.

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Soil Sampling and Fertility Build-up Management

Gene Stevens and David Dunn

Many soil test laboratories allow farmers to select the number of years they want to build low or medium P or K soil levels in fields back to optimum levels. Sometimes this decision has a huge effect on the amount of fertilizer that a farmer will apply in a given year. If a grower does not check an option box on a soil test submission form, MU soil test labs use an 8-year default build-up time to calculate fertilizer recommendations.

Unfortunately, no field research has been conducted to suggest which buildup option is the most profitable method to manage crop nutrients. Long build-up programs help farmers manage their financial resources by spreading fertilizer costs over many years. However, growers need information concerning the magnitude of yield loss that may occur early in an 8-year build-up as compared to shorter build-up (1 to 4 years).

Accomplishments in Year 2

In 2005, soil nutrient buildup from fertilizer was studied in three cropping systems at Portageville, Qulin, and West Plains, Missouri. Cropping systems included continuous corn, continuous soybean, corn/soybean/wheat rotation, rice/soybean rotation, and fescue hay and pasture. All experiments were randomized complete blocks with four replications. Permanent markers were placed to help locate research plots in following years. In early March, composite soil samples were collected from each plot and analyzed at the MU Delta Center Soil Test Laboratory.

Yield goals used to calculate P and K fertilizer recommendations were 175 bu/acre for corn, 45 bu/acre for soybean, 6075 lb (135 bu)/acre for rice, 2 tons fescue hay/acre, and 175 cow days/yr for fescue pasture. Standard treatments include an untreated check, 1-year, 3 or 4-year, and 8-year buildup fertilizer programs. In the soybean/rice rotation test, treatments were included to compare using soybean versus rice soil test target levels. Current MU recommend target soil P buildup for rice is 35 lb Bray-P/acre and soybeans is 45 lb Bray-P/acre. Target ammonium acetate extractable K target buildup for rice is 125+(5XCEC) and 220+(5XCEC) for soybeans. In the fescue tests, three S treatments were added to the standard treatments. Corn plots received 175 lb N/acre, rice received 150 lb N/acre (3-way split), and fescue received 50 lb N/acre in April and 30 lb N/acre in September.

Since we intentionally selected fields that needed P or K fertilizer, the untreated check usually produced lower yields than other treatments (Table 1-4). Overall, the 3 and 4-year buildups showed the most consistent profitability. As expected the 1-year buildup was the most expensive treatment. In the fescue hay experiment 1-year buildup treatment resulted in an economic loss for the first year. Results from the corn/soybean/wheat test were not reported in 2005 because of significant yield losses from birds in the wheat and raccoons in the corn. The field is adjacent to a wooded area along the Portage Bay ditch.

Objectives for year three

We will follow the profitability and soil nutrient levels of these treatments over time. In 2006, the only P and K that will be applied to the 1-year buildup will be an amount to offset annual crop removal. All plots will be sampled and tested again in March 2006.

Table 1. Effect of fertilizer build-up programs on first-year rice and soybean yields on a Crowley silt loam soil at Missouri Rice Research Farm, Qulin, Missouri in 2005.

Planted Crop	Buildup program † Soil crop target	2005 Rates P_2O_5	2005 Rates K_2O	2004 Yield	2005 Yield
Rice		---lb/acre---		---bu/acre---	
	N only check	0	0	135	114
	1-year/rice target	41†	38†	138	131
	4-year/rice target	52	69	136	129
	8-year/rice target	45	67	132	124
	1-year/soybean target	41†	38	154	128
	4-year/soybean target	74	130	155	129
	8-year/soybean target	56	97	150	128
Soybean	Untreated check	0	0	40	39
	1-year/rice target	38†	65†	53	47
	4-year/rice target	38	65	53	49
	8-year/rice target	38	65	51	45
	1-year/soybean target	38†	65	58	54
	4-year/soybean target	58	39	51	46
	8-year/soybean target	50	32	51	43

† Only crop removal P and K was applied to 1-yr treatment following full buildup applications in 2004. Rice and soybeans were rotated between Field 4 and 5 at the Missouri Rice Farm. Initial soil test levels in the Field 4 was 29 lb P/a, 165 lb K/a, and 9.2 CEC and Field 5 was 37 lb P/a, 249 lb K/a, and 10.4 CEC.

Table 2. Average annual effect of fertilizer build-up on profits of rice/soybean cropping system on a Crowley silt loam soil at Missouri Rice Farm, Qulin, Missouri in 2004-5.

Buildup program † Soil crop target	Fertilizer Costs	Gross Return ‡ Rice/Soybean	Gross-Fert
	-------------dollars per acre------------		
N only check	\$23	\$309	\$287
1-year/rice target	\$48	\$354	\$307
4-year/rice target	\$46	\$355	\$309
8-year/rice target	\$45	\$338	\$294
1-year/soybean target	\$72	\$382	\$310
4-year/soybean target	\$57	\$362	\$306
8-year/soybean target	\$49	\$354	\$304

† Current MU recommended target soil P rice buildup is 35 lb Bray1-P/a and P target for soybean 45 lb P/a (target K buildup rice 125+(5XCEC) and 220+(5XCEC) for soybeans). Cost calculations include N on rice. Economics based on \$0.30 per lb N (urea), \$0.30 per lb P_2O_5, \$0.17 per lb K_2O, \$5.46 bu soybean, and \$3.24 bu rice.

‡Rice and soybeans were rotated between two fields at the Missouri Rice Farm.

Table 3. Dry matter yields from two cuttings of fescue hay in fertilizer buildup experiment at West Plains, Missouri in 2005.

Trt No.	Buildup program	Sulfur	Recommended P_2O_5	Recommended K_2O	2005 Harvest Date June 2	2005 Harvest Date Nov 16	Total
		lb/acre	---lb/acre---		-------ton/acre ------		
1	Untreated check	0	0	0	0.53	0.34	0.87
2	N only	0	0	0	0.79	0.46	1.25
3	1-year	9	18†	68†	1.40	0.62	2.03
4	4-year	9	117	90	1.43	0.57	1.99
5	8-year	9	65	79	1.28	0.67	1.94
6	8-year	0	65	79	1.31	0.59	1.89
7	8-year	12	65	79	1.44	0.57	2.01
8	8-year	24	65	79	1.26	0.62	1.88

† Only crop removal P and K was applied to 1-yr treatment following full buildup applications in 2004.

Table 4. Cumulative effect of fertilizer build-up programs (2004+2005) profits and fescue hay yields from a non-renovated pasture on a Tonti-Hogcreek complex (2% slope) near West Plains, Missouri.

Trt No.	Buildup program†	S	P_2O_5	K_2O	Cost‡	Hay	Gross-PKS
		----------------Two-year Cumulative------------------					
		lb/acre	---lb/acre---		per acre	ton/acre	per acre
1	Untreated check	0	0	0	$0	2.4	$72
2	N only	0	0	0	$40	3.3	$60
3	1-year	18	423	223	$204	5.0	-$54
4	4-year	18	230	180	$138	4.8	$6
5	8-year	18	130	160	$104	4.6	$33
6	8-year	0	130	160	$88	4.2	$38
7	8-year	24	130	160	$88	4.9	$58
8	8-year	48	130	160	$88	4.5	$47

† Initial average soil test levels were 8 lb Bray1-P/a and 162 lb am. acetate extractable K/a.

‡ Economics based on $0.37 per lb N (am. nitrate), $0.30 per lb P_2O_5, $0.17 per lb K_2O, $0.41 per lb S, and $30.00 per ton fescue hay ($15 for 1000 lb round bale). N credit was given to DAP and am. sulfate and S credit to triple super phosphate.

Budget

Expenses	2004	**2005**	2006
Res. Specialist salary (0.4)	$12,400	$12,958	$13,541
Fringe benefits	$3,100	$3,240	$3,385
Supplies	$1,500	$1,545	$1,591
Travel	$1,000	$1,030	$1,061
Total	$18,000	$18,773	$19,578

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