# Missouri
# Soil Fertility and Fertilizers
# Research Update
# 2004

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

# Thank You
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# Agricultural Lime

# 2003

## Conservation Tillage Systems and Liming Materials

Report for Second Year (2003)

Gene Stevens and David Dunn

**Objective:**

(1) Determine the soil depth that surface applied lime in conservation tillage systems will neutralize soil acidity on clay and silt loam soils.

(2) Evaluate calcitic (white) lime and dolomitic (red) lime materials in no-till and strip-till corn/soybean rotation systems.

**Current status/importance of research area:**

The adoption of conservation tillage systems continues to increase across Missouri. However, no-till and strip-till farmers have expressed concern that lime may need to be incorporated with conventional tillage equipment to neutralize soil acidity below the 0 to 2-inch soil depth. Research at the University of Tennessee Milan Experiment Station showed that surface applied lime on a no-till field effectively increased soil pH in the soil profile. However, this study was conducted on a loessial silt loam soil with good internal drainage. Whether the same would be true on a poorly drained Sharkey clay soil is not known. Solubility of the liming material may also be a factor. Tests with conventional till cotton at the University of Missouri Delta Center showed that dolomitic lime increased soil pH slower than calcitic lime, but both types of lime resulted in the same amount of cotton yield increase.

**Research activities in 2003:**

Tests were conducted at four locations. Fields on the University of Missouri-Delta Center with Dubbs silt loam (average initial $pH_{salt}$ 5.2) and Tiptonville silt loam soils (average $pH_{salt}$ 5.3) were used. Two fields with Sharkey clay soil (average initial $pH_{salt}$ 4.6) at the University of Missouri Lee Farm were also used. A corn-soybean rotation system was used at the silt loam and clay sites. A split-plot design was used with no-till, strip-till and conventional till main plots. Soil $pH_{salt}$ and Woodruff buffer pH were used to determine the recommended amount of ENM needed to raise the pH to the 6.1 to 6.5 range. Liming materials were obtained from local dealers and tested for ENM value. Sub-plot treatments were the recommended rate of calcitic (white) lime, recommended rate of dolomitic (red) lime, and an untreated check. Liming materials were applied in the April 2002 on the silt loam sites and April 2003 on the clay sites. These were surface applied before any tillage was done.

In July and September, soil cores were collected from the 0 to 6-inch soil depth. The cores were cut into 2-inch increments (0 to 2-inch, 2 to 4-inch, and 4 to 6-inch soil depths) and tested for soil pH and extractable Mn. Plots will be mechanically harvested for yield.

**Results in 2003:**

Ideally, we would have found a more acid soil for the silt loam test sites. Although the soil test recommended lime based on pH, the initial extractable Mn was only around 25 ppm. Corn and soybeans were not significantly increased by applications of either lime source in 2002 or 2003 (Table 1). Perhaps, we should be evaluating soil Mn as well as pH in making liming recommendations. Historically, we have used soil pH for making lime recommendations because it is easy to measure with relatively inexpensive tools such as litmus paper or pH electrodes. However, plants can grow well in nutrient solutions at very low pH. It is the indirect effect of pH on soil elements that is important. Low soil pH increases Mn and Al availability (toxic at high levels) and decreases the availability of important nutrients like P. Although Mn is an essential element, Mn toxicity is more common than Mn deficiency. Mn is a micronutrient, which can now be easily tested by most soil laboratories. The initial soil Mn levels in the clay soil averaged 59 ppm in the 0 to 6-inch soil depth. Yields were significantly increased with lime on the strip till plots but not on the conventional or no-till plots (Table 2).

At the end of the first growing season after liming in the spring, most of the red and white lime was still visible on the soil surface in treated no-till plots on the clay soil. Soil tests for pH and Mn also confirmed that the lime was not moving into the soil as effectively as had occurred on the silt loam soil (Figures 1-4). Most of the effect of lime as compared to the untreated check could only be found in the 0 to 2-inch soil layer. This indicates that some tillage (either strip or conventional) may be needed to incorporate lime on clay soils. On the silt loam soils, incorporation of lime by tillage was not required to increase the soil pH and reduce extractable Mn in the 2 to 4-inch and 4 to 6-inch soil layers (Figures 5–8). This supports findings of the previous lime work at Tennessee on no-till soils. White lime tended to increase pH faster and reduce Mn than red lime.

Table 1. Effect of lime material on soybeans and corn at the MU Delta Center Marsh Farm averaged across 2002 and 2003 on a Reelfoot sandy loam soil with initial soil $pH_{salt}$ of 5.2.

| Lime | Soybeans | | Corn | |
|---|---|---|---|---|
| | ------bushels per acre------- | | | |
| Red | 55 | A | 125 | A |
| White | 52 | A | 119 | A |
| None | 54 | A | 127 | A |

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

Table 2. Effect of lime material and tillage on soybeans and corn at the MU Delta Center Lee Farm in 2003 on a Sharkey clay with initial soil $pH_{salt}$ of 4.6.

| Lime | Soybean | | Corn | |
|---|---|---|---|---|
| | --------bushels/acre------- | | | |
| | Conventional tillage | | | |
| Red | 34 | CDE | 56 | B |
| White | 38 | BC | 56 | B |
| None | 32 | DE | 56 | B |
| | Strip tillage | | | |
| Red | 44 | AB | 84 | A |
| White | 46 | A | 63 | AB |
| None | 31 | E | 53 | B |
| *No-tillage* | | | | |
| Red | 38 | BCD | 77 | AB |
| White | 34 | CDE | 65 | AB |
| None | 44 | AB | 62 | AB |

## Sharkey clay soil 2003

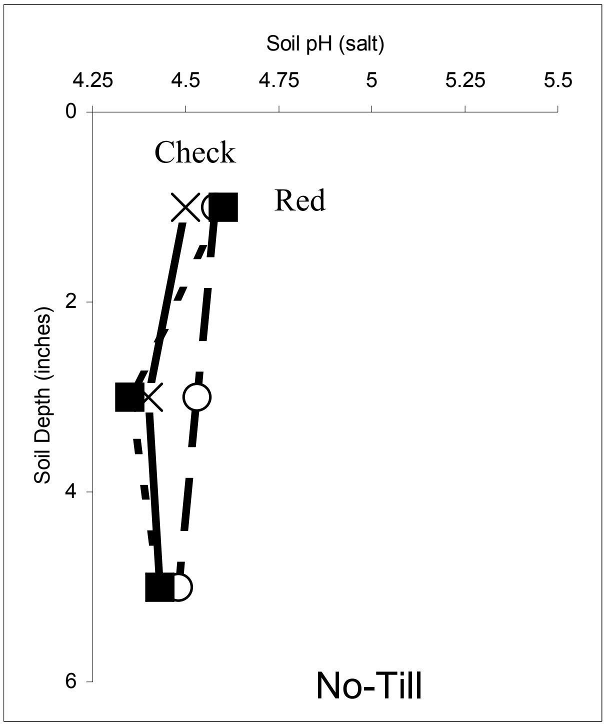



Figure 1. Effects of liming treatments on soil pH in no-till soybeans.

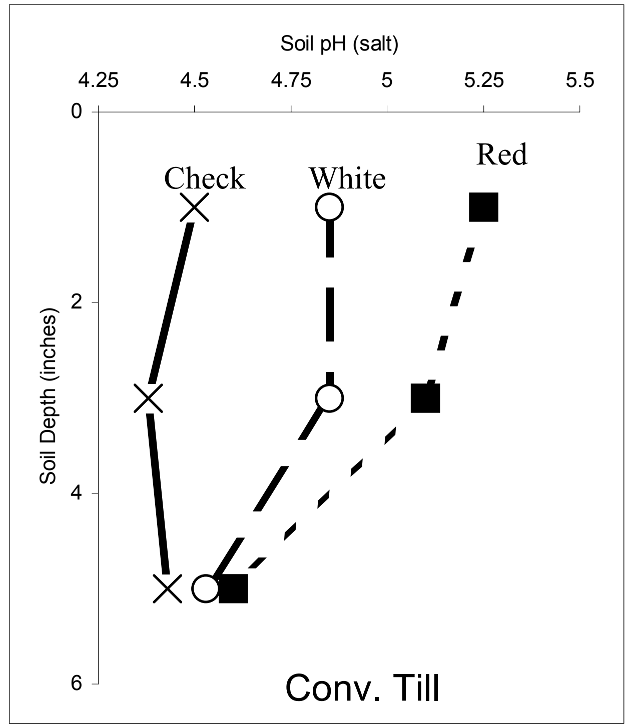



Figure 2. Effects of liming treatments on soil pH in conventional till soybeans.

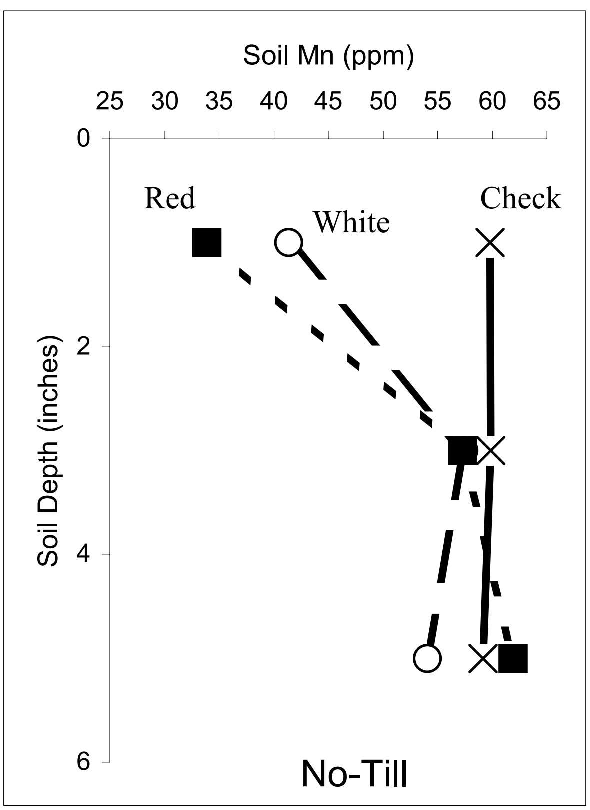



Figure 3. Effects of liming treatments on soil Mn in no-till soybeans.

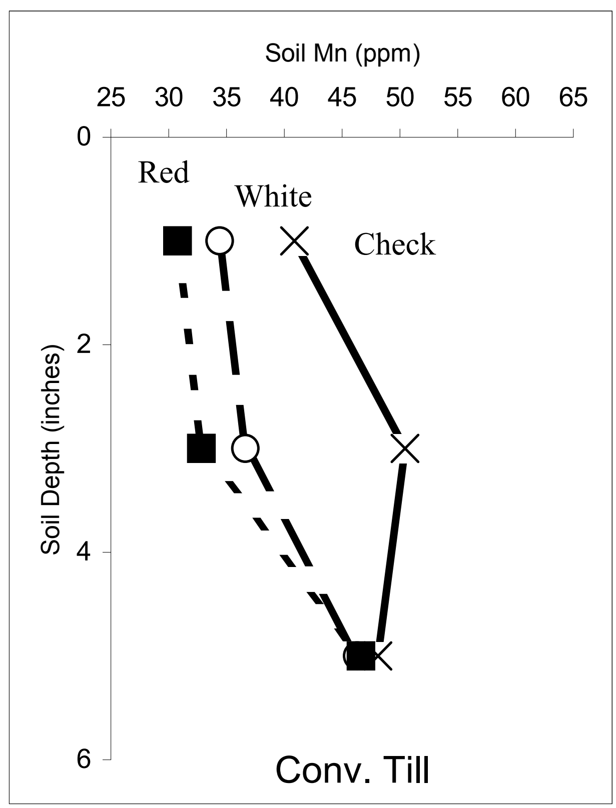



Figure 4. Effects of liming treatments on soil Mn in conventional till soybeans.

## Silt loam soil 2003

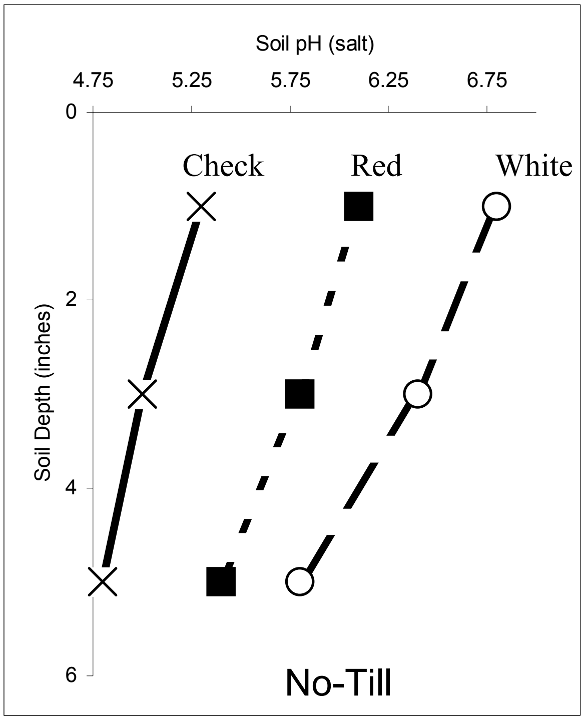



Figure 5. Effects of liming treatments on soil pH in no-till soybeans.

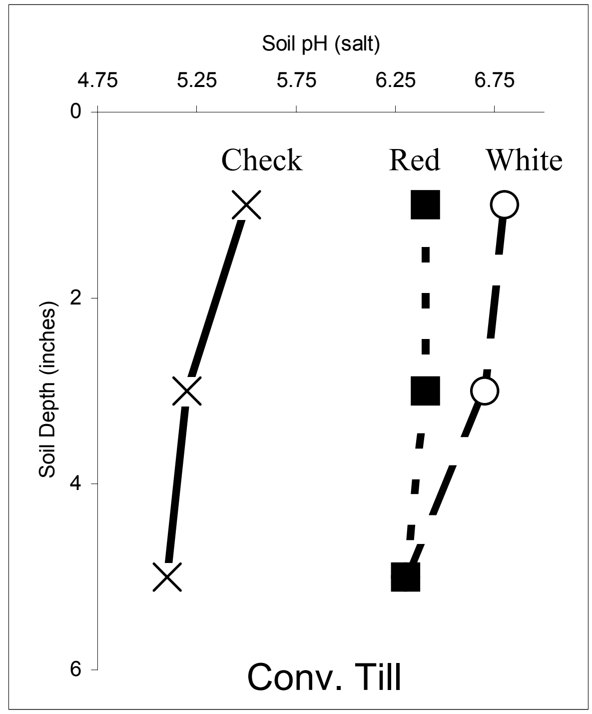



Figure 6. Effects of liming treatments on soil pH in conventional till soybeans.

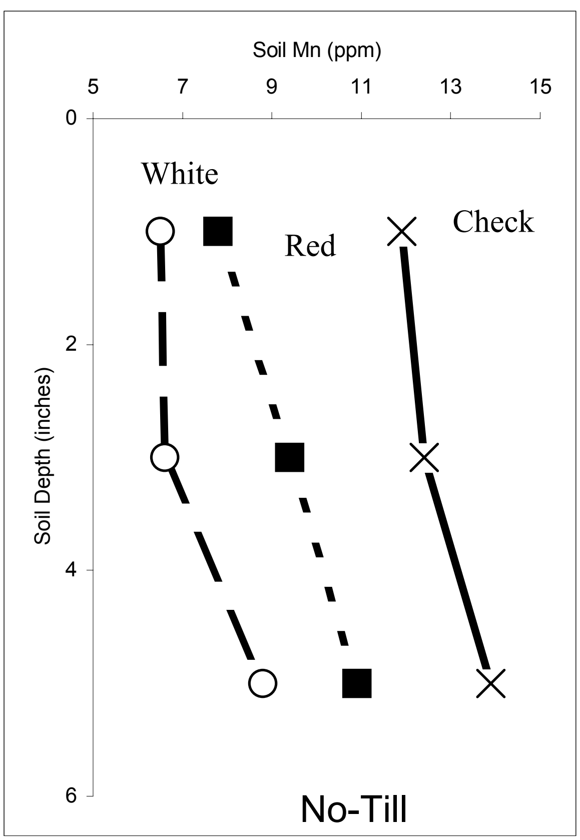



Figure 7. Effects of liming treatments on soil Mn in no-till soybeans.

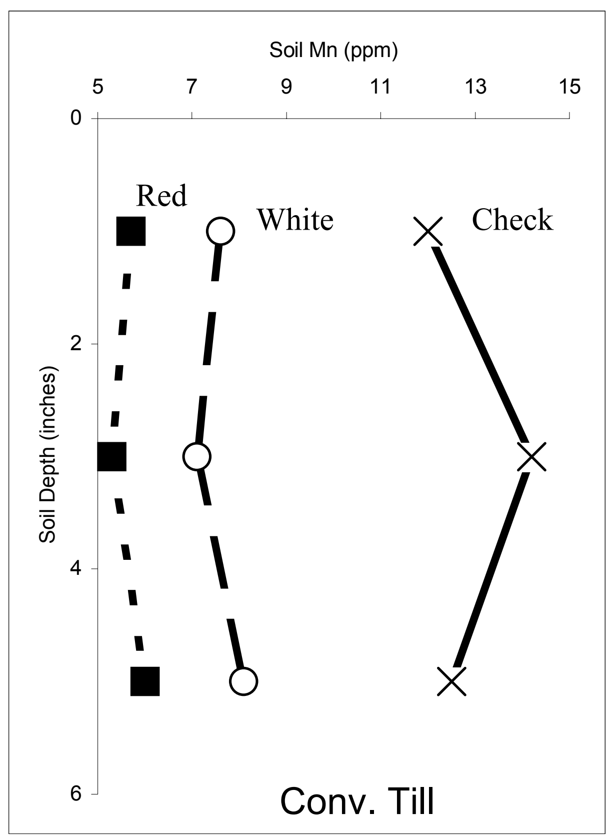



Figure 8. Effects of liming treatments on soil Mn in conventional till soybeans.

# Soil pH effects on atrazine carryover damage to no-till soybean

Peter Scharf, Reid Smeda, and Kevin Bradley
Agronomy Department, University of Missouri

**Accomplishments for 2003:**

- Additional lime and iron sulfate applications were made in fall 2002 to maintain a wide range of soil pH levels in the top inch of soil.
  - 2 tons lime/acre
  - 1 ton lime/acre
  - no treatment
  - 1 ton iron sulfate/acre
  - 2 tons iron sulfate/acre
- We had already created a wide range of soil pH levels in the top inch of soil using surface applications of lime and iron sulfate in 1998-1999. The same treatments were applied to the same plots in fall 2002 in order to reinforce and maintain the pH range created by the original applications.
- No-till corn was planted in all 160 plots in 2003.
- Herbicide programs applied to corn in 2003 were:
  - Untreated check
  - Atrazine 1.25 lb a.i./acre preplant
  - Atrazine 2.5 lb a.i./acre preplant
  - Atrazine 1.25 lb a.i./acre preplant followed by 1.25 lb a.i./acre post
    - This is a new treatment in the study. Many producers use post applications of atrazine, which carry greater carryover risk than preplant applications.
- Roundup Ready corn was used and Roundup was used to control weeds so that the only effect of soil pH is on carryover damage, allowing us to focus on carryover issues.
- The plots are ready to be planted to no-till soybean in 2004, so that the carryover effects of 2003 treatments on soybean yield can be measured.

**Objectives for 2004:**

- Plant no-till soybean in plots with atrazine treatments applied in 2003 over a range of soil pH values.
- Maintain weed control.
- Rate visual appearance of soybean if any visual symptoms are noted.
- Harvest soybeans.
- Analyze data to determine effects of soil pH and atrazine treatments on soybean yield.
- Write a final report combining 2004 results with results from 1999-2002, giving our best assessment of average risk of yield loss from atrazine carryover damage when surface soil pH is either high or low.
  - In 1999-2000, we saw a 6 bu/acre soybean yield loss on plots with high surface soil pH and either 1.25 or 2.5 lb/acre atrazine applied to the previous year's corn.
  - In 1999-2000, we saw a 2 bu/acre soybean yield loss on plots with low surface soil pH and either 1.25 or 2.5 lb/acre atrazine applied to the previous year's corn.
  - In 2001-2002, we saw a 1.2 bu/acre soybean yield loss on plots with low surface soil pH and 2.5 lb/acre atrazine applied to the previous year's corn.
- Develop educational materials based on research results to help corn/soybean producers evaluate risks and develop management strategies.

# 2004

## Conservation Tillage Systems and Liming Materials

Report for Third Year (2004)

Gene Stevens and David Dunn

The adoption of conservation tillage systems continues to increase across Missouri. However, no-till and strip-till farmers have expressed concern that lime may need to be incorporated with conventional tillage equipment to neutralize soil acidity below the 0 to 2-inch soil depth. Research at the University of Tennessee Milan Experiment Station showed that surface applied lime on a no-till field effectively increased soil pH in the soil profile. However, this study was conducted on a loessial silt loam soil with good internal drainage. Whether the same would be true on a poorly drained Sharkey clay soil is not known. Solubility of the liming material may also be a factor. Tests with conventional till cotton at the University of Missouri Delta Center showed that dolomitic lime increased soil pH slower than calcitic lime, but both types of lime resulted in the same amount of cotton yield increase. A study was begun in 2002 to determine the soil depth that surface applied lime in conservation tillage systems will neutralize soil acidity on clay and silt loam soils.

**Research activities in 2004:**

Tests were conducted at four locations. Fields on the University of Missouri-Delta Center with Dubbs silt loam (average initial $pH_{salt}$ 5.2) and Tiptonville silt loam soils (average $pH_{salt}$ 5.3) were used. Two fields with Sharkey clay soil (average initial $pH_{salt}$ 4.6) at the University of Missouri Lee Farm were also used. A corn-soybean rotation system was used at the silt loam and clay sites. A split-plot design was used with no-till, strip-till and conventional till main plots. Soil $pH_{salt}$ and Woodruff buffer pH were used to determine the recommended amount of ENM needed to raise the pH to the 6.1 to 6.5 range. Liming materials were obtained from local dealers and tested for ENM value. Sub-plot treatments were the recommended rate of calcitic (white) lime, recommended rate of dolomitic (red) lime, and an untreated check. Liming materials were applied in the April 2002 on the silt loam sites and April 2003 on the clay sites. These were surface applied before any tillage was done. In September or October each year, soil cores were collected from the 0 to 6-inch soil depth. The cores were cut into 2-inch increments (0 to 2-inch, 2 to 4-inch, and 4 to 6-inch soil depths) and tested for soil pH and extractable Mn. Plots will be mechanically harvested for yield.

**Conclusion**

We found no consistent soil pH or yield results indicating tillage is needed to incorporated lime in soybean or cornfields (Tables 1 and 2 ). Yield response to liming materials was generally positive but no always statistically significant compared to the untreated check. Soil tests from the 0 to 6-inch depth showed that dolomitic and calcitic lime both increased soil pH and reduced extractable Mn levels (Figures 1 and 2). Low soil pH increases Mn and Al availability (toxic at high levels) and decreases the availability of important nutrients like P. Although Mn is an essential element, Mn toxicity is more common in Missouri than Mn deficiency.

We will continue the experiment on the Sharkey clay soil in 2005 without funding to gain more results and publish the information from both soils in a scientific journal.

Table 1. Effect of lime material on soybeans and corn at the MU Delta Center Marsh Farm averaged from 2002 to 2004 on a Reelfoot sandy loam soil with initial soil $pH_{salt}$ of 5.2.

| Tillage | Lime | Grain yield † | |
|---|---|---|---|
| | | Corn | Soybean |
| | | -----bu/acre---- | |
| No tillage | Dolomitic | 123 a | 59 a |
| | Calcitic | 107 b | 58 a |
| | Check | 103 b | 56 a |
| Strip tillage | Dolomitic | 115 a | 55 a |
| | Calcitic | 123 a | 54 a |
| | Check | 108 a | 56 a |
| Conventional | Dolomitic | 110 a | 56 a |
| | Calcitic | 123 a | 51 b |
| | Check | 114 a | 50 b |

† Within a tillage system, yields followed by the same letter were non-significant at 0.05 level.

Table 2. Effect of lime material and tillage on soybeans and corn at the MU Delta Center Lee Farm in 2003 and 2004 on Sharkey clay with initial soil $pH_{salt}$ of 4.6.

| Tillage | Lime | Grain yield † | |
|---|---|---|---|
| | | Corn | Soybean |
| | | -----bu/acre---- | |
| No tillage | Dolomitic | 96 a | 38 a |
| | Calcitic | 82 a | 41 a |
| | Check | 78 a | 43 a |
| Strip tillage | Dolomitic | 105 a | 41 ab |
| | Calcitic | 78 ab | 43 a |
| | Check | 67 b | 37 b |
| Conventional | Dolomitic | 79 ab | 37 a |
| | Calcitic | 101 a | 37 a |
| | Check | 70 b | 32 a |

† Within a tillage system, yields followed by the same letter were non-significant at 0.05 level.

# Tiptonville Silt Loam

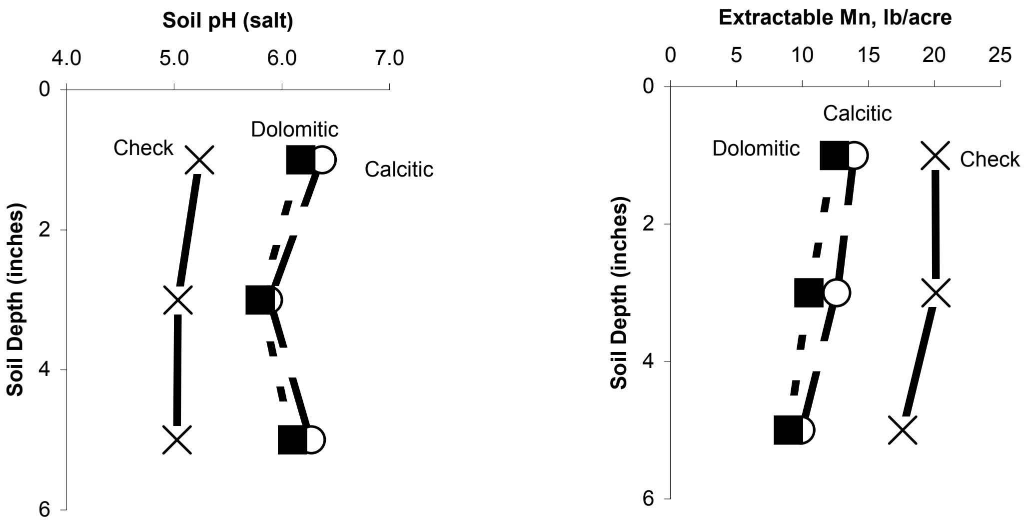



Figure 1. Conventional tillage soil $pH_{salt}$ and Mn levels in the surface 0 to 6-inch soil layer in 2004.

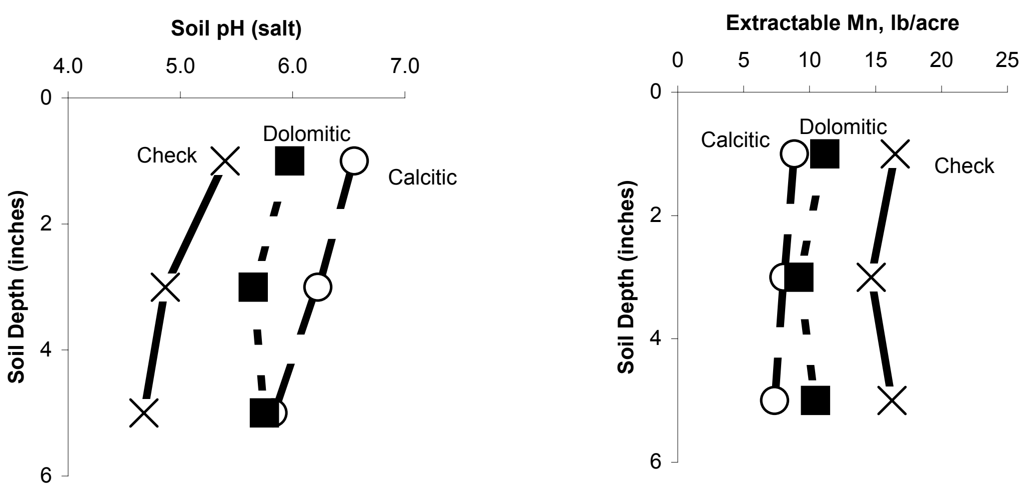



Figure 2. No-tillage soil $pH_{salt}$ and Mn levels in the surface 0 to 6-inch soil layer in 2004.

# Soil pH effects on atrazine carryover damage to no-till soybean

Peter Scharf, Reid Smeda, and Kevin Bradley
Agronomy Department, University of Missouri

**Accomplishments for 2004:**

- Soybeans were grown in 160 plots with:
  - a wide range of soil pH values and
  - four atrazine treatments applied to the 2003 corn crop:
    - Atrazine 1.25 lb a.i./acre preplant
    - Atrazine 2.5 lb a.i./acre preplant
    - Atrazine 1.25 lb a.i./acre preplant followed by 1.25 lb a.i./acre post
    - Untreated check
  - Weeds in both 2003 corn and 2004 soybean crops were controlled with glyphosate, so that atrazine effectiveness was not a factor

**Results for 2004:**

- **Soybean yields were excellent**, with an average yield in this experiment of 69.1 bu/acre.
- **Yield loss associated with atrazine carryover was minimal in 2004.**
  - High-pH plots (salt pH of 6.5 to 7.0 in the top inch of soil) that had received atrazine yielded on average 1.4 bu/acre less than medium-pH plots (see Table 1). Statistics indicate 82% confidence that this is a true yield difference.
  - High-pH plots that had not received atrazine yielded 0.6 bu/acre less than medium-pH plots, with little or no statistical evidence that this difference was real.
  - Thus we would conclude, but not with great confidence, that it appears that atrazine carryover at high soil pH resulted in a 0.8 bu/acre yield loss in these plots.
  - We saw larger yield loss associated with low pH, but it was the same regardless of previous atrazine treatment (see below).

- **Soil pH had a substantial effect on yield, regardless of last year's herbicide treatment.** This is the first time (in three two-year cycles) that soil pH has influenced yield of plots that had not received atrazine the previous year.
  - Plots that had received one of the acidifying treatments (either 2 or 4 tons/acre of ferrous sulfate applied over the six-year study period) yielded 3.6 bu/acre less than plots that had not received either lime or ferrous sulfate. Statistics indicate 99% confidence in this conclusion. Yields were numerically, but not statistically, 1.4 bu/acre lower for the 4-ton ferrous sulfate treatment than for the 2-ton treatment.
  - The yield decline for the low-pH plots was the same for plots that had not received any atrazine in 2003 as for the average of all atrazine treatments (see table). This means that there was no yield loss due to atrazine carryover at low soil pH this year (as had been seen in both the 2000 and the 2002 soybean crops).
  - Acidifying treatments had, by the sixth year of the study, affected the soil pH to a greater depth than during the early years of the study. Soil pH values were lower at the 0-1" depth than in previous cycles, but more notably they were lower at the 0-6" depth. In 2004, for the first time, we saw plots with the 0-6" salt pH below 5. The movement of the

acidity down into a greater proportion of the root zone probably was responsible for the negative effect on soybean yield. It is well known that soybean yields drop off in acid soil conditions, but we had not seen any yield loss associated with acidity alone in the previous years of the study.

- There was also a possible small yield decrease associated with the liming treatments. Average yield for all plots receiving lime was 1.2 bu/acre less than unlimed plots, with 81% confidence that this difference was real. It is likely that this was due mainly to yield loss on plots that had received both lime and atrazine (see above).

- Plots that had received the split atrazine treatment in 2003 yielded 2.4 bu/acre more than plots that had received no atrazine in 2003 (95% confidence). The reason for this is not clear.

Table 1. Yield loss of low and high pH plots (compared with medium-pH plots) for various atrazine treatments applied to the 2003 corn crop. Yield loss was the same, 3.6 bu/acre (99% confidence), with highly acid surface soil for plots that had received no atrazine in 2003 and for the average of all plots receiving atrazine in 2003, indicating no yield loss due to atrazine carryover at low pH. A small yield loss appeared to occur due to atrazine carryover at high pH, where plots with atrazine yielded 1.4 bu/acre less (82% confidence) than plots with atrazine at medium pH. Soil pH was measured in the top inch, where atrazine is mainly active, and where pH extremes can occur in no-till. Nitrogen fertilizer had been surface-applied to the corn about a month before measuring pH, resulting in acidification of the top inch. Soil pH values had gone up by about 0.2 units by May 2004 as this acidity spread farther into the soil.

| Soil salt pH level in top inch, May 2003 | Yield loss with 2003 atrazine treatment: | | | | |
|---|---|---|---|---|---|
| | low rate atrazine | high rate atrazine | spllit pre/post atrazine | no atrazine | all atrazine treatments averaged |
| | ---------------------------------------------------------------bu/acre---------------------------------------------------------------- | | | | |
| 4.1 to 4.6 | 5.9 | 3.5 | 1.3 | 3.6 | 3.6 |
| 6.5 to 7.0 | 1.4 | 1.9 | 0.8 | 0.6 | 1.4 |

**Overall conclusions**

- This two-year study focused on atrazine carryover. It is a follow-up to a prior four-year project that included other potentially pH-sensitive herbicides. Because pH-sensitive carryover damage to soybean yield was seen only with atrazine in the previous project, this study focused on atrazine, and the overall conclusions that we present will relate only to atrazine over the six years of the combined studies.
  - Corn was planted in odd years and received several herbicide treatments including a low (1.25 lb a.i./acre) and high (2.5 lb/acre)

atrazine rate in all years, and a split pre/post atrazine treatment in 2003.
  - Soybean was planted in 2000, 2002, and 2004 to study the effects of possible atrazine carryover on soybean yield.

- **Summary of soybean yield losses (see Table 2):**
  - Three-year average yield losses that were apparently due to pH-related atrazine carryover were:
    - **1.3 bu/acre in low-pH plots**
      - Small losses were observed in each of the first two 2-year study cycles. At low pH, atrazine is tightly bound to soil particles and breakdown is slower.
    - **2.3 bu/acre in high-pH plots**
      - This loss came almost entirely in 2000, following a long drought. Normally, degradation of atrazine can proceed at high pH, but water availability may have limited degradation in this season. The remaining atrazine would be extremely soluble at high soil pH, enabling it to cause significant damage to soybeans.
      - Yield loss with atrazine carryover at high pH is consistent with Iowa State research showing low soybean yields in high-pH areas of fields.

  - **In addition, a 3.6 bu yield loss was seen at low pH in 2004 regardless of whether atrazine had been applied the previous year.** This is simply a reflection of the negative effect that low soil pH can have on the soybean plant directly. In the early years of the study, low pH due to the acidifying treatments was probably confined to the top inch or two, but as it spread downward into the root zone, came to influence the crop more negatively.
- In the long term, uncorrected acidity problems will probably reduce soybean yields mainly by their direct influence on the root system.
- However, even in the short term, it appears that, when the soil pH of the top inch gets too high or too low, atrazine carryover can reduce the yield of the following soybean crop.
- Managing the pH of the top inch of soil in no-till can help to prevent this type of yield loss, which appears to be 1 to 2 bushels on average.
  - Smaller, more frequent lime applications can help to prevent wide swings in the surface soil pH in no-till fields.
  - Monitoring the pH of the surface inch of soil can alert the producer to the need to manage soil pH.
  - Subsurface applications of nitrogen fertilizer (anhydrous ammonia or injected UAN solution, for example) help to avoid acidification of the top inch of soil.
  - Variable-rate lime applications may help to avoid problems with atrazine carryover in areas with higher or lower soil pH than the field average. Many fields in Missouri have a pH range of 2 units from one part of the field to another.

Table 2. Estimates of soybean yield loss with or without atrazine at high or low surface soil pH levels, relative to plots with medium pH levels. These results suggest that atrazine carryover causes small yield losses when surface soil pH gets too low or too high. Low pH can also cause direct yield losses, as in 2004, regardless of atrazine use in the previous year.

| Year | Herbicide treatment | Yield loss with: | |
|---|---|---|---|
| | | low pH (top inch) | high pH (top inch) |
| | | ---bu/acre--- | |
| 2000 | no atrazine | 0 | 0 |
| 2000 | atrazine (ave. low & high) | 2.6 | 6.2 |
| 2002 | no atrazine | 0 | 0 |
| 2002 | atrazine (high) | 1.2 | 0 |
| 2004 | no atrazine | 3.6 | 0.6 |
| 2004 | atrazine (ave. all) | 3.6 | 1.4 |
| 3-year average | no atrazine | 1.2 | 0.2 |
| 3-year average | atrazine | 2.5 | 2.5 |
| **3-year average** | **loss due to atrazine carryover** | **1.3** | **2.3** |

# 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

The project was initiated in the late summer and early fall with the selection of the field plots at Southwest Research Center at Mt. Vernon and the Bradford research and Extension Center in Columbia. At each location, established tall fescue stands were assessed for suitability relative to pH; Bray PI; Bray PII; neutralizable acidity; and other regular soil test components via analysis through the Missouir Soil Testing Laboratory.
Those areas that exhibited suitable soil test attributes were fertilized with 100 lbs N/A as well as maintenance P and K via soil test assessment. Plots with dimensions of 10 ft by 25 ft with a 10 ft border were delineated at each location with each treatment replicated 6 times (plot diagrams attached). The early season foragewas cut and removed from the established stand, the calcitic and dolomitic limestone treatments were applied at the rates of 0X, 1/2X, 1, and 2X of the soil test recommendation based on the Woodruff Buffer. Soil test values, fertilizer treatments, and lime applications for plots at each location are provided in the following table

| **Parameter** | **Location** | |
|---|---|---|
| | **Bradford** | **Mt. Vernon** |
| **Soil** | **Mexico** | **Gerald** |
| | **SOIL TEST VALUES** | |
| **Phosphorus (lbs/A)** | **7.6** | **32.2** |
| **Potassium (lbs/A)** | **150** | **154** |
| **Calcium (lbs/A)** | **3007** | **1968** |
| **Magnesium (lbs/A)** | **497.7** | **158** |
| **pH-salt** | **5.2** | **5.1** |
| **N.A. (meq/100g)** | **3.8** | **3.9** |
| **CEC (meq/100g)** | **13.6** | **9.7** |
| **Organic Matter** | **3.0** | **2.4** |
| | **FERTILIZER AND LIME APPLICATIONS** | |
| **N (lbs/A)** | **100** | **100** |
| **P2O5 (lbs/a)** | **62.5** | **65** |
| **K2O (lbs/a)** | **225** | **203** |
| **Limestone (1X recommendation)** | | |
| **Dolomite ENM = 467 (T/A)** | **1.734** | **1.927** |
| **Calcite ENM = 417 (T/A)** | **1.942** | **2.158** |

Composite soil samples for each individual plot were collected and archived to provide baseline extractable Aluminum (Al) levels by KCL and $LaCl_2$ extraction before the treatments were applied and will be used to compare to annual Al levels as the project progresses.

## OBJECTIVES FOR YEAR TWO

The objectives of year two will parallel those of the main objectives of the project are to determine: 1.) the influence of calacitic and dolomitic aglime on the releases and 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. To accomplish these objectives, starting in January, collared leaves will be sampled monthly for calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorus (P), and Al analysis. Additionally, soil samples for each plot will be taken in the summer to assess for Bray PI, Bray PII, pH, total fixed P, exchangeable Mg and Al, and Al speciation by KCL and LaCl2 extraction. Also, mid-June and fall harvest yields will be taken.

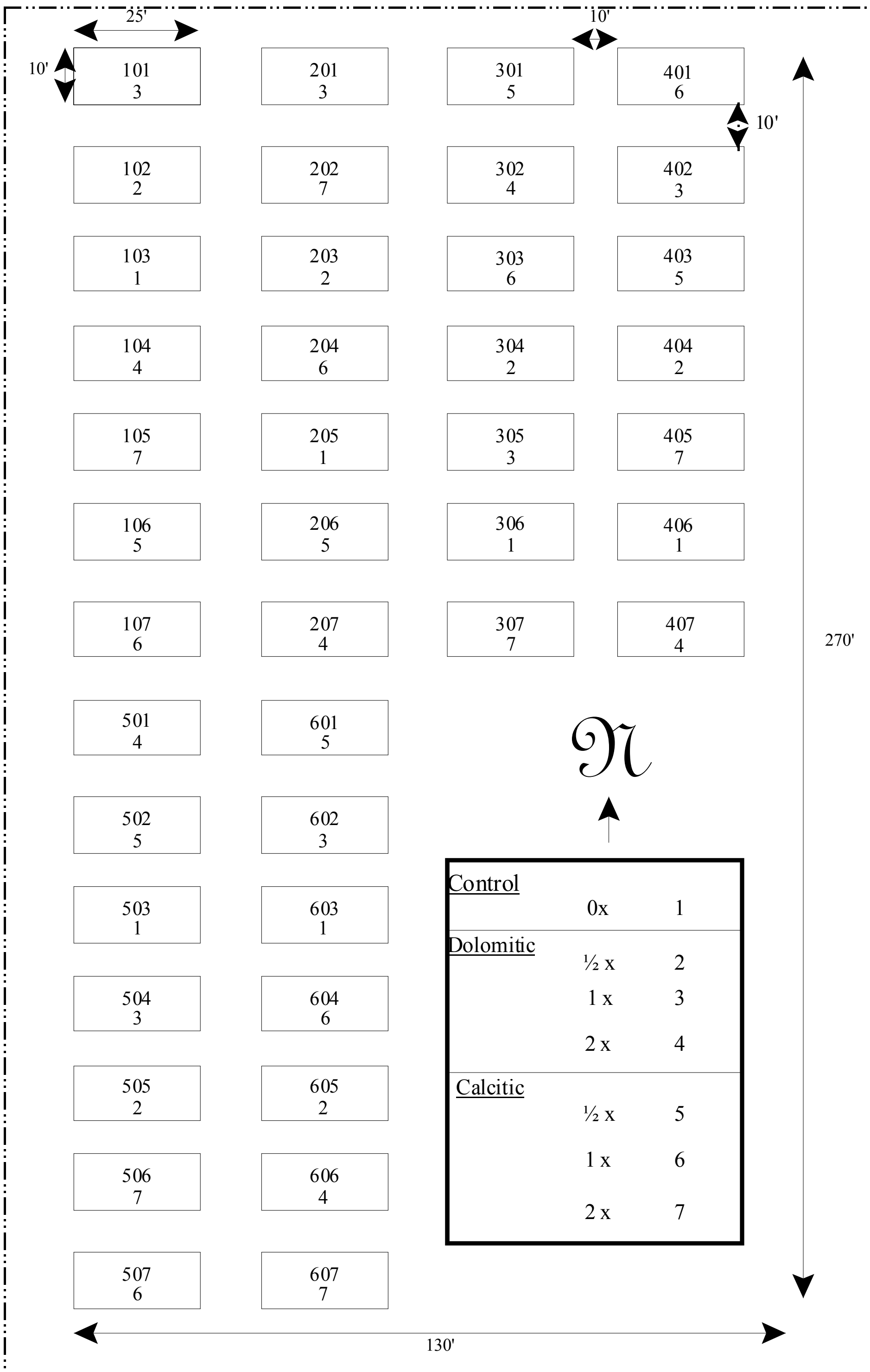
## BUDGET

Because the initial field delineation for the plots was somewhat delayed and a graduate student, Elizabeth Hamilton, started on the project in September, the original budgeted monies for 2005 (year 2) and that remaining for 2004 is needed to fulfill the objectives of the project. This carryover of the year one (2004) budget is requested because many of the field sampling and laboratory analyses that were projected to be in late 2004 will now be performed in early 2005 along with many of the major analysis for 2005 which were projected in the original proposal. The total requested for 2005 in the original budget was $30,325 partitioned as follows: $18,500 for a 50% Research Assistant with $4,625 for benefits as well as $2,00 for part-time student labor, $4,000 for supplies, and $1,200 for travel. It is expected that much of the budgeted monies for 2004 such as part-time student labor ($2,000), supplies ($4,000), and travel ($1,200) will be used to provide the analysis and assessment of the soil and plant samples.

# Lime Study Plot Layout

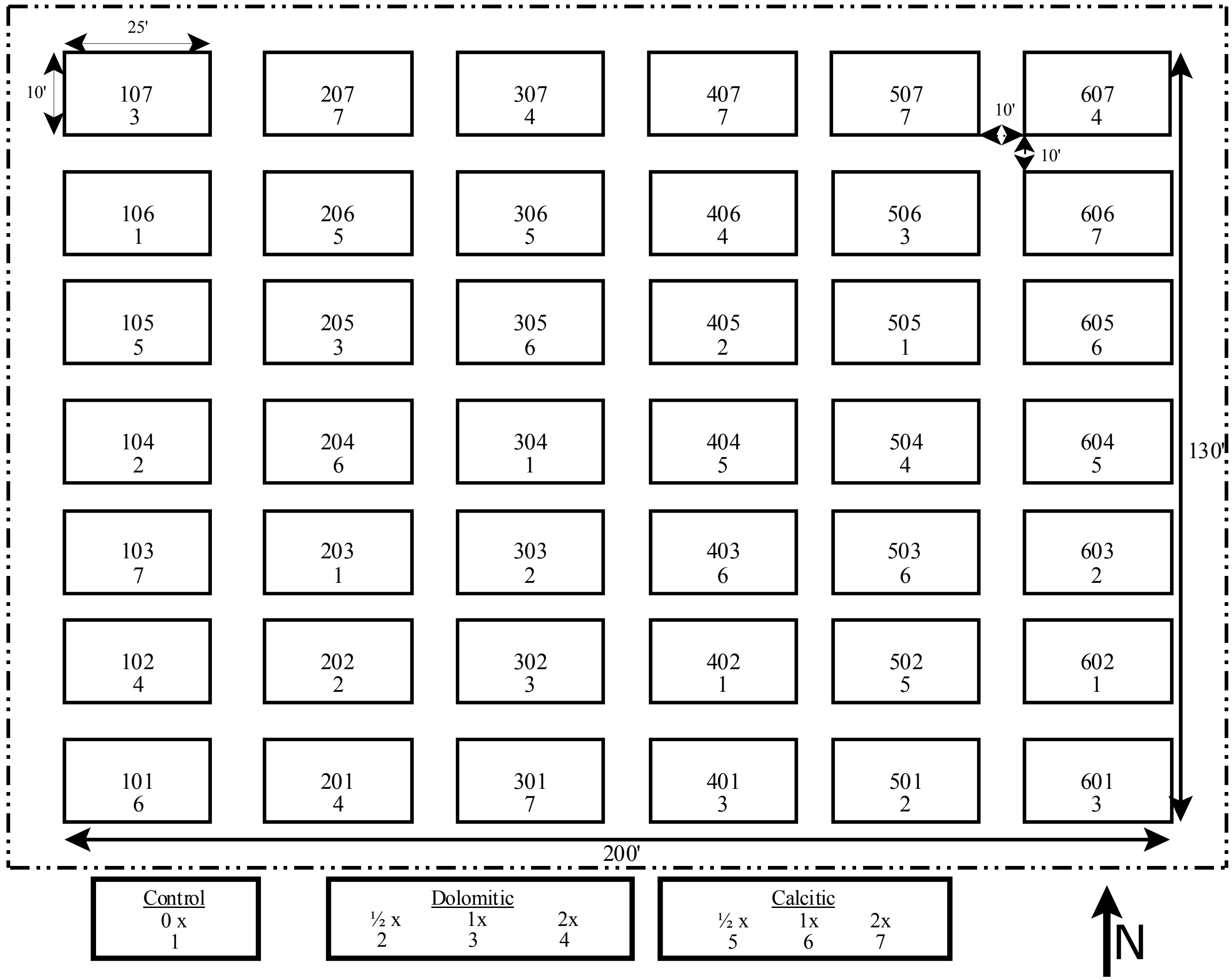
Bradford

5 October 2004



## Lime Study Plot Layout
**Mt. Vernon**

**15 October 2004**



# Nitrogen Management

# 2003

## Evaluating Grain Sorghum Nitrogen Fertilization Recommendations

Final Report for Last Year (2003)

Gene Stevens and David Dunn

**Objective:**

(3) To evaluate grain sorghum yield response to nitrogen fertilizer rates at different plant populations.

**Current status/ importance of research:**

Farmers often have difficulty obtaining an optimum plant population of grain sorghum because of soil crusting, seedling diseases, or insufficient soil moisture at planting. In grain sorghum fields with thin or "skippy" populations, farmers need to know whether nitrogen fertilizer rates should be adjusted up or down from current soil test recommendations. One of the challenges with grain sorghum fertilization is estimating a realistic yield goal for fields with reduced plant populations. Yield goal is the most important variable in the Missouri soil N recommendation equation for grain sorghum. The recommendations for a 5000 lb/acre grain sorghum yield goal is 110 lb N/acre for silt loam and 120 lb N/acre for clay soils. The equation for calculating N recommendations in Missouri is 60+(yield goal in lb)(0.014)-organic matter adjustment. The organic matter adjustment for soils with less than 2.0% is –20 lb N/acre for silt loam soil and –10 lb N/acre for clay loam soil.

**Research activities in 2003:**

Two experiments were conducted at the University of Missouri- Delta Research Center at Portageville, Missouri. A randomized complete block design with four replications was used in each test. Grain sorghum was planted on 30-inch rows in each test. In the first plant population test, grain sorghum was planted at a high seeding rate (150,000 seeds per acre). After emergence, plots were evenly thinned by hand to low and high populations (35,000 and 105,000 plants per acre). Five early-season N Treatments were applied at rates of 0, 50, 100, 150, and 200 lb N/acre (ammonium nitrate) when grain sorghum was 4 inches tall. In the second test, plots were intentionally thinned unevenly. A factorial with a 3-feet, 6-feet, or 9-feet long skip applied 1, 2, or 3 times per 50 feet of row was used. Three fertilizer rates were applied to each skip treatment at rates of 45, 90, and 135 lb N/acre.

Results in 2003:

Grain sorghum plants demonstrated a strong capacity to compensate for reduced plant populations by producing larger heads (Figure 1). No significant interactions between plant population and nitrogen rates were found in the evenly thinned or skippy stand experiments. Although thinning plants in rows reduced yields, N yield response in high and low population plots were similar on the silt loam soil. Solving quadratic equations for maximum yield showed the highest values on the silt loam were with 119 lb N/acre in the low population plots and 121 lb N /acre on the high population plots (Figure 2). On the clay soil the highest yields for low and high populations were 152 and 165 lb N/acre, respectively. Average yields for nitrogen rates across plant populations are shown in Table 1.

In "real-life" farm conditions, poor stand in grain sorghum fields are due to long plant skips (long spaces between plants) in rows rather than a uniform low plant population. As expected, we found that a few long skips in rows had a more negative effect on grain sorghum yields than more frequent short skips in rows (Table 2). Grain sorghum in plots with 9-feet skips did not respond to greater that 45 lb N/acre. Grain sorghum with 3-feet skips yielded and responded to N almost the same as the check plots with an optimum stand.

**Conclusions:**

Whether nitrogen fertilizer rates should be adjusted down in fields with low grain sorghum plant population scenarios depends on whether the plants are evenly spaced or not. In our experiments, grain sorghum plants compensated some for yield by producing larger heads. If the grain sorghum plants are evenly spaced in the rows, a nitrogen fertilizer rate for a normal yield goal in the field should be used. Grain sorghum plots with three 9-feet skips per 50 feet of row were not able to completely compensate regardless of the nitrogen rate. In this situation a farmers should either conserve money by applying less N; or, if it is not too late in the season, replant it in grain sorghum or another crop.

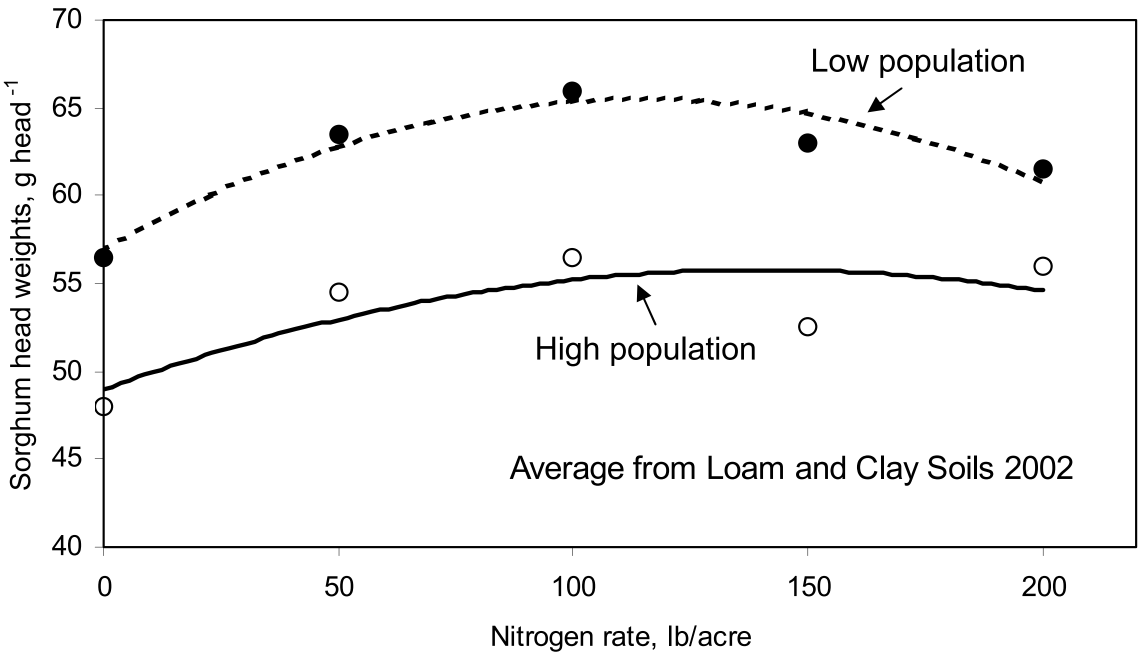



Figure 1.
Effect of evenly thinned plant populations and N fertilizer rate on grain sorghum head fresh weight averaged across Tiptonville silt loam and Sharkey clay soils in 2002 at Portageville, Missouri.

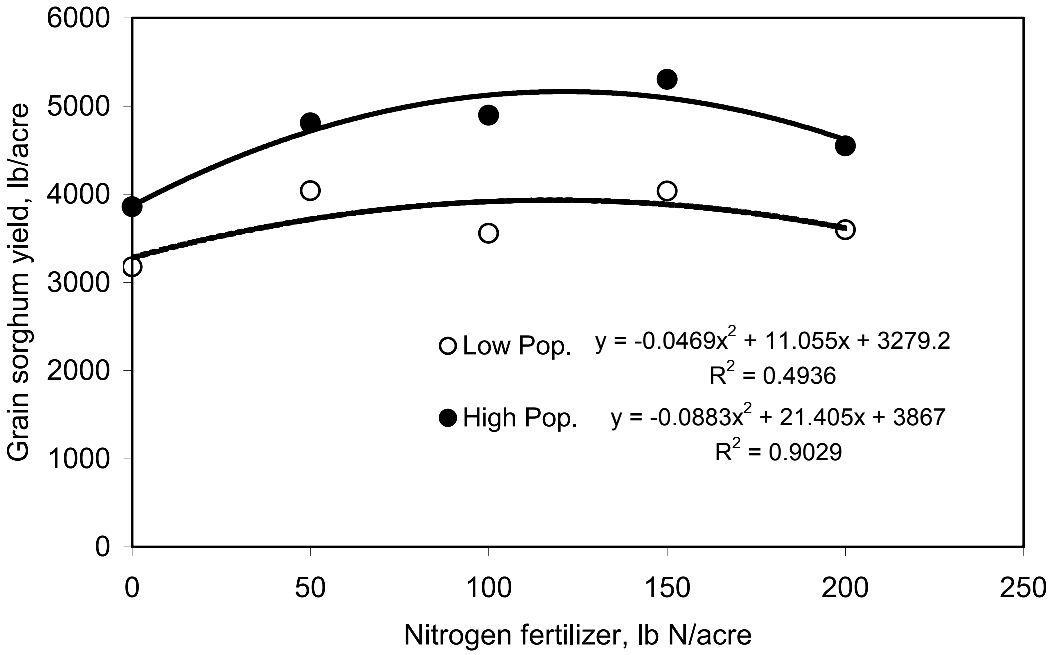



Figure 2. Effect of nitrogen fertilizer rates on low and high plant populations on Tiptonville silt loam soil averaged across 2001-2003.

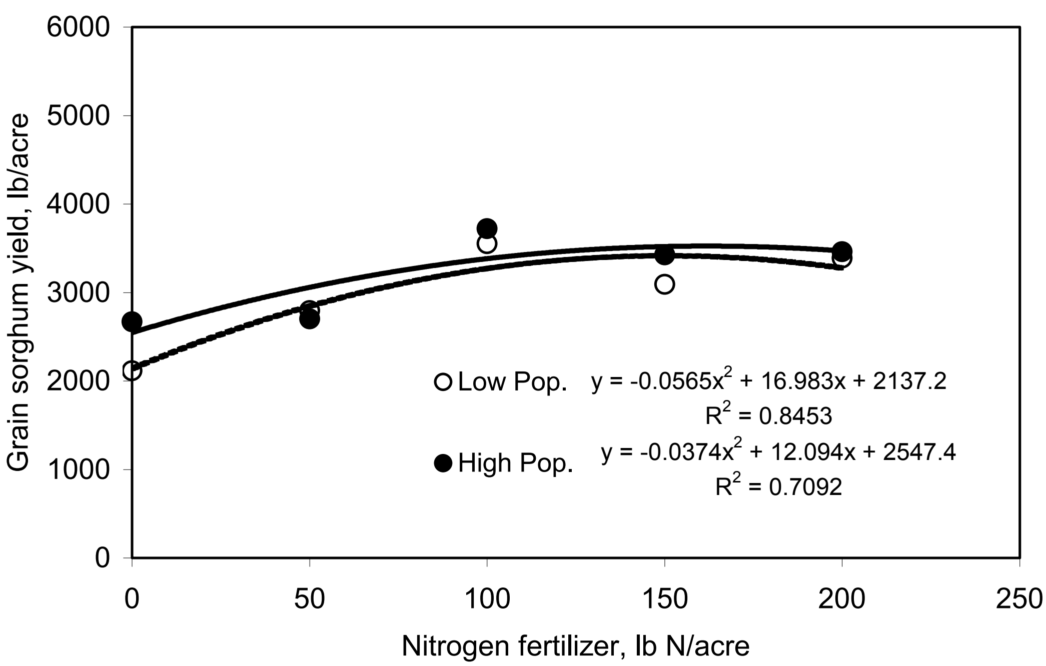



Figure 3. Effect of nitrogen fertilizer rates on low and high plant populations on Sharkey clay soil averaged across 2001-2002.

Table 1. Effect of nitrogen rate on grain sorghum yields averaged across populations on a Sharkey clay and Tiptonville silt loam soil.

| Year | Soil | Nitrogen rate | Yield | Letter group † |
|---|---|---|---|---|
| | | lb N/acre | lb/acre | |
| 2001 | Sharkey clay | 0 | 2237 | B |
| | | 50 | 2089 | B |
| | | 100 | 2783 | AB |
| | | 150 | 2437 | B |
| | | 200 | 2912 | A |
| 2002 | | 0 | 2598 | C |
| | | 50 | 3451 | BC |
| | | 100 | 4540 | A |
| | | 150 | 4129 | AB |
| | | 200 | 3988 | AB |
| 2001 | Tiptonville silt loam | 0 | 3129 | BC |
| | | 50 | 3695 | B |
| | | 100 | 4203 | AB |
| | | 150 | 4787 | A |
| | | 200 | 4348 | AB |
| 2002 | | 0 | 3148 | B |
| | | 50 | 3824 | AB |
| | | 100 | 2830 | B |
| | | 150 | 4017 | A |
| | | 200 | 3044 | B |
| 2003 | | 0 | 4274 | BC |
| | | 50 | 5755 | A |
| | | 100 | 5644 | A |
| | | 150 | 5207 | AB |
| | | 200 | 4828 | BC |

† Within year and soil type, grain sorghum yields followed by the same letter were not significantly different at the 0.05 probability level.

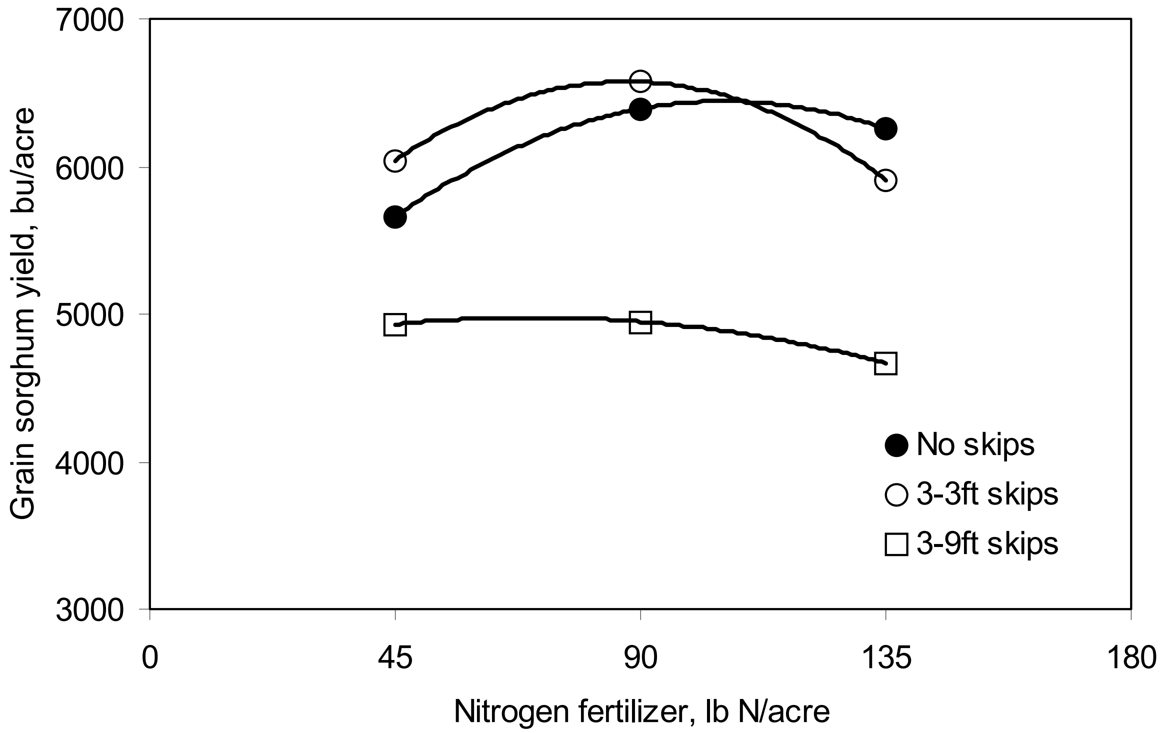



Figure 4. Effect of three 3-feet and 9-feet skips in 50 feet of plot row on grain sorghum yield response to N fertilizer on Tiptonville silt loam soil averaged across 2002 and 2003.

Table 2. Effects of length row skips and total area of skips in grain sorghum averaged across years and nitrogen rates on a Tiptonville silt loam soil in 2002 and 2003.

| Row skip length | Total skips | Percentage of total area in skips | Yield | Letter group† |
|---|---|---|---|---|
| ft | skips/acre | % | lb/acre | |
| 0 | 0 | 0 | 6101 | A |
| 3 | 342 | 6.5 | 6011 | AB |
| 3 | 684 | 13 | 6192 | A |
| 3 | 1026 | 19.5 | 6173 | A |
| 6 | 342 | 13 | 6054 | AB |
| 6 | 684 | 23 | 5787 | ABCD |
| 6 | 1026 | 39 | 5342 | CDE |
| 9 | 342 | 19.5 | 5828 | ABC |
| 9 | 684 | 39 | 5265 | DE |
| 9 | 1026 | 58.5 | 4848 | E |

† Grain sorghum yields followed by the same letter were not significantly different at the 0.05 probability level.

# Evaluating Fall N Applications for Corn

Peter Scharf, Larry Mueller, and Gary Lesoing
Agronomy Department, University of Missouri and Ray County Extension, University of Missouri

**Objectives:**
The objective of this study is to evaluate fall N applications in production cornfields over several weather years. This includes:

a. Tracking how much fall-applied N is lost from production cornfields.
b. Determining how much yield potential is lost.
c. Determining the economics of additional spring N applications.

**Accomplishments for 2003:**

- Eighteen experiments were established in production cornfields that had received N applications in fall/winter 2002 (Figure 1 and Table 1). Most of these experiments were in west-central Missouri, near the Missouri River, and in the claypan region of northeast Missouri. Fall 2002 applications of $NH_3$ in Missouri were higher than ever before (Figure 2), and these regions were among the highest in the state. Three experiments were established in Vernon County because it is a higher-risk area for loss of fall-applied N, though less fall N is applied in that area. $NH_3$ was applied after November 1 in all experimental fields. Seven fields had N-Serve added to the $NH_3$. In one field, 28% UAN solution was used as the fall N source.

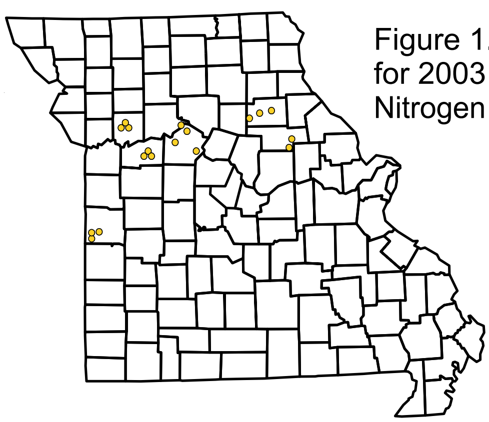


Figure 1. Locations for 2003 Fall Applied Nitrogen Trials

Figure 2. Fall $NH_3$ applications in Missouri have gone up dramatically the past two years.

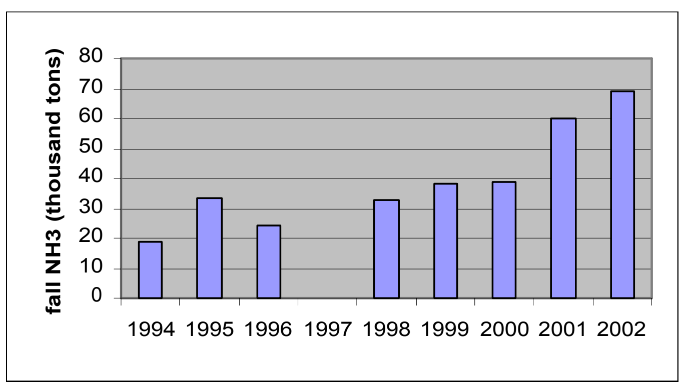


**Table 1. 2003 LOCATIONS FOR FALL APPLIED NITROGEN TRIALS**

| COUNTY | LOCATION | SOIL SERIES | HYBRID |
|---|---|---|---|
| Vernon | Deerfield 1 | Parsons Silt Loam | Pioneer 33M95 |
| Vernon | Deerfield 2 | Parsons Silt Loam | Pioneer 33M95 |
| Vernon | Hong | Parsons Silt Loam | NC+ 6868 |
| Carroll | DeWitt | Gilliam Silty Clay | Pioneer 33R79 |
| Saline | Blackburn | Sibley Silt Loam | Asgrow 741 RR YG |
| Saline | Miami | Sibley Silt Loam | Pioneer 33D31 |
| Saline | Napton | Macksburg Silt Loam | Pioneer [A] |
| Ray | Dockery | Sampsel Silty Clay Loam | Stone M8H |
| Ray | Knoxville | Lagonda Silt Loam | Stone E7S |
| Ray | Morton | Sibley Silt Loam | Pioneer 33P67 [B] |
| Lafayette | Higginsville 1 | Marshall Silt Loam | Vineyard 433 [C] |
| Lafayette [D] | Higginsville 2 | Marshall Silt Loam | Pioneer 33K72 [C] |
| Lafayette [D] | Higginsville 4 | Marshall Silt Loam | Zimmerman 1851W [C] |
| Audrain | Scott's Corner | Mexico Silt Loam | Asgrow RX 730 YG |
| Audrain | Martinsburg | Mexico Silt Loam | Pioneer 34B24 |
| Monroe [E] | Middle Grove | Putnam Silt Loam | Mycogen 6888 |
| Monroe | Madison | Putnam Silt Loam | N/A |
| Monroe | Paris | Putnam Silt Loam | Golden Harvest 9247 Bt |

[A] A Pioneer waxy hybrid was planted, but the number was not recorded
[B] 8 row planter with 6 rows Pioneer 33P67 and 2 rows Pioneer 33D31
[C] White corn
[D] 28% liquid nitrogen primary fertilizer source used at this location
[E] This location was irrigated

# Table 2. Fall N applications and spring N samples for 2003 experiments

| COUNTY | LOCATION | FALL N, ANHYDROUS + DAP | | N SERVE APPLIED | SOIL SAMPLE DATE | AMMONIUM 0-36" LBS/AC | NITRATE 0-36" LBS/AC | TOTAL N 0-36" LBS/AC |
|---|---|---|---|---|---|---|---|---|
| | | RATE (lb/ac) | DATE [A] | | | | | |
| Vernon | Deerfield 1 | 150 | 2/13/2002 | YES | 4/11/2003 | 159 | 102 | 261 |
| | | | | | 5/27/2003 | 217 | 158 | 375 |
| Vernon | Deerfield 2 | 150 | 2/13/2002 | NO | 4/11/2003 | 262 | 111 | 373 |
| | | | | | 5/27/2003 | 84 | 236 | 320 |
| Vernon | Hong | 125 | 11/18/2002 | YES | 4/11/2003 | 85 | 230 | 315 |
| | | | | | 5/27/2003 | 37 | 220 | 257 |
| Carroll | DeWitt | 180 | 11/12/2002 | YES | 4/12/2003 | 57 | 225 | 282 |
| | | | | | 5/21/2003 | 34 | 253 | 287 |
| Saline | Blackburn | 180 | 11/22/2002 | NO | 4/13/2003 | 105 | 251 | 356 |
| | | | | | 5/21/2003 | 15 | 346 | 361 |
| Saline | Miami | 175 | 12/15/2002 | YES | 4/14/2003 | 210 | 133 | 343 |
| | | | | | 5/21/2003 | 139 | 201 | 340 |
| Saline | Napton | 150 | 12/10/2002 | NO | 4/14/2003 | 149 | 281 | 430 |
| | | | | | 5/21/2003 | 19 | 180 | 199 |
| Ray | Dockery | 150 [B] | 11/2/2002 | NO | 4/12/2003 | 34 | 203 | 237 |
| | | | | | 5/20/2003 | 20 | 193 | 213 |
| Ray | Knoxville | 155 [B] | 11/2/2002 | NO | 4/12/2003 | 202 | 114 | 316 |
| | | | | | 5/20/2003 | 76 | 199 | 275 |
| Ray | Morton | 190 | 11/1/2002 | NO | 4/12/2003 | 141 | 225 | 366 |
| | | | | | 5/20/2003 | 46 | 230 | 276 |
| Lafayette | Higginsville 1 | 165 | 11/20/2002 | YES | 4/12/2003 | 100 | 139 | 239 |
| | | | | | 5/20/2003 | 49 | 235 | 284 |
| Lafayette | Higginsville 2 | 140 [C] | 12/5/2002 | NO | 4/12/2003 | 14 | 182 | 196 |
| | | | | | 5/20/2003 | 32 | 205 | 237 |
| Lafayette | Higginsville 4 | 140 [C] | 4/10/2003 | NO | 5/20/2003 5/20/2003 | 34 | 205 | 239 |
| Audrain | Scott's Corner | 160 | 12/2/2002 | YES | 4/14/2003 | 71 | 81 | 152 |
| | | | | | 5/22/2003 | 62 | 132 | 194 |
| Audrain | Martinsburg | 150 | 11/1/2002 | NO | 4/13/2003 | 146 | 267 | 413 |
| | | | | | 5/22/2003 | 55 | 284 | 339 |
| Monroe [D] | Middle Grove | 190 [E] | 11/22/2002 | YES | 4/14/3003 | 75 | 111 | 186 |
| | | | | | 5/22/2003 | 109 | 170 | 279 |
| Monroe | Madison | N/A | N/A | N/A | 4/14/2003 | 51 | 255 | 306 |
| | | | | | 5/22/2003 | 29 | 246 | 275 |
| Monroe | Paris | 135 | 11/9/2002 | NO | 4/15/2003 | 56 | 211 | 267 |
| | | | | | 5/22/2003 | 23 | 196 | 219 |

[A] When application dates vary or were given as ranges the midpoint was used.
[B] Also received 5 gallon 6-24-6-1 at planting.
[C] 28% Urea-ammonium nitrate solution was used as the N source in these two fields.
[D] This location was irrigated.
[E] 100 lbs./ac 10-34-0 applied at planting.

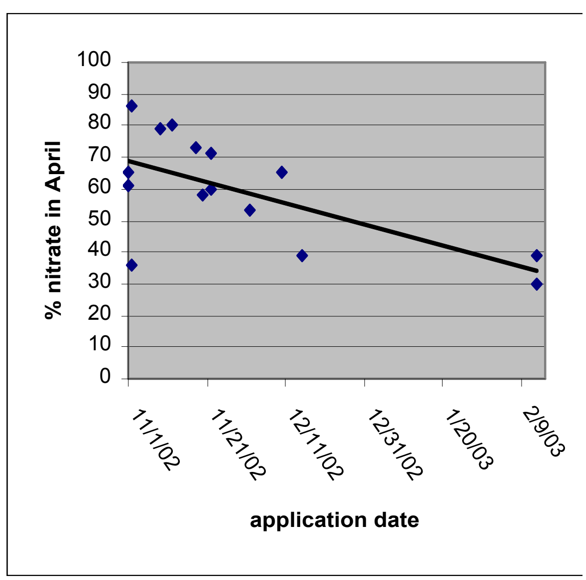
**Results:**

Soil sample results

Soil samples were taken in all experiments to a three foot depth in April and May. These samples were analyzed for nitrate and ammonium (Table 2).

- The amount of N found in the soil samples was higher than expected. Normally there is about 50 lb/acre of available N (nitrate + ammonium) in the soil in April if no fertilizer has been applied. For fertilized fields, the expected N content is about 50 lb/acre above the producer's N application rate (if none has been lost).
  - This is the second year in a row that we have found high soil N levels in spring–higher than expected given the N application rate of the producer. This is out of line with our past experience. In about 50 past experiments with corn N response in producer fields, conducted from 1995 to 1998, very few fields with grain-only rotations gave numbers as high as we have seen in this study. We don't have any explanation for why soil N levels were so high in these fields.
  - It is clear that little or no fertilizer N was lost during winter and early spring in these fields.
  - With the soil N supply this much higher than fertilizer application rates, it would be unlikely to lose enough N to get a yield response to our additional N applications in spring.

- More than half of the fertilizer had converted to nitrate by the April sampling time in 13 of the 18 experimental fields (Table 2).
  - Nitrate is the form of N that can be lost through leaching or denitrification. These fields were more at risk of N loss (but only with wet weather) than if the fertilizer had been spring-applied.
  - Conversion of fall-applied N to nitrate was greater by April 2003 than it had been by April 2002. This is surprising considering that the winter of 2002-2003 was colder (except for March).
  - The proportion of N converted to nitrate by the time of sampling in April was primarily controlled by the application date (graph at right). The later the application date, the less fertilizer was converted to nitrate by April. The main exception to this rule was a field with very low pH (4.8), where less than 40% of the N was nitrate by April even though the N was applied on November 1 (one of the earliest fields fertilized). Low pH



inhibits conversion of fertilizer to the nitrate form of N.Loss of soil N between April and May was minimal.
- On average, total available N in the top 3 feet declined by about 17 lb N/acre from the April sampling to the May sampling.
- Actual losses were probably somewhat greater than this. Normally soil organic matter begins to release N in May, so we would expect numbers to go up from April to May if no losses occurred.
- From a management standpoint, nearly all fields still had well more N available in May than would be needed to produce high yields.
- It is surprising that so little N was lost. Wet weather set in about a week after the April samples were taken, and prevented planting over much of northern Missouri from late April until about the time that our May sampling started. Given the high amounts of soil nitrate in most of these fields in April, substantial N losses seemed likely, but apparently did not happen.

- Fields that had N-Serve applied with the anhydrous ammonia were, on average, almost as high in nitrate as fields without N-Serve.
  - Average percent of soil-N plus fertilizer-N as nitrate in April was:
    - 57% for anhydrous ammonia with N-Serve
    - 63% for anhydrous ammonia without N-Serve
    - 94% for UAN solution
  - Average percent of fertilizer-N as nitrate in May was:
    - 70% for anhydrous ammonia with N-Serve
    - 85% for anhydrous ammonia without N-Serve
    - 89% for UAN solution

<u>Yield response to supplemental spring N</u>
Average yield for these 18 experiments was 138 bu/acre. Yield levels were good considering the low rainfall in July and August for most of these fields.

When fall-applied N is lost, there is potential for yield loss, and for yield response to supplemental spring N. We applied either 0, 50, or 100 lb N/acre to small plots in the experimental fields between planting and emergence. In each field, six plots received no spring N, six received the 50 lb N/acre rate, and three received the 100 lb N/acre rate. These small-plot experiments were hand-harvested before the cooperating producers harvested the surrounding field.

- On average, there was no yield response to either the 50 or 100 lb/acre rates of additional spring-applied N.
- Statistical analysis indicated three locations where yield may have responded to N: DeWitt, Middle Grove, and Higginsville 4 (Table 3).
  - At DeWitt, both N rates appeared to give about a 5 or 6 bu/acre yield response.
  - The Middle Grove experiment was irrigated and was one of the highest-yielding fields. In this field, either the 50 or 100 lb/acre N rate gave a 7 bu/acre yield increase.
  - At Higginsville 4, average yield with 50 lb N/acre was 15 bu/acre

higher than plots with no additional spring N. It is doubtful that this was a real yield response to N. Plots receiving the 100 lb/acre N rate yielded 7 bu/acre less than untreated plots. If N was the reason for the yield increase in plots receiving 50 lb N, a yield increase would also be expected in the plots receiving 100 lb N. This is the opposite of what was seen. Yields were highly variable from plot to plot in this experiment, which was adjacent to a terrace channel. Water availability seemed to be variable across the experiment and was probably the reason for large variations in yield.

- Thus, of the three possible yield increases to N, one yield increase was questionable and the other two were barely profitable or not profitable.
- Loss of fall-applied N did not occur in these 18 fields at a level leading to situations where corn was N deficient or responded to additional N applications.

<u>Yield response to zinc</u>

Zinc treatments were also included in these experiments because of promising results in 2001 in another set of experiments. We did not find any sites with yield response to zinc among the 18 fields in this study. Averaged over 53 experiments from 2001 to 2003, no yield response to zinc has been found.

**<u>Summary and Conclusions:</u>**

- Despite a normal-to-cold winter, fall $NH_3$ applications had more than half-converted to the nitrate form by April at 13 of the 18 experimental fields.
  - Conversion to nitrate created a situation with risk for N loss.
  - However, due to a dry winter (1.9 inches of precipitation from Nov. 1 to Feb. 28 averaged over the northwestern 1/6 of Missouri), there was little potential for over-winter N losses, even where N had converted to nitrate.
- High soil N levels were found in soil samples taken in April. Levels were higher than would be expected, given N fertilizer application rates. The supply of available N from the soil was higher than what is typically seen in grain fields in Missouri.
- The weather turned wet in late April, but soil N losses between mid-April and late May were small averaged over all experimental fields, and in most individual fields.
- High soil N levels were again found in soil samples taken in late May.
- Because little fertilizer N was lost, and soil N availability was high, corn yield responses to additional N treatments was minimal.
- Overall:
  - Little or no fall-applied N was lost from these fields.
  - Little or no yield potential was lost due to N limitations from N loss.
  - No fields responded to additional N enough to make application of additional N profitable.

# Table 3. Yields From 2003 Fall Applied Nitrogen Trials.

| COUNTY | LOCATION | YIELD WITH FERTILIZER TREATMENT: | | | |
|---|---|---|---|---|---|
| | | **CHECK** | **+ 50 N** | **+ 100 N ADDED** | **Zn** |
| Vernon | Deerfield 1 | 132 | 132 | 131 | 134 |
| Vernon | Deerfield 2 | 129 | 129 | 130 | 131 |
| Vernon | Hong | 128 | 129 | 121 | 131 |
| Carroll | DeWitt | 169 | 174 | 175 § | 174 |
| Saline | Blackburn | 197 | 198 | 195 | 196 |
| Saline | Miami | 172 | 170 | 166 | 161 |
| Saline | Napton | 129 | 115 | 125 | 129 |
| Ray | Dockery | 132 | 135 | 128 | 136 |
| Ray | Knoxville | 119 | 118 | 117 | 118 |
| Ray | Morton | 145 | 139 | 141 | 138 |
| Lafayette | Higginsville 1 | 104 | 106 | 109 | 101 |
| Lafayette [A] | Higginsville 2 | 137 | 137 | 137 | 137 |
| Lafayette [A] | Higginsville 4 | 100 | 115 § | 93 | 103 |
| Audrain | Scott's Corner | 159 | 165 | 158 | 151 |
| Audrain | Martinsburg | 127 | 120 | 128 | 122 |
| Monroe [B] | Middle Grove | 190 | 197 + | 197 § | 187 |
| Monroe | Madison | 94 | 96 | 88 | 96 |
| Monroe | Paris | 112 | 110 | 110 | 115 |

+ This yield is statistically higher than yield of the check with 90 to 95% confidence.

§ This yield is statistically higher than yield of the check with 80 to 90% confidence.

[A] These locations used 28% N liquid nitrogen as the fertilizer source.

[B] This location was irrigated.

# The influence of nitrogen rate and pasture composition on the toxicity, quality and yield of stockpiled tall fescue

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**Accomplishments:**

- A three-year field trial studying the effects of nitrogen rate and pasture composition on the toxicity, quality, and yield of stockpiled tall fescue began in August, 2002. The study has 10 treatments; five rates (0, 50, 100, 150 and 300 lb. per acre) of N applied in August and two pasture types (tall fescue with or without red clover). The study is replicated six times.

- We established the study in an existing endophyte-infected tall fescue/red clover pasture at the Forage Systems Research Center (FSRC) near Linneus, MO. Before the treatments were applied, the stand was approximately 30% red clover and 70% tall fescue. For the tall fescue treatments without red clover, existing red clover plants were controlled by spraying 2,4-D and Remedy. The forage in all treatments was clipped to a 3-inch stubble height in early August prior to starting the study.

- Soil samples were taken to a 40-inch depth prior to applying fertilizer treatments in 2002 and in March and August of 2003. Samples were split into three depth classes (0-10, 10-20, and 20-40 inches) and then analyzed for $NH_4$ and $NO_3$ content. Initial results showed that plots had equal ($P>0.05$) levels of pre-experiment $NH_4$ and $NO_3$. Subsequent results are shown later in this report.

- Forage was harvested on a monthly basis starting in mid-November of 2002. Forage harvests continued monthly during winter (November to March). In addition, all plots were harvested in May and July of 2003 to measure any residual effects from the fertilizer treatments.

- Because this project examines forage yield, quality and toxicity of stockpiled tall fescue over winter, we are only part-way through the second year. Some preliminary results are:

- Stockpiled forage yield:

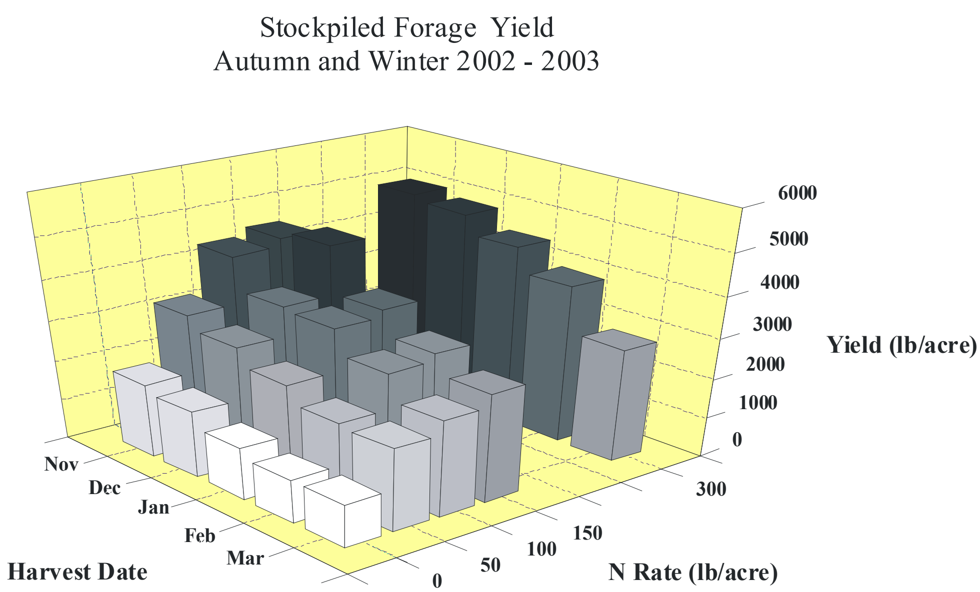
  - Stockpiled forage yields increased substantially when N was applied in August, despite the dry growing conditions in the autumn of 2002 (Fig. 1). Regardless of whether plots contained red clover, a nearly linear response to N rates up to 100 lb. per acre was observed. Rates above 100 lb. per acre showed little increase in stockpiled forage yield. These data suggest at least two things:

    1. Having red clover in stands of tall fescue does not decrease forage yield in autumn, but neither does it improve yields for stockpiling. The amount of red clover in the mixed plots is about 30% in the 0, 50, and 100 lb. per acre N-treatments which is considered ideal for a grazing system. Much less red clover was present in the 150 and 300 lb. per acre N treatments, likely due to competition from the tall fescue. If the red clover contributes any nitrogen to improve grass growth in autumn, then it is likely that the competition from the red clover or

the space that the red clover uses offsets any N contribution. Red clover does not maintain its dry matter as well in winter as does tall fescue, and the red clover plants themselves contribute little to yield, especially after mid-December.

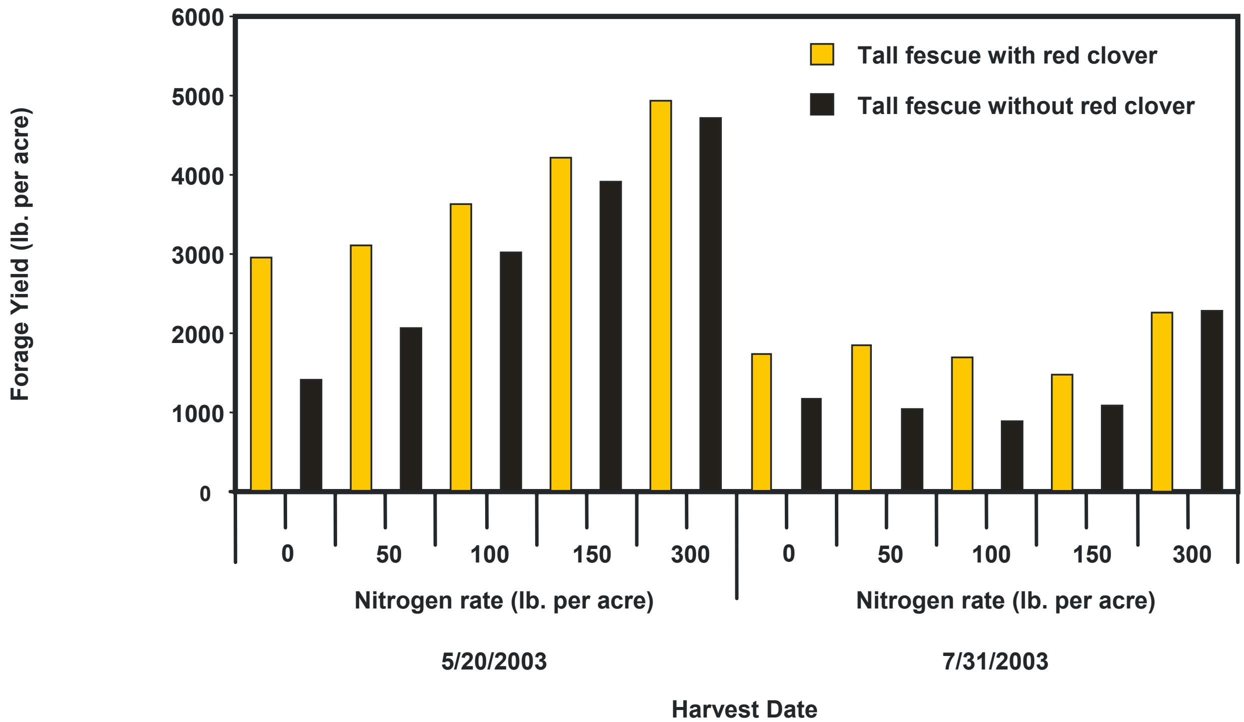
2. Although many producers limit late-summer or fall applications of N to 50 or 60 lb. per acre, our data show that even in dry years N rates up to 100 lb. per acre give acceptable yield responses. An preliminary economic analysis for this appears later in this report.

Fig. 1. Stockpiled forage yield in autumn and winter 2002 – 2003. Forage yields for plots with red clover were the same (P>0.05) as those without red clover so data were averaged across pasture types.




- Forage yields in spring and summer:
  - While the tall fescue responded in autumn to N, there were large carry over effects the following spring (Fig. 2). Yields taken in May of 2003 showed a nearly linear increase in forage yield in response to N applied in autumn although the response was greater for tall fescue without red clover that for tall fescue with red clover. At the three lowest N rates (0, 50, and 100 lb. per acre N) tall fescue with red clover yielded more than plots without red clover but at the two highest N rates the differences were not significant (P>0.05). In July, yields were lower than in spring for all treatments due to drought and hot weather. However, there was no response to fall applied N in July, except that the 300 lb. per acre N treatment yielded more than the other treatments. The addition of red clover improved yields at all N rates except the 150 and 300 lb. per acre treatments.

Fig. 2. Forage yields in May and July of 2003 from tall fescue with and without red clover and fertilized with 0, 50, 100, 150 or 300 lb. per acre of N the previous August.

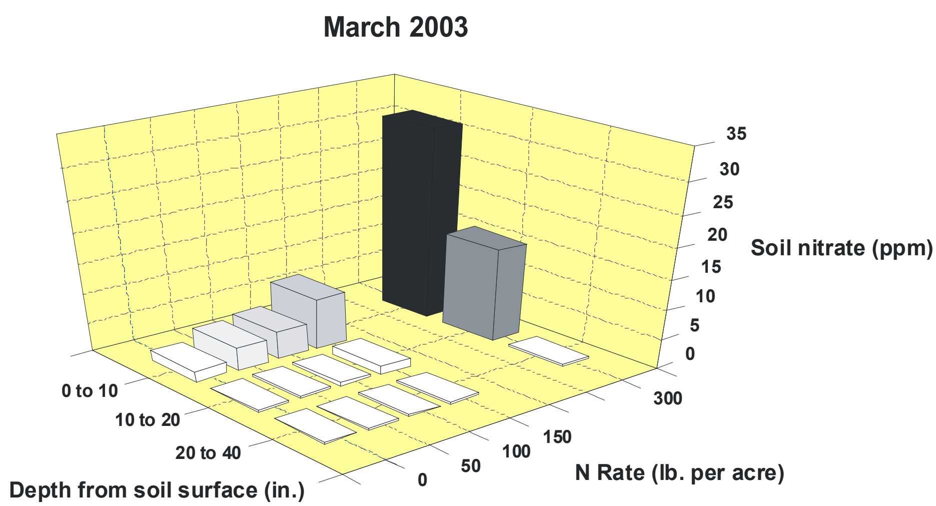


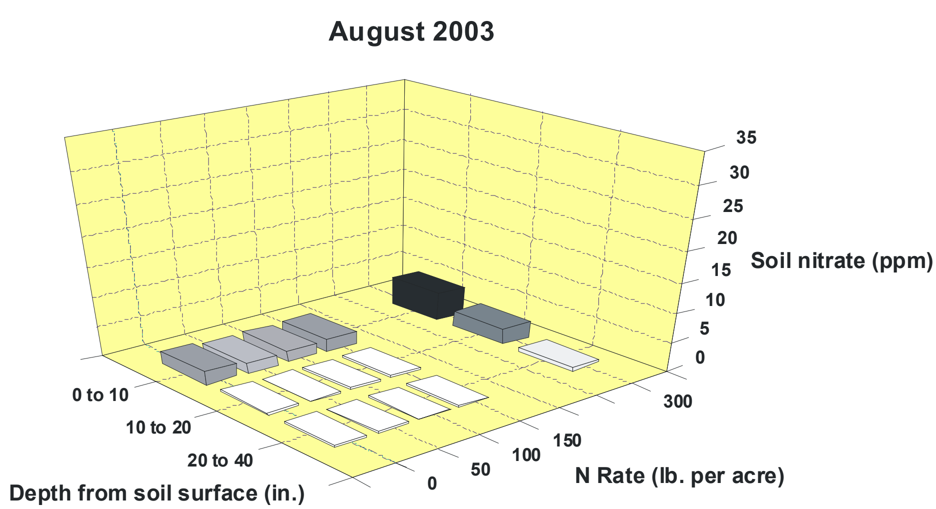

- Red clover stands:
  - Red clover stands were impacted by autumn applied N but red clover stands in all but the 150 and 300 lb. of N per acre treatments were at or above the ideal density of 5 plants per square foot in spring. This along with the yield data discussed above suggests that mixed tall fescue/red clover pastures can benefit from modest rates of autumn applied N without the red clover component being lost. When applying N fertilizer in late summer, rates of 150 or more lb. per acre should be avoided if red clover stands are desired.

- Nitrate accumulation:
  - As expected, soil nitrate levels in March of 2003 were highest in the 300 lb. per acre N treatment, especially in the 0 to 10 inch layer (Fig. 3). Soil nitrate levels in the 0 to 10 inch layer were 30 ppm for the 300 lb. per acre N treatment but only 5 ppm or less for all the other treatments. In the 10 to 20 inch layer, soil nitrate levels were 40 to 70% lower than for the 0 to 10 inch layer but the trend for the 300 lb. per acre N treatment to have much higher soil nitrate levels was similar. In the 20 to 40 inch layer, only small amounts of soil nitrate were found for all treatments.

- By August, soil nitrate levels had declined for all treatments and all depths to levels of 4 ppm or less. Given that forage yields in spring and summer were highly correlated to soil nitrate levels in spring, it is most likely that the decline in soil nitrate levels between March and August is due to plant uptake.

Fig. 3. Soil nitrate levels in March and August of 2003 when fertilized with 0, 50, 100, 150 or 300 lb. per acre of N the previous August.

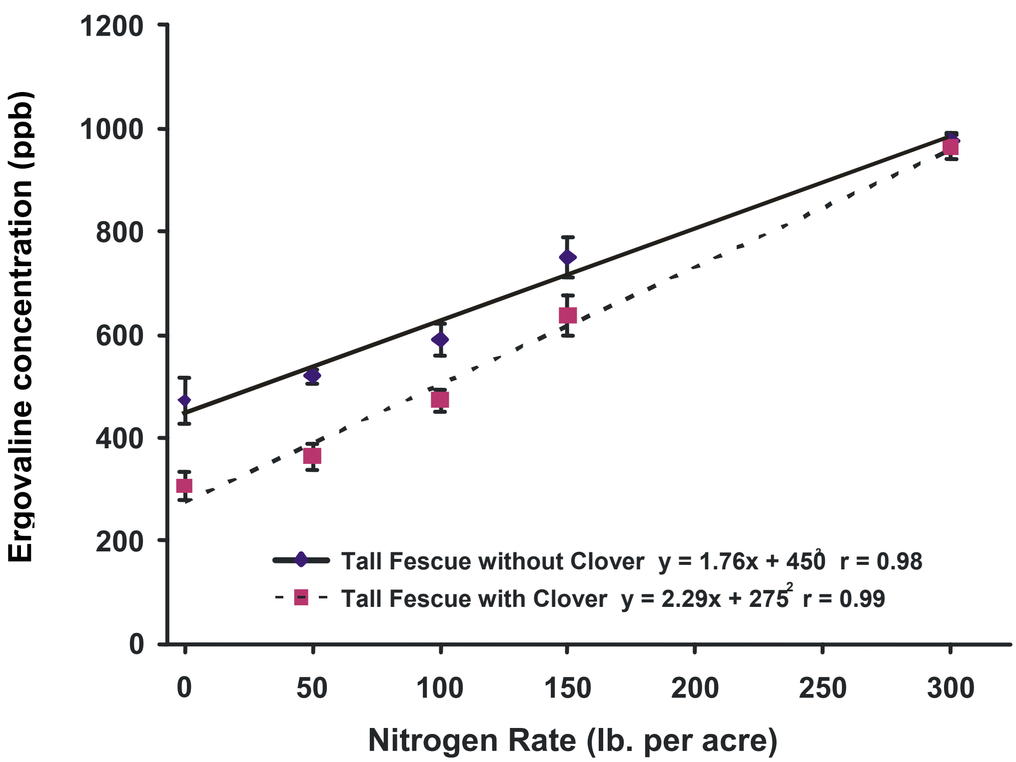


- These data show that in a healthy grassland system, little nitrate is lost from the system even when 300 lb. per acre of N is applied in late August. Although economic considerations make it unlikely that commercial fertilizer would applied at such a high rate, it does suggest that high N levels from other sources such as manure might not pose a serious nitrate leaching problem.

- Ergovaline concentrations in forage:
  - The ergovaline concentrations we found in stockpiled forage are approximately 25 to 50% lower than those reported by Rottinghaus et al. (1991) for spring-grown tall fescue. However, the ergovaline concentration in all treatments was in excess of the 150 ppb threshold for livestock reported by Stamm et al. (1994). This suggests that while stockpiled forage has lower ergovaline levels than tall fescue during the growing season, it still is a potential problem for livestock owners in winter and that N fertilizer management plays an important role (Fig. 4).

Fig. 4. Ergovaline concentrations in stockpiled tall fescue with and without red clover and fertilized with 0, 50, 100, 150 or 300 lb. per acre of N in August 2002. Samples were collected in November 2002.




- Preliminary economic analysis:
  - When previous moisture conditions cause limited on-farm hay supplies, a late summer N application might be more cost effective than previously thought. A basic economic analysis shows that if ammonia nitrate costs \$0.37 per N unit, plus \$3 per acre spreading cost and fair quality grass hay is valued at \$45.00 per ton that the optimum N fertilization rate in autumn is over 100 lb. per acre (Table 1).

Table 1. Preliminary economic analysis showing the cost and benefit of nitrogen applied in August to tall fescue pastures that are stockpiled. Yields used in the analysis are the average of all winter harvest dates.

| N rate applied in Aug. | Stockpiled forage yield | Fertilizer Cost † | Additional cost per ton of forage ‡ |
|---|---|---|---|
| ------------- lb. per acre | ------------- | $ per acre | $ per ton |
| 0 | 1,401 | 0 | - |
| 50 | 2,605 | 21.50 | 35.72 |
| 100 | 3,416 | 40.00 | 39.70 |
| 150 | 3,815 | 58.50 | 48.47 |
| 300 | 4,231 | 114.00 | 80.58 |

† Fertilizer costs include ammonia nitrate @ $0.37 per N unit plus $3 per acre for spreading.
‡ Cost compared to 0 N rate.

- More than 500 people have seen this research as part of various extension education programs conducted at the Forage Systems Research Center. In addition, the research plots have been used as part of Dr. McGraw's *Forages* class at the University of Missouri.

**Objectives for Year 3:**

- Over the next year we will continue our research on the impact of N on stockpiled tall fescue. As outlined in our original proposal, the tasks in the table below will be conducted over the next year.

| | |
|---|---|
| Continue to harvest appropriate sub-subplots for forage yield and retain subsamples for forage quality and ergovaline analysis (Year 2) | 1/15/04, 2/15/04 and 3/15/04 |
| Seed 5 lb/a of red clover on appropriate plots to maintain grass/legume mix. | 3/1/04 |
| Take soil cores from each sub-plot to determine residual soil N. | 3/19/04 |
| Harvest all sub-subplots for forage yield and retain subsamples for forage quality and ergovaline analysis. (This should measure the residual effects) | 5/19/04 and 7/24/04 |
| Count the legume plants in six, 1.0 $ft.^2$ quadrats in each plot | 5/25/04 and 8/12/04 |
| Take soil core samples to a 40-inch depth for soil nitrogen. (Year 3 starts) | 8/13/04 |
| Apply N fertilizer for the third year of experimentation. Treatments are 0, 50, 100, 150 and 300 lb/acre of actual N. (Year 3) | 8/14/04 |
| Analyze samples taken to date for forage quality and ergovaline content | 8/30/04 |
| Harvest appropriate sub-subplots for forage yield and retain subsamples for forage quality and ergovaline analysis (Year 3) | 11/15/03, 12/15/03, 1/15/04, 2/15/04 and 3/15/04 |

- In addition, to completing the tasks outlined above, we will be analyzing our field data more fully. Specifically, we are interested in determining the rate and extent of forage degradation over winter, with a special focus on ergovaline concentrations. Based on previous data published by Kallenbach et al. (2003), ergovaline levels are expected to drop over winter in stockpiled tall fescue. Although the influence of N rate on this process is unknown, we would like to develop prediction equations that could guide producers, fertilizer dealers, crop consultants and other about the potential toxicity and use of stockpiled tall fescue in winter.
- We will continue to integrate our findings into the curriculum of the Missouri Grazing Schools and the annual Winter Grazing Workshops at Linneus and Mt. Vernon. These outreach efforts can be expected to reach more than 1,000 producers, agency staff, and agri-business personnel. Additionally, as more comprehensive data are collected, we will start work on a new guidesheet about stockpiling tall fescue as well as prepare articles to be published in statewide and national magazines such as Missouri Ruralist, Graze, Stockman Grass Farmer and scientific journals.

## References

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# Nitrogen fertilization strategies for annual ryegrass pasture

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**Accomplishments for Year 1:**

- A three-year field trial studying the effects of nitrogen rate and date of application on the yield and quality of annual ryegrass began in August, 2002. This replicated (4x) experiment has 16 treatments; four N rates in autumn (0, 50, 100, and 150 lb. per acre of N) followed by the either 0, 50, 100, or 150 lb. per acre of N in early spring. The table below describes the rate and date of N applications for treatments.

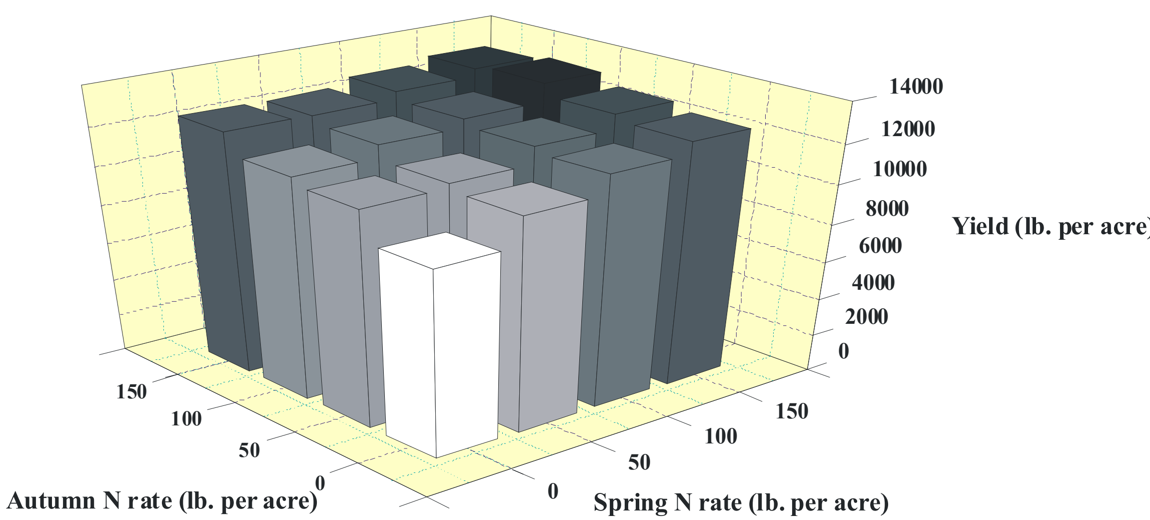
| Treatment | N in autumn | N in early spring |
|---|---|---|
| | --------- lb. N per acre --------- | |
| 1 | 0 | 0 |
| 2 | 0 | 50 |
| 3 | 0 | 100 |
| 4 | 0 | 150 |
| 5 | 50 | 0 |
| 6 | 50 | 50 |
| 7 | 50 | 100 |
| 8 | 50 | 150 |
| 9 | 100 | 0 |
| 10 | 100 | 50 |
| 11 | 100 | 100 |
| 12 | 100 | 150 |
| 13 | 150 | 0 |
| 14 | 150 | 50 |
| 15 | 150 | 100 |
| 16 | 150 | 150 |

- We established the annual ryegrass into a conventionally tilled seedbed at the Southwest Research and Education Center near Mt. Vernon, MO in late August of 2002 and again in 2003 (Fig. 1). The seeding rate was 30 lb. per acre of pure live seed. After seeding, the autumn fertilizer treatments were applied.

Fig. 1. Planting annual ryegrass at the Southwest Research and Education Center near Mt. Vernon, MO. The annual ryegrass was planted into a conventional seedbed in late August of 2002 and again in 2003. In 2002, the stand established well but dry weather conditions in autumn limited fall growth. Growth in the autumn of 2003 has been excellent.

- Dry autumn weather limited autumn forage growth in 2002. Our initial harvest was taken on 4 March 2003 and subsequent harvests were taken when an individual treatment reached 8 to 10 inches in height. Despite the lack of fall growth in autumn 2002, total season yields were more than 12,000 lb. per acre for the best treatments (Fig. 2). While the highest N rates provided the greatest yields, it appears that 50 lb. per acre of N in autumn followed by 100 lb. per acre in early spring provides enough N for annual ryegrass growth. Forage growth this autumn (2003) is much greater with yields through December exceeding 6000 lb. per acre.

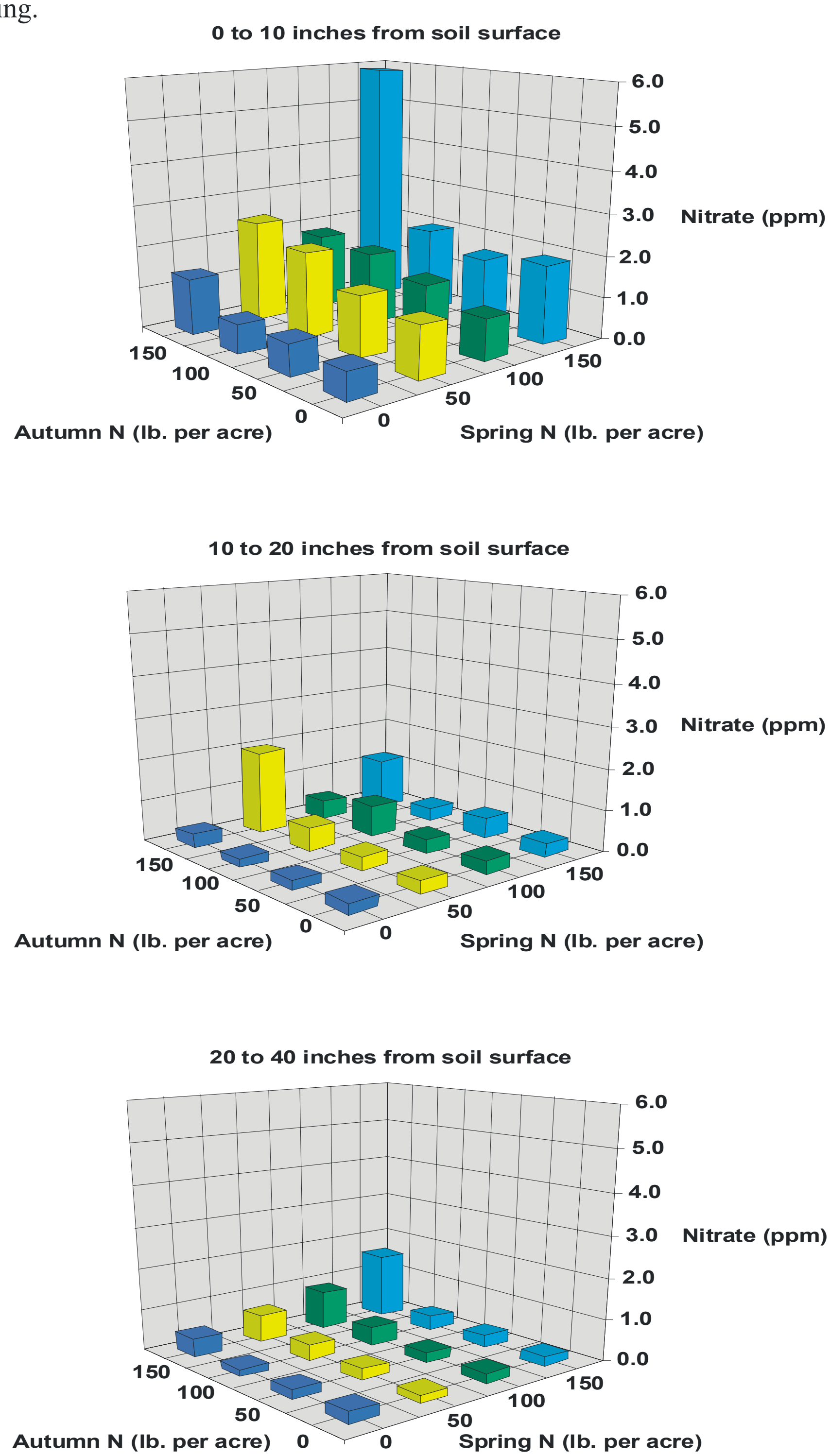
Fig. 2. Season-long (August 2002 to June 2003) annual ryegrass yields in response to fall and spring applied N at Mt. Vernon, MO.



- Forage quality samples show that annual ryegrass is excellent forage. Samples for 2002-2003 showed that annual ryegrass averaged 24% crude protein and had acid detergent fiber values less than 22%. In short, few other forages can produce such excellent quality feed for winter and early spring grazing.

- Soil samples were taken to a 40-inch depth prior to applying fertilizer treatments in 2002 and again after the annual ryegrass ended its spring growth in June of 2003. Samples were split into three depth classes (0-10, 10-20, and 20-40 inches) and then analyzed for $NH_4$ and $NO_3$ content. Initial results showed that plots had equal ($P>0.05$) levels of pre-experiment $NH_4$ and $NO_3$. Samples collected in June 2003 showed that soil nitrate levels, 0 to 10 inches from the soil surface, were nearly 6 ppm when 150 lb. per acre of N was applied in both autumn and spring, while the all the other treatments had about 2 ppm of nitrate or less (Fig. 3). At deeper depths, (10 to 20 and 20 to 40 inches from the surface) soil nitrate levels were less than 2 ppm for all treatments. This suggests that little N is lost due to leaching from annual ryegrass pastures at the rates of N we examined.

Fig. 3. Soil nitrate levels June of 2003 when fertilized with 0, 50, 100, 150 lb. per acre of N in autumn and 0, 50, 100, 150 lb. per acre of N in early spring.




- More than 1,000 individuals had the opportunity to view this research project as part of various extension education programs and field days conducted at the Southwest Research and Education Center.

As we develop more comprehensive data over the next year, we will be able to extend our results even further.

**Objectives for Year 3:**

- Over the next year we will continue our research on N fertilization of annual ryegrass. Because annual ryegrass is planted in August and harvested through winter and early spring, we are only partway through the second year of data collection. As outlined in our original proposal, the tasks in the table below will be conducted over the next year.

| | |
|---|---|
| Harvest plots for forage yield and retain subsamples for forage quality analysis | Ongoing as forage growth dictates. Anticipate 5 to 7 harvests per year. |
| Apply N to plots receiving early spring fertilizer | 3/1/04 |
| Take five, 3 inch diameter cores from each plot & count the number of tillers | 4/15/04 |
| Take soil cores from each plot to determine residual soil N | 6/1/04 |
| Analyze samples taken to date for forage quality | 7/31/04 |
| Prepare seedbed for annual ryegrass planting (Year 3 of study begins) | 8/20/04 |
| Take soil core samples to a 40-inch depth for initial soil nitrogen determinations (Year 3) | 8/31/04 |
| Plant annual ryegrass at 30 lb/acre (Year 3) | 9/1/04 |
| Apply N fertilizer to plots receiving an autumn application (Year 3) | 9/1/04 |
| Take five, 3 inch diameter cores from each plot & count the number of tillers (Year 3) | 10/10/04 |
| Harvest plots for forage yield and retain subsamples for forage quality analysis (Year 3) | Ongoing as forage growth dictates. Anticipate 5 to 7 harvests per year. |

- In addition, we will be fully analyzing our field data from the first two years next summer. We are most interested in refining N recommendations for annual ryegrass so that maximum economic productivity can be obtained by forage-livestock producers. In addition, we would like to understand more about the fate of N applied at relatively high rates to annual ryegrass. Work from other regions suggests that annual ryegrass can capture nearly all of the N applied to the surface. This may make it an ideal crop for operations with a large amount livestock manure.
- We will continue to integrate our findings into the curriculum of the Missouri Grazing Schools, grazing workshops statewide, and at the Southwest Research and Education Center Field day. These outreach efforts can be expected to reach more than 1,000 producers, agency staff, and agri-business personnel. Additionally, as more comprehensive data are collected, we will start work on a new guidesheet about annual ryegrass fertilization. In addition we will prepare articles to be published in statewide and national magazines such as Missouri Ruralist, Graze, Stockman Grass Farmer and scientific journals.

# Soft Red Winter Wheat Replant Decision Aid Based on Spring Nitrogen Recommendations and % Winterkill: 2003 Report

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University of Missouri, Columbia

**Project Summary Statements:**

- Field trials were established in October 2003.

- Crop health appears to be excellent at each research location going into winter dormancy.

**Objectives and Goals:**

The objectives of this research are:

1) To quantify the affect of spring nitrogen rate and % winterkill on soft red winter wheat yield and quality.

2) To develop a procedure to accurately assess early season stand reduction in wheat due to winterkill

The goal of this research is:

1) To develop an on-line, predictive replant decision aid to assist growers in managing winterkill in wheat.

**Procedures:**

- The experiment will be located at three sites:
  - Columbia: Bradford Research and Extension Center
  - Lamar: Eric Lawrence farm
  - Portageville: Delta Research Center
- Experimental Design: Randomized complete block design
  - Five nitrogen rates: 0, 30, 60, 90, and 120 lbs. N $acre^{-1}$
    - Nitrogen treatments applied at greenup
  - Five winter wheat % winterkill treatments: 0, 15, 30, 45, and 60
    - % winterkill treatments will be established by planting a mixture of spring oat and winter wheat in the fall. Spring oat was substituted for spring wheat in this trial so that % winterkill treatments could be more easily established.
  - Four replications:
  - Data collected:
    - Tiller number, head number, and spikelet number per head
    - Leaf area index measurements and digital image analysis
    - Grain yield, test weight, 1000 kernel weight

**Results 2003:**

Research plots were planted on October 6th at the Bradford Research and Extension Center, on October 23rd at the Delta Center Research Station. The southwest location was planted on October 22nd on a cooperating grower's operation near Lamar. In late early December we visited each location to visually assess crop stand and apply herbicides to control winter annual weeds. A herbicide application of Achieve was also applied at this time to control the spring oats and aid in establishing the % stand loss treatments. Fertility treatments will be applied at green-up.

**Timetable and Strategy for Application:**

| | |
|---|---|
| October: 2004 | Initiate experiment |
| January: 2005 | Present first year data to the PFC. |
| January to February 2005 | Schedule and complete meetings with growers, regional agronomists, and state faculty, to promote and implement research |
| February to March: 2005 | Apply treatments |
| March to July: 2005 | Record growth data |
| April to May: 2005 | Field days to promote research |
| June to July: 2005 | Harvest plots and analyze grain quality. |
| July: 2005 | Analyze data, develop initial state recommendations, and post results on website |
| August: 2005 | Submit manuscript to Agronomy journal for publication and develop a MU guide |
| January: 2006 | Present second year of data to the PFC. |

# Grain Sorghum Ratoon Cropping System for SEMO: 2003 Report

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University of Missouri, Columbia

**Project Summary Statements:**

- Starter fertilizer did decrease the number of days to 50% bloom in the early season ratoon variety.
- Starter fertilizer did not effect days to 50% bloom in the full season variety or increase grain yield.
- Total grain yield was greater in the grain sorghum ratoon cropping system than in the conventional grain sorghum system.
- Ratoon cropping may prove to be a successful alternative to traditional grain sorghum production systems in SEMO.

**Objectives and Goals:**

The objectives of this research are:

3) To quantify the affect of starter fertilizer on grain sorghum, growth, development, yield, and quality.
4) To quantify the optimal fertility requirements for a ratoon cropping system.
5) To determine the feasibility of introducing a grain sorghum ratoon cropping system into SE Missouri.

The overall goal of this research is:

2) To develop a best crop management program for grain sorghum production in SE Missouri.

**Procedures:**

- The experiment was located at two locations in SE Missouri
  - Pemiscot: The University of Missouri Lee Farm at Portageville
  - Dunklin: The University of Missouri Rhodes Farm at Clarkton
- Experimental Design: Randomized complete block design
  - Seeding rate: 110,000 plants per acre
  - Two cultivars:
    - Early season ratoon: KS-310 (55 to 59 days to 50% bloom)
    - Late season check: KS-955 (74 to 78 days to 50% bloom)
  - Starter treatment:
    - 45# N and 30# $P_2O_5$ applied at planting (dribble placement)
  - First planting Nitrogen rate (pounds per acre):
    - 120 pounds total
  - Ratoon Nitrogen rate (pounds per acre, side-dressed):
    - 0, 30, 60, 90, 120
  - Ratoon Phosphorus rate (pounds per acre, side-dressed):
    - 0 or 30
  - Four replications:
  - Data collected:
    - Days to 50% bloom
    - Maturity and harvest date
    - Grain yield

**Full treatment list:**

| **Treatment** | **Starter** | **Ratoon N rate** | **Ratoon P rate** |
|---|---|---|---|
| Mid to late season cultivar (KS-710) | Y | - | - |
| Mid to late season cultivar (KS-710) | N | - | - |
| Early season cultivar (KS-310) | Y | 0 | 0 |
| Early season cultivar (KS-310) | Y | 30 | 0 |
| Early season cultivar (KS-310) | Y | 60 | 0 |
| Early season cultivar (KS-310) | Y | 90 | 0 |
| Early season cultivar (KS-310) | Y | 120 | 0 |
| Early season cultivar (KS-310) | Y | 0 | 30 |
| Early season cultivar (KS-310) | Y | 30 | 30 |
| Early season cultivar (KS-310) | Y | 60 | 30 |
| Early season cultivar (KS-310) | Y | 90 | 30 |
| Early season cultivar (KS-310) | Y | 120 | 30 |
| Early season cultivar (KS-310) | N | 0 | 0 |
| Early season cultivar (KS-310) | N | 30 | 0 |
| Early season cultivar (KS-310) | N | 60 | 0 |
| Early season cultivar (KS-310) | N | 90 | 0 |
| Early season cultivar (KS-310) | N | 120 | 0 |
| Early season cultivar (KS-310) | N | 0 | 30 |
| Early season cultivar (KS-310) | N | 30 | 30 |
| Early season cultivar (KS-310) | N | 60 | 30 |
| Early season cultivar (KS-310) | N | 90 | 30 |
| Early season cultivar (KS-310) | N | 120 | 30 |

**Results 2003:**

The experimental locations were selected based on soil type and yield potential. The soil type at Lee Farm was a Tiptonville silt loam, whereas the soil type at Clarkton was a Malden fine sand. At each location the field experiment was planted on April 14$^{th}$, 2003. The early season ratoon variety (KS 310) was first harvested on July 28$^{th}$. The ratoon (second cutting) grain sorghum crop was harvested on November 21$^{st}$. The full-season single crop variety (KS 955) was harvested on August 14$^{th}$. Based on environmental conditions in 2003 we estimate that we lost two full weeks of growing conditions for the ratoon grain sorghum crop. However as the results indicate below, ratoon cropping systems may be a viable option for Missouri grain sorghum growers in SEMO.

**Lee Farm Results:**

Based on first cutting data a variety by starter interaction existed for the 50% bloom date; therefore data was analyzed separately. The average date of 50% bloom did differ in the early season ratoon grain sorghum variety (KS 310). The average 50% bloom date with starter was June 21$^{st}$; whereas the average date without starter was June 24$^{th}$. The application of starter fertilizer did not effect the 50% bloom date in the full season grain sorghum variety (KS 955). The average date of 50% bloom was July 5$^{th}$. Starter did not affect grain yield in 2003, however yield did differ between varieties. The mean yield for KS 310 and KS 955 were 89.8 and 72.9 bu $a^{-1}$, respectively. The decreased yield of KS 955 may have been due to a later 50% bloom date. The mean air temperature two days prior to 50% bloom for KS 310 was 82° F, whereas the mean air temperature was 92° F for KS 955. Decreased yield may also have been partly caused by increased bird pressure. However, air cannons were used and plots were evaluated at harvest to determine visual bird damage. The results appeared negligible.

The 50% bloom date in the ratoon (second) cutting was not quantified due to extreme variability in bloom date across each plot. Bloom dates began in mid-September and ran through mid-October. Crop yield did not differ between the starter and no starter treatments in the ratoon cutting, therefore crop yield was pooled. In 2003, crop yield increased linearly as nitrogen rate increased (Figure 1). At the high nitrogen rate grain sorghum yield was 66% of the early season yield. In total, the ratoon cropping system grain yield was 149.4 bu $a^{-1}$ compared to 72.9 9 bu $a^{-1}$ with the full season variety.

**Clarkton Results:**

Based on first cutting data a variety by starter interaction existed for the 50% bloom date; therefore data was analyzed separately. The average date of 50% bloom did differ in the early season ratoon grain sorghum variety (KS 310). The average 50% bloom date with starter was June 25th; whereas the average date without starter was June 28th. The application of starter fertilizer did not effect the 50% bloom date in the full season grain sorghum variety (KS 955). The average date of 50% bloom was July 3rd. Starter did not affect grain yield in 2003, however yield did differ between varieties. The mean yield for KS 310 and KS 955 were 16.1 and 23.6 bu $a^{-1}$, respectively. The decreased yield of KS 310 may have been due to water limitations during grain fill. Though Clarkton was an irrigated location, water was a yield limiting factor all season.

The mean 50% bloom date in the ratoon (second) cutting was not quantified due to extreme variability in bloom date across each plot. Bloom dates began in mid-September and ran through mid-October. Crop yield did not differ between the starter and no starter treatments in the ratoon cutting therefore crop yield was pooled. In 2003, crop yield increased non-linearly as nitrogen rate increased (Figure 2). At the high nitrogen rate grain sorghum yield was 124% of the early season yield. In total the ratoon cropping system yielded 40.2 bu $a^{-1}$ compared to 23.6 bu $a^{-1}$ with the full season variety.

**2003 Summary and Conclusions**

The application of starter fertilizer did decrease the number of days to 50% bloom in the early season variety (KS 310). This may decrease the number of days until harvest and allow growers to capture more growing degree units for the ratoon crop. Starter fertilizer did not affect the 50% bloom date in the full season variety. Starter fertilizer also did not affect crop yield. Crop yield was variable among locations; however at each location the total crop yield of the ratoon system out performed the full season check variety. Preliminary results from 2003 indicate that the application of starter fertilizer may prove beneficial in a ratoon cropping system and that ratoon cropping may prove to be a successful alternative to traditional grain sorghum production systems in SEMO.

Image 1. Visual comparison of KS 955 (left) and KS 310 (right).

**Timetable and Strategy for Application 2004:**

| | |
|---|---|
| April: 2004 | Initiate experiment |
| May to October: 2004 | Record plant growth and development data. |
| September to November: 2004 | Harvest plots and analyze grain quality |
| August: 2004 | Possible speaker at Delta Center Field Day |
| December: 2004 | Analyze data and develop state recommendations |
| January: 2004 | Present second year of data to the PFC and post results on website |
| January to March: 2003 | Schedule and complete meetings with growers, regional agronomists, and state faculty, to promote and implement research findings |
| February: 2004 | Develop MU Guide and submit manuscript for publication |

Figure 1. Effect of Ratoon Nitrogen Rate on Crop Yield at the University of Missouri Lee Farm in 2003.

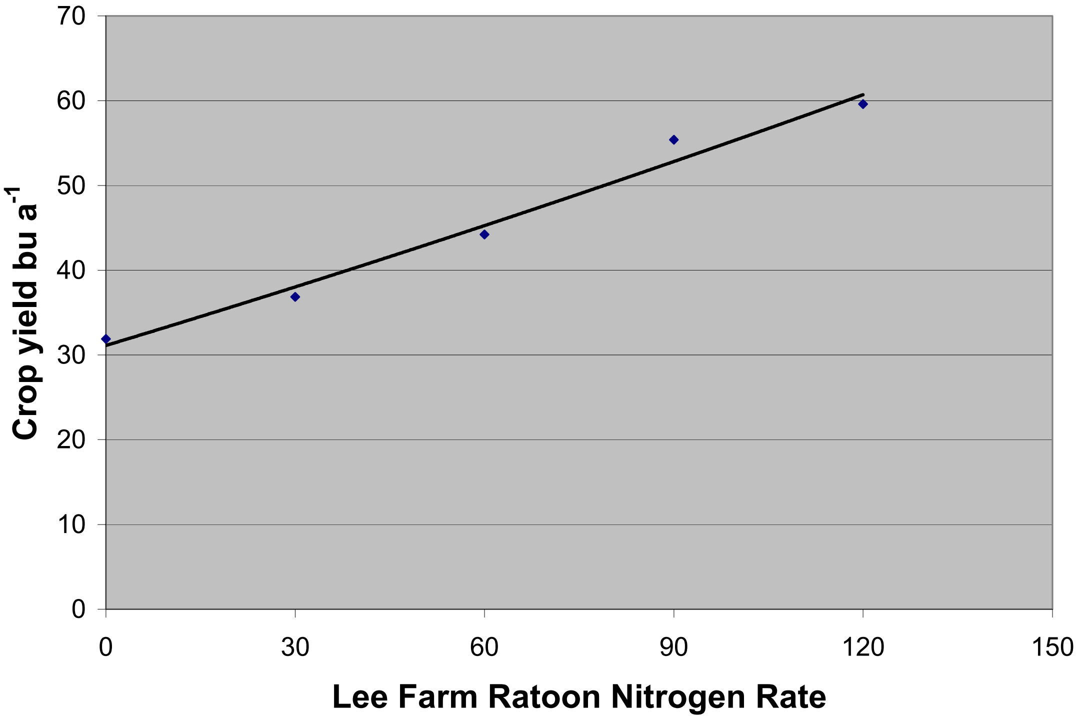
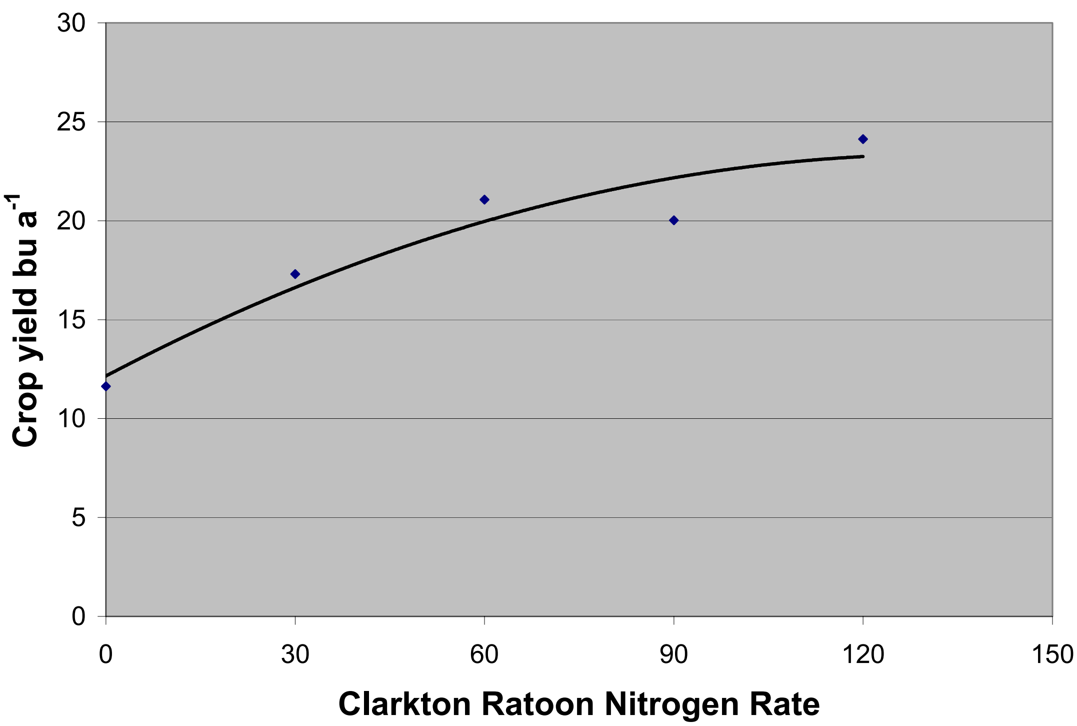



Figure 2. Effect of Ratoon Nitrogen Rate on Crop Yield at the University of Missouri Rhodes Farm in 2003.



# Determining the Correct Nitrogen Rate for Cotton Following Soybeans

**First Year (2003) Progress report**

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 NO3 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, 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 2003 crop 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 2003**

Data collected in 2003 are presented in Tables 1-3 and Figure 1. The clay soil and the silt-loam sites responded differently to N fertilization in 2003. Nitrogen fertilization significantly increased lint yields at the clay soil site (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. In 2004 the treatment of soil test recommended N plus 50 lbs will be added. 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. This would indicate that the previous soybean crop had supplied sufficient N to maximize cotton lint production. In terms of fiber properties increasing nitrogen rates at the clay soil site produced longer, stronger and more uniform fibers with higher micronaire readings (Table 1). Increasing nitrogen rates reduced turn out. At the silt-loam site increasing N rates generally increased micronaire readings, had a mixed effect on length, and no effect on fiber strength or uniformity. Gin turn out was highest for the zero nitrogen rate at the silt-loam site. Tables 2a and 2b shows total returns to producers. At the clay soil site yields soil test recommended N and the Soil test plus 25 lbs were statistically equivalent differences in the fiber properties length and uniformity resulted in higher returns to producers. Net returns to producers indicate that N fertilization was profitable. At the silt-loam site increasing N fertilization and application costs resulted in mostly negative returns for nitrogen expenditures. In Missouri the cultural practice is for the gin to retain the cottonseed as payment for the ginning process. Larger amounts of cottonseed associated with lower gin turnouts do have a value. This value, while not available to Missouri cotton producers, is calculated in Tables 3a and 3b. At the clay soil site the larger amount of seed obtained with increasing N added value to the crop. The writers speculate that increasing N rates would produce seed that is higher in protein content. Presently cottonseed is not sold for a premium based on protein. In the future a premium may be added for higher protein levels. At the silt-loam site gin turn out was not increased by N fertilization and total value of the crop was negatively affected.

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.

This information will be presented in poster form to cotton producers and researchers at the Belt-Wide Cotton Conferences, in San Antonio, TX January 5,6,7,8,9-2004. This information will also be presented as an oral presentation at the Missouri Cotton Producers Conference in Kennett, MO February 10, 2004.

Table 1. Average cotton lint yields, gin turnout, and cotton fiber properties for N treatments in 2003

| N Treatment | Cotton lint yields lbs/acre | | Turn out % | | Micronaire | | Length | | Strength | | Uniformity | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Clay | Silt loam | Clay | Silt loam | Clay | Silt loam | Clay | Silt loam | Clay | Silt loam | Clay | Silt loam |
| 0 | 491 d | 761a | 0.4ab | 0.38a | 4.63c | 4.68a | 1.047b | 1.095bc | 27.90b | 28.58a | 82.30c | 82.95a |
| 60 | 750 c | 680a | 0.41a | 0.36b | 4.67bc | 4.47ab | 1.047b | 1.113a | 28.45ab | 29.07a | 82.88bc | 83.17a |
| 85 | 956 b | 721a | 0.4ab | 0.36b | 4.88ab | 4.23ab | 1.08a | 1.110ab | 28.83ab | 28.70a | 83.55ab | 83.23a |
| 110 | 1059a | 870a | 0.39bc | 0.36ab | 4.90a | 4.50ab | 1.082a | 1.080c | 28.97ab | 28.85a | 83.88a | 82.82a |
| 135 | 1098a | 764a | 0.38c | 0.36b | 4.95a | 4.18a | 1.09a | 1.095bc | 29.63a | 29.15a | 83.52ab | 83.05a |
| LSD 0.05 | 94 | 244 | 0.014 | 0.0019 | 0.21 | 0.45 | 0.03 | 0.016 | 1.29 | 1.072 | 0.89 | 0.94 |
| CV % | 7.1 | 20.4 | 2.3 | 3.4 | 2.8 | 6.5 | 1.7 | 0.9 | 2.9 | 0.7 | 0.7 | 0.6 |

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

Table 2a. Returns to producers based on fiber quality for N treatments on clay soil, 2003.

| N Treatment | Yield lbs/acre | Penalty or premium (basis points) | | | Price $/lbs | Gross Return | N cost | Application cost | Net returns to Producers |
|---|---|---|---|---|---|---|---|---|---|
| | | Length | Strength | Uniformity | | | | | |
| 0 | 491 | -0.0115 | 0.0000 | 0.0000 | 0.512 | $251.39 | $0.00 | $0.00 | $251.39 |
| 60 | 750 | -0.0115 | 0.0000 | 0.0000 | 0.512 | $384.00 | $14.40 | $5.00 | $364.60 |
| 85 | 956 | 0.0180 | 0.0000 | 0.0025 | 0.544 | $520.06 | $20.40 | $10.00 | $489.66 |
| 110 | 1059 | 0.0180 | 0.0000 | 0.0025 | 0.544 | $576.10 | $26.40 | $10.00 | $539.70 |
| 135 | 1098 | 0.0325 | 0.0035 | 0.0025 | 0.562 | $617.08 | $32.40 | $10.00 | $574.68 |

Table 2b. Returns to producers based on fiber quality for N treatments on silt-loam soil, 2003.

| N Treatment | Yield lbs/acre | Penalty or premium (basis points) | | | Price $/lbs | Gross Return | N cost | Application cost | Net returns to Producers |
|---|---|---|---|---|---|---|---|---|---|
| | | Length | Strength | Uniformity | | | | | |
| 0 | 761 | 0.0325 | 0.0000 | 0.0000 | 0.556 | $423.12 | $0.00 | $0.00 | $423.12 |
| 60 | 680 | 0.0325 | 0.0000 | 0.0025 | 0.5585 | $379.78 | $14.40 | $5.00 | $360.38 |
| 85 | 721 | 0.0325 | 0.0000 | 0.0025 | 0.5585 | $402.68 | $20.40 | $10.00 | $372.28 |
| 110 | 870 | 0.0180 | 0.0000 | 0.0000 | 0.5415 | $471.11 | $26.40 | $10.00 | $434.71 |
| 135 | 764 | 0.0325 | 0.0000 | 0.0025 | 0.5585 | $426.69 | $32.40 | $10.00 | $384.29 |

Table 3a. Total returns, lint plus seed, to cotton industry for N treatments on clay soil, 2003. Value of crop due to N fertilization is also presented.

| N Treatment | Lbs Seed | Seed Value | Lint Value | Total Value | Added Value of N |
|---|---|---|---|---|---|
| 0 | 737 | $40.51 | $251.39 | $291.90 | $0.00 |
| 60 | 1079 | $59.36 | $364.60 | $423.96 | $132.06 |
| 85 | 1434 | $78.87 | $489.66 | $568.53 | $276.63 |
| 110 | 1656 | $91.10 | $539.70 | $630.80 | $338.90 |
| 135 | 1791 | $98.53 | $574.68 | $673.21 | $381.31 |

Table 3b. Total returns, lint plus seed, to cotton industry for N treatments on silt-loam soil, 2003. Value of crop due to N fertilization is also presented.

| N Treatment | Lbs Seed | Seed Value | Lint Value | Total Value | Added Value of N |
|---|---|---|---|---|---|
| 0 | 1242 | $68.29 | $423.12 | $491.41 | $0.00 |
| 60 | 1209 | $66.49 | $360.38 | $426.87 | -$64.54 |
| 85 | 1282 | $70.50 | $372.28 | $442.78 | -$48.63 |
| 110 | 1547 | $85.07 | $434.71 | $519.77 | $28.37 |
| 135 | 1358 | $74.70 | $384.29 | $459.00 | -$32.41 |

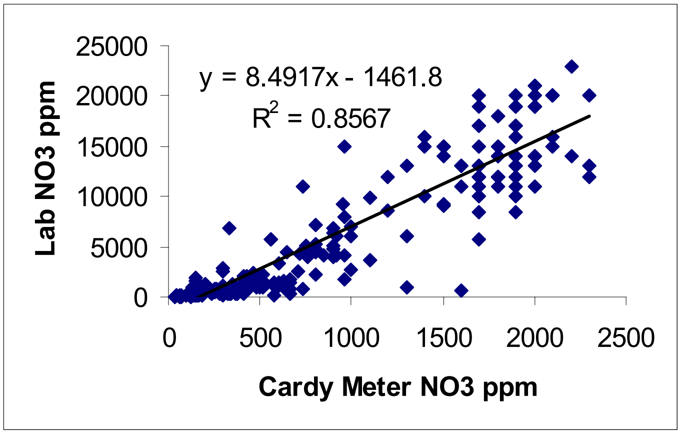



Figure 1 Relationship between laboratory cotton petiole analysis and Cardy meter $NO_3$-N determinations for both sites in 2003.

# Rescue N Applications for Corn: Yield Response, Leaf Burn, and Yield Loss

Progress Report for 2003

Kelly A. Nelson, Peter Scharf, Bruce Burdick, and Gene Stevens

**Accomplishments for year 1 (2003):**

***Crop injury.***

- Preplant applications did not injure corn (data not presented).
- None of the between-row treatments injured corn except urea ammonium nitrate (UAN) at Portageville (Table 3). Injury was 9 to 33% greater than the untreated control depending on corn height at the time of application.
- Broadcast applied N injury was ranked UAN > AN (ammonium nitrate) > urea = urea + Agrotain (Table 3).
  - UAN injured corn 19 to 38% at Novelty and Albany and 40 to 69% at Columbia and Portageville 7 days after treatment (DAT) and injury was generally greater than 10% 14 DAT.
  - AN injured corn 4-20% at Novelty, Columbia, and Albany while injury was 14 to 55% at Portageville 7 DAT. Injury was less than 10% at Novelty, Columbia, and Albany 14 DAT; however, recovery was notably slower at Portageville.
  - Urea and urea + Agrotain injured corn 0 to 10% at all locations 7 DAT and complete recovery was generally noted by 14 DAT.

***Yield response.***

- Low grain yield environments at Albany and Columbia in 2003 (Table 4).
  - All rescue N application treatments had grain yields and gross margins similar to the preplant N applications except UAN applied broadcast to 4 ft corn.
    - UAN applied broadcast to 4 ft corn reduced grain yield 34 bu/a when compared to UAN applied preplant and reduced grain yield 23 bu/a when compared to the untreated control.
  - Preplant, broadcast applied urea plus Agrotain, urea plus Agrotain applied broadcast to 2 ft tall corn, urea applied between-row to 2 ft tall corn, and AN applied between-row to 2 ft tall corn had grain yields 17 to 21 bu/a greater than the untreated control.
  - All treatments had gross margins similar to or less than the untreated control in a low yield environment in 2003. AN applied broadcast to corn 2 and 3 ft tall, UAN applied broadcast to 3 and 4 ft tall, and urea applied between-row to 4 ft corn had gross margins $38 to 92 less than the untreated control.
  - Urea alone had grain yields and gross margins similar to urea plus Agrotain at all application timings.
- Medium grain yield environment at Novelty in 2003 (Table 5).
  - All rescue N application treatments had grain yields similar to or greater than the preplant N applications except UAN applied broadcast to 4ft corn.
    - Urea applied broadcast to 3 and 4 ft corn, AN applied between-row to 3 and 4 ft corn, and UAN applied between-row to 3 and 4 ft corn increased grain yield 15 to 23 bu/a when compared to preplant N applications. These treatments except increased gross margins $33 to 55/acre when compared to

preplant applications except AN applied to 4 ft corn.
    - UAN applied broadcast to 4 ft corn reduced grain yield 18 bu/a when compared to UAN applied preplant.
  - All treatments increased corn grain yield when compared to the untreated control.
  - AN applied broadcast to 4 ft corn and UAN applied broadcast to 2, 3, or 4 ft tall corn should be avoided due to avoid grain yield loss when compared to other N sources applied at similar timings. A between-row application of UAN to 3 and 4 ft corn had grain yields and gross margins greater than a broadcast application.
- High grain yield environment at Portageville in 2003 (Table 6).
  - All rescue N application treatments had grain yields and gross margins similar to the preplant applications except:
    - AN applied broadcast to 2, 3, or 4 ft corn which had grain yields and gross margins 41 to 93 bu/a and $95 to 209/a, respectively, less than the broadcast, preplant application.
    - UAN applied broadcast to 3 or 4 ft corn reduced grain yield and gross margins 48 to106 bu/a and $108 to 235/a, respectively, when compared to UAN applied broadcast, preplant. UAN applied broadcast to 4 ft corn reduced grain yield 46 bu/a when compared to the untreated control.
    - UAN applied between-row to 2, 3, or 4 ft corn had corn grain yields and gross margins 40 to 60 bu/a and $90 to 134/a, respectively, less than UAN applied between-row, preplant.
    - Urea applied broadcast or between-row to 1, 2, 3, or 4 ft corn had grain yields and gross margins 48 to 80 bu/a and $48 to 87/a, respectively, less than a broadcast, preplant application.
    - Urea + Agrotain applied broadcast to 1, 3, and 4 ft corn or between-row to 3 and 4 ft corn had grain yields and gross margins 33 to 70 bu/a and $84 to 166/a, respectively, less than a preplant, broadcast application.
  - Corn grain yield increased when broadcast and between-row sidedress applications were applied to 1, 2, 3, and 4 ft corn when compared to the untreated control. However, careful selection of N source and application method is needed. Broadcast UAN to 4 ft corn should be avoided or yield loss may occur.

**Objectives for year 2 (2004):** The objective of this study is to evaluate yield response of corn to rescue N applications, including broadcast applications that cause leaf burn and to evaluate dry and liquid nitrogen sources.

**Abstract**. Rescue N (nitrogen) applications in a standing corn crop may be necessary when wet conditions prevented preplant N applications or loss of N was suspected due to wet conditions after application. Field research at Albany, Columbia, Novelty, and Portageville in 2003 evaluated the impact of AN (ammonium nitrate), UAN (urea ammonium nitrate), urea, and urea plus Agrotain applied broadcast and between-row as a preplant and postemergence application to 1, 2, 3, and 4 ft corn. None of the between-row treatments injured corn except UAN at Portageville. Broadcast applied N injury was ranked UAN > AN > urea = urea + Agrotain. Yield response and returns related to rescue N applications were dependent on the grain yield environment. Rescue N treatments had gross margins similar to the untreated control in a low yield environment. In a medium yield environment, all rescue N treatments had grain yield similar to the highest yielding N source for any given timing except between-row urea to 2 ft corn, broadcast UAN to 2, 3, and 4 ft corn, and broadcast AN to 4 ft corn. Broadcast AN and UAN to 1 ft corn, urea to 2, 3 , and 4 ft corn, and urea plus Agrotain to 2 and 4 ft corn had grain yields similar to the highest yielding N source for any given rescue N application timing. Recommendations for rescue N applications depend on anticipated grain yield, available nitrogen source, timing, injury, and application method.

**Nomenclature:** Ammonium nitrate, $NH_4NO_3$; corn, *Zea mays* L; urea, $((NH_2)_2CO)$; and urea ammonium nitrate, $NH_4NO_3$.

**Additional index words:** foliar fertilizer, injury, phytotoxicity.
**Abbreviations:** AN, 33.5% ammonium nitrate; N, nitrogen; and UAN, 32% urea ammonium nitrate.

## INTRODUCTION

Rescue N applications in a standing corn crop may be necessary when wet conditions prevented preplant N applications or loss of N was suspected due to wet conditions after application. In these situations, either tractor-mounted or high-clearance-mounted applicators can sidedress N fertilizer between corn rows, avoiding leaf burn. However, these applicators are not always available, or may be configured for other uses such as spraying herbicides: therefore, broadcast applications may be easier to accomplish. In addition, broadcasting N fertilizer by airplane is another option for rescue applications of N when soil conditions are too wet to carry traffic. Broadcast applications of N will cause leaf burn, but little if any research has been conducted to measure how much yield is lost due to this leaf burn for various application times and nitrogen forms. The amount of yield recovered may depend on the stage at which N is applied. Understanding yield loss associated with nitrogen burn at different stages of corn development would help corn producers to make informed decisions about whether to attempt rescue N applications and what type of application equipment to use. The objective of this study was to evaluate yield response of corn to rescue N applications, including broadcast applications that cause leaf burn and to evaluate dry and liquid nitrogen sources.

## MATERIALS AND METHODS

Field research was conducted at the University of Missouri Greenley Research Center near Novelty (40.035997 N, 92.243783 W), Bradford Research and Extension Center near Columbia (38.894165 N, 92.274145 W), Hundley-Whaley Research Center near Albany (40.251282 N, 94.326977 W), and Delta Center near Portageville (36.427945 N, 89.700234 W) in 2003. The soil was a Putnam silt loam (fine, montmorillonitic, mesic Mollic Albaqualf), Mexico silt loam (fine, montmorillonitic, mesic Vertic Albaqualfs), Grundy silt loam (fine, montmorillonitic, mesic Aquic Argiudolls), and Tiptonville silt loam (fine-silty, mixed, thermic Typic Argiudolls) at Novelty, Columbia, Albany, and Portageville, respectively. Researchers at each site utilized management practices commonly used by farmers in the area. Field information about the locations and selected management practices is shown in Table 1.

Research was arranged as a randomized complete block design with four replications at Novelty, Columbia, and Portageville and three replications at Albany. Ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, or urea plus

Agrotain at 1 qt/ton was applied broadcast or between the row at 150 lb N/acre preplant and to 1, 2, 3, and 4 ft tall corn except between-row, preplant urea and urea plus Agrotain at 1 gallon/ton; 1 ft corn treated with urea at Novelty, Columbia, and Albany; and 3 ft corn treated with urea and urea plus Agrotain at Novelty, Columbia, and Albany. Corn injury from 0 (no visual crop injury) to 100% (complete crop death) was evaluated 7 and 14 days after treatment based on the combined visual effects of N source on necrosis, chlorosis, and stunting. Corn was harvested with a small-plot combine and final weight adjusted to 15% moisture.

Injury data were subjected to single factor ANOVA and reported by location due to interactions between locations and different environmental conditions. The cost-effectiveness of the rescue N applications was reported as a gross margin calculated as: [(grain yield * market price of $2.20/bu) – (cost of N fertilizer + additive + application)]. The application cost for a preplant broadcast application and sidedress application was estimated at $4.00/acre and $6.80/acre, respectively (Plain et al., 2001). An eight year average of the April cost of AN, UAN, and urea was $0.107/lb, $0.82/gal, and $0.115/lb, respectively (Anonymous 2003). Agrotain cost was $7.34/a. Yield data were grouped according to low, medium and high yield environments in 2003 and subjected to analysis of variance and means separated at p = 0.05 using Fisher's Protected LSD.

ACKNOWLEDGEMENTS

The authors would like to express a special thanks to Matthew Jones and Larry Mueller for their technical assistance.

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Table 1. Field information and selected management practices for Novelty, Albany, Portageville, and Columbia in 2003.

| | Novelty | Albany | Portageville | Columbia |
|---|---|---|---|---|
| **Planting Date** | 19 May | 7 May | 2 April | 23 April |
| **Hybrid** | Pioneer 33P67 | DKC60-19 | Cropland 818BT | Asgrow RX 7118RR |
| **Seeding Rate** (Seeds/Acre) | 29,900 | 28,500 | 30,000 | 29,100 |
| **Tillage** | No-till | Minimum | Disk, bed, harrow | Field Cultivate, mulch |
| **Plot size** | 10x35' | 10x30' | 10x37' | 10x30' |
| SOM (%) | 3.2 | | | |
| pHs | 5.5 | | | |
| Sand, silt, clay (%) | 20, 55, 25 | | | |
| Weed management | | | | |
| **Timing, date** | Burndown, 28 April | Preemergence, 14 May | Burndown, 31 March | Postemergence, 3 May |
| Herbicide | Touchdown + Clarity + AMS | Bicep II Mag | Roundup Weather Max | Dual + Attrex 4L |
| Rates | 1qt/a + ½ pt/a + 17 lb/100gal | 2.4 qt/A | 26oz/a | 1.25 pt/A + 1.5 qt/A |
| **Timing, date** | Preemergence, 20 May | Postemergence, 12 June | Preemergence, 2 April | |
| Herbicide | Degree Xtra + Princep | Roundup Weathermax | Degree X-tra | |
| Rates | 3 qt/a + 1 qt/a | 22 oz/a | 3qt/a | |
| **Timing, date** | | | Postemergence, 23 May | |
| Herbicide | | | Permit + Basis Gold | |
| Rates | | | 1.3 oz/a + 14 oz/a | |
| **Harvest Date** | 22 October | 30 September | 15 September | 26 September |
| Insect management | None | None | None | None |
| **Maintenance fertilizer** | None | None | None | None |

Table 2. Environmental information for preplant, 1, 2, 3, and 4 ft tall broadcast and between-row N applications at Novelty, Albany, Portageville, and Columbia in 2003.

| | **Novelty** | **Albany** | **Portageville** | **Columbia** |
|---|---|---|---|---|
| **Preplant** | | | | |
| **Date treated** | 20 May | 12 May | 3 April | 7 May |
| Time treated | 3:00 pm | 10:00 am | 1:00 pm | |
| Air temperature (F) | 67 | 61 | 72 | 71 |
| Relative humidity (%) | 37 | 65 | 68 | 76 |
| Leaf surface moisture (1 = wet to 5 = dry) | 5 | 5 | No leaves | 5 |
| Soil moisture (1 = wet to 5 = dry) | 3 | 3 | 3 | 4 |
| **1 ft corn** | | | | |
| **Date treated** | 23 June | 11 June | 12 May | 4 June |
| Time treated | 5:00 pm | 10:30 am | 3:00 pm | |
| Air temperature (F) | 85 | 70 | 73 | 72 |
| Relative humidity (%) | 58 | 75 | 38 | 74 |
| Leaf surface moisture (1 = wet to 5 = dry) | 5 | 5 | 5 | 5 |
| Soil moisture (1 = wet to 5 = dry) | 5 | 4 | 4 | 4 |
| **2 ft corn** | | | | |
| **Date treated** | 2 July | 18 June | 22 May | 18 June |
| Time treated | 6:00 pm | 10:30 am | 2:00 pm | |
| Air temperature (F) | 92 | 70 | 71 | 85 |
| Relative humidity (%) | 48 | 75 | 58 | 70 |
| Leaf surface moisture (1 = wet to 5 = dry) | 5 | 5 | 5 | 5 |
| Soil moisture (1 = wet to 5 = dry) | 5 | 5 | 4 | 3 |
| **3 ft corn** | | | | |
| **Date treated** | 9 July | 3 July | 5 June | 23 June |
| Time treated | 2:00 pm | 1:00 pm | 2:00 pm | |
| Air temperature (F) | 89 | 94 | 78 | 86 |
| Relative humidity (%) | 71 | 60 | 96, rained after application | 71 |
| Leaf surface moisture (1 = wet to 5 = dry) | 5 | | 5 | 5 |
| Soil moisture (1 = wet to 5 = dry) | 4 | | 4 | 2 |
| **4 ft corn** | | | | |
| **Date treated** | 17 July | 8 July | 9 June | 30 June |
| Time treated | 8:00 pm | 1:00 pm | 3:00 pm | |
| Air temperature (F) | 84 | 89 | 80 | 85 |
| Relative humidity (%) | 70 | 65 | 73 | 76 |
| Leaf surface moisture (1 = wet to 5 = dry) | 5 | 5 | 5 | 5 |
| Soil moisture (1 = wet to 5 = dry) | 1 | 5 | 5 | 3 |

Table 3. Broadcast and between-row ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus Agrotain injury to corn at Novelty, Albany, Portageville, and Columbia 7 and 14 days after treatment (DAT) for 1, 2, 3, and 4 ft corn application timings. All nitrogen sources were applied at 150 lb N/acre. Agrotain was applied at 1 qt/ton.

| | 1 ft | | 2 ft | | 3 ft | | 4 ft | |
|---|---|---|---|---|---|---|---|---|
| | 7 DAT[a] | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT |
| | Injury (%) | | | | | | | |
| Novelty | | | | | | | | |
| Untreated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Broadcast | | | | | | | | |
| AN | 11 | 8 | 7 | 5 | 8 | 4 | 12 | 11 |
| UAN | 19 | 11 | 21 | 9 | 41 | 20 | 35 | 28 |
| Urea | 5 | 3 | 0 | 1 | 3 | 2 | 1 | 0 |
| Urea + Agrotain | 7 | 3 | 1 | 1 | 4 | 2 | 0 | 0 |
| Between-row | | | | | | | | |
| AN | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| UAN | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urea | —[b] | —[b] | 0 | 0 | —[b] | —[b] | 0 | 0 |
| Urea + Agrotain | 0 | 1 | 0 | 0 | —[b] | —[b] | 0 | 0 |
| LSD ($p < 0.05$) | 1 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |
| Albany | | | | | | | | |
| Untreated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Broadcast | | | | | | | | |
| AN | 13 | 4 | 12 | 3 | 12 | 2 | 7 | 1 |
| UAN | 27 | 15 | 28 | 12 | 23 | 10 | 38 | 17 |
| Urea | 0 | 0 | 5 | 1 | 5 | 0 | 5 | 2 |
| Urea + Agrotain | 2 | 0 | 5 | 1 | 8 | 1 | 7 | 1 |
| Between-row | | | | | | | | |
| AN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urea | —[b] | —[b] | 0 | 0 | —[b] | —[b] | 0 | 0 |
| Urea + Agrotain | 0 | 0 | 0 | 0 | —[b] | —[b] | 0 | 0 |
| LSD ($p < 0.05$) | 2 | 1 | 2 | 2 | 3 | 2 | 3 | 2 |
| Portageville | | | | | | | | |
| Untreated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Broadcast | | | | | | | | |
| AN | 14 | 10 | 39 | 31 | 55 | 65 | 38 | 30 |
| UAN | 50 | 28 | 53 | 26 | 48 | 30 | 68 | 63 |
| Urea | 2 | 1 | 8 | 2 | 3 | 2 | 3 | 0 |
| Urea + Agrotain | 2 | 1 | 4 | 2 | 4 | 1 | 2 | 1 |
| Between-row | | | | | | | | |
| AN | 2 | 1 | 2 | 0 | 3 | 0 | 2 | 0 |

Table 3. con't

| | 1 ft | | 2 ft | | 3 ft | | 4 ft | |
|---|---|---|---|---|---|---|---|---|
| | 7 DAT[a] | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT |
| | Injury (%) | | | | | | | |
| UAN | 9 | 4 | 17 | 6 | 33 | 15 | 28 | 25 |
| Urea | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 |
| Urea + Agrotain | 0 | 0 | 1 | 3 | 3 | 0 | 2 | 0 |
| LSD (p< 0.05) | 7 | 6 | 9 | 10 | 16 | 13 | 8 | 9 |
| Columbia | | | | | | | | |
| Untreated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Broadcast | | | | | | | | |
| AN | 20 | 0 | 15 | 3 | 20 | 10 | 10 | 10 |
| UAN | 50 | 20 | 40 | 23 | 55 | 30 | 69 | 60 |
| Urea | 10 | 1 | 6 | 3 | 10 | 3 | 10 | 3 |
| Urea + Agrotain | 10 | 0 | 9 | 3 | 10 | 0 | 10 | 3 |
| Between-row | | | | | | | | |
| AN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| UAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Urea | —[b] | —[b] | 0 | 0 | —[b] | —[b] | 0 | 0 |
| Urea + Agrotain | 0 | 0 | 0 | 0 | —[b] | —[b] | 0 | 0 |
| LSD (p< 0.05) | 0 | 1 | 3 | 1 | 3 | 0 | 1 | 0 |
| Average of four locations | | | | | | | | |
| Untreated | | | | | | | | |
| Broadcast | | | | | | | | |
| AN | 15 | 6 | 18 | 11 | 24 | 20 | 17 | 13 |
| UAN | 37 | 19 | 36 | 18 | 42 | 23 | 53 | 42 |
| Urea | 4 | 1 | 5 | 5 | 5 | 2 | 5 | 1 |
| Urea + Agrotain | 5 | 1 | 5 | 7 | 7 | 1 | 5 | 1 |
| Between-row | | | | | | | | |
| AN | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| UAN | 2 | 1 | 4 | 2 | 8 | 4 | 7 | 6 |
| Urea | —[b] | —[b] | 1 | 0 | —[c] | —[c] | 0 | 0 |
| Urea + Agrotain | 0 | 0 | 0 | 1 | —[c] | —[c] | 1 | 0 |

[a]Comparisons within columns are valid for individual locations.
[b]Treatments were not applied.
[c]Averages were not calculated.

Table 4. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus Agrotain applied broadcast and between-row as preplant and sidedress to 1, 2, 3, and 4 ft corn in a low yield environment at Columbia and Albany in 2003.

| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | bu/a | | | | | gross margin ($/a) | | | | |
| Untreated | 70 | | | | | 154 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 86 | 82 | 76 | 78 | 86 | 136 | 126 | 111 | 116 | 133 |
| UAN | 81 | 74 | 79 | 67 | 47 | 140 | 121 | 133 | 106 | 62 |
| Urea | 81 | 81 | 84 | 75 | 77 | 128 | 133 | 140 | 122 | 125 |
| Urea + Agrotain | 87 | 81 | 87 | 79 | 80 | 150 | 126 | 141 | 122 | 125 |
| Between-row | | | | | | | | | | |
| AN | 80 | 85 | 83 | 91 | 86 | 124 | 132 | 127 | 144 | 134 |
| UAN | 86 | 84 | 77 | 80 | 80 | 150 | 142 | 127 | 134 | 133 |
| Urea | — | — | 90 | — | 69 | — | — | 154 | — | 109 |
| Urea + Agrotain | — | 80 | 80 | — | 83 | — | 131 | 124 | — | 131 |
| LSD ($p \leq 0.05$) | 17 | | | | | 37 | | | | |

Table 5. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus Agrotain applied broadcast and between-row as preplant and sidedress to 1, 2, 3, and 4 ft corn in a medium yield environment at Novelty in 2003.

| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | yield (bu/a) | | | | | gross margin ($/a) | | | | |
| Untreated | 58 | | | | | 127 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 115 | 122 | 112 | 113 | 110 | 200 | 212 | 190 | 194 | 187 |
| UAN | 108 | 114 | 110 | 106 | 90 | 198 | 209 | 200 | 190 | 157 |
| Urea | 105 | 115 | 118 | 128 | 125 | 183 | 209 | 216 | 238 | 230 |
| Urea + Agrotain | 111 | 116 | 126 | 120 | 120 | 203 | 203 | 226 | 213 | 211 |
| Between-row | | | | | | | | | | |
| AN | 110 | 112 | 118 | 126 | 125 | 189 | 191 | 203 | 222 | 219 |
| UAN | 105 | 114 | 118 | 124 | 125 | 192 | 208 | 217 | 230 | 233 |
| Urea | — | — | 110 | — | 120 | — | — | 197 | — | 221 |
| Urea + Agrotain | — | 118 | 121 | — | 120 | — | 215 | 216 | — | 212 |
| LSD ($p \leq 0.05$) | 15 | | | | | 33 | | | | |

Table 6. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus Agrotain applied broadcast and between-row as preplant and sidedress to 1, 2, 3, and 4 ft corn in a high yield environment at Portageville in 2003.

| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | yield (bu/a) | | | | | gross margin ($/a) | | | | |
| Untreated | 102 | | | | | 225 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 177 | 178 | 136 | 84 | 93 | 338 | 335 | 243 | 129 | 149 |
| UAN | 162 | 181 | 130 | 114 | 56 | 317 | 357 | 245 | 209 | 82 |
| Urea | 208 | 155 | 160 | 159 | 134 | 408 | 297 | 307 | 306 | 250 |
| Urea + Agrotain | 187 | 154 | 171 | 117 | 140 | 371 | 287 | 325 | 205 | 255 |
| Between-row | | | | | | | | | | |
| AN | 170 | 202 | 141 | 143 | 152 | 321 | 390 | 255 | 258 | 279 |
| UAN | 181 | 176 | 141 | 121 | 128 | 359 | 346 | 269 | 225 | 239 |
| Urea | — | 143 | 155 | 146 | 128 | — | 270 | 297 | 277 | 238 |
| Urea + Agrotain | — | 178 | 175 | 141 | 117 | — | 348 | 334 | 258 | 205 |
| LSD ($p \leq 0.05$) | 33 | | | | | 73 | | | | |

Table 7. Rescue N application recommendations for ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus Agrotain applied broadcast and between-row to 1, 2, 3, and 4 ft corn.

| | 1 ft | 2 ft | 3 ft | 4 ft |
|---|---|---|---|---|
| Broadcast | | | | |
| AN | ✓[a] | | | NR |
| UAN | ✓ | NR[b] | NR | NR |
| Urea | | ✓ | ✓ | ✓ |
| Urea + Agrotain | | ✓ | | ✓ |
| Between-row | | | | |
| AN | ✓ | | ✓ | ✓ |
| UAN | ✓ | | | ✓ |
| Urea | __[c] | | __[c] | ✓ |
| Urea + Agrotain | ✓ | ✓ | __[c] | |

[a]✓, grain yield was similar to the highest yielding rescue N application treatment at Novelty (medium yield environment) and Portageville (high yield environment) in 2003.

[b]NR, not recommended.

[c]Insufficient data.

# 2004

## The influence of nitrogen rate and pasture composition on the toxicity, quality and yield of stockpiled tall fescue

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**Accomplishments:**

- A three-year field trial studying the effects of nitrogen rate and pasture composition on the toxicity, quality, and yield of stockpiled tall fescue began in August, 2002. The study has 10 treatments; five rates (0, 50, 100, 150 and 300 lb. per acre) of N applied in August and two pasture types (tall fescue with or without red clover). The study is replicated six times.

- We established the study in an existing endophyte-infected tall fescue/red clover pasture at the Forage Systems Research Center (FSRC) near Linneus, MO. Before the treatments were applied, the stand was approximately 30% red clover and 70% tall fescue. For the tall fescue treatments without red clover, existing red clover plants were controlled by spraying 2,4-D and Remedy.

- Soil samples were taken to a 40-inch depth prior to applying fertilizer treatments in 2002 and in March and August of 2003 and 2004. Samples were split into three depth classes (0-10, 10-20, and 20-40 inches) and then analyzed for $NH_4$ and $NO_3$ content. Initial results showed that plots had equal (P>0.05) levels of pre-experiment $NH_4$ and $NO_3$. Subsequent results are shown later in this report.

- Forage was harvested on a monthly basis starting in mid-November of 2002 and 2003. Forage harvests continued monthly during winter (November to March). In addition, all plots were harvested in May and July of 2003 and 2004 to measure any residual effects from the fertilizer treatments.

- Because this project examines forage yield, quality and toxicity of stockpiled tall fescue over winter, we are only part-way through the third year. Some preliminary results are:

- Stockpiled forage yield:

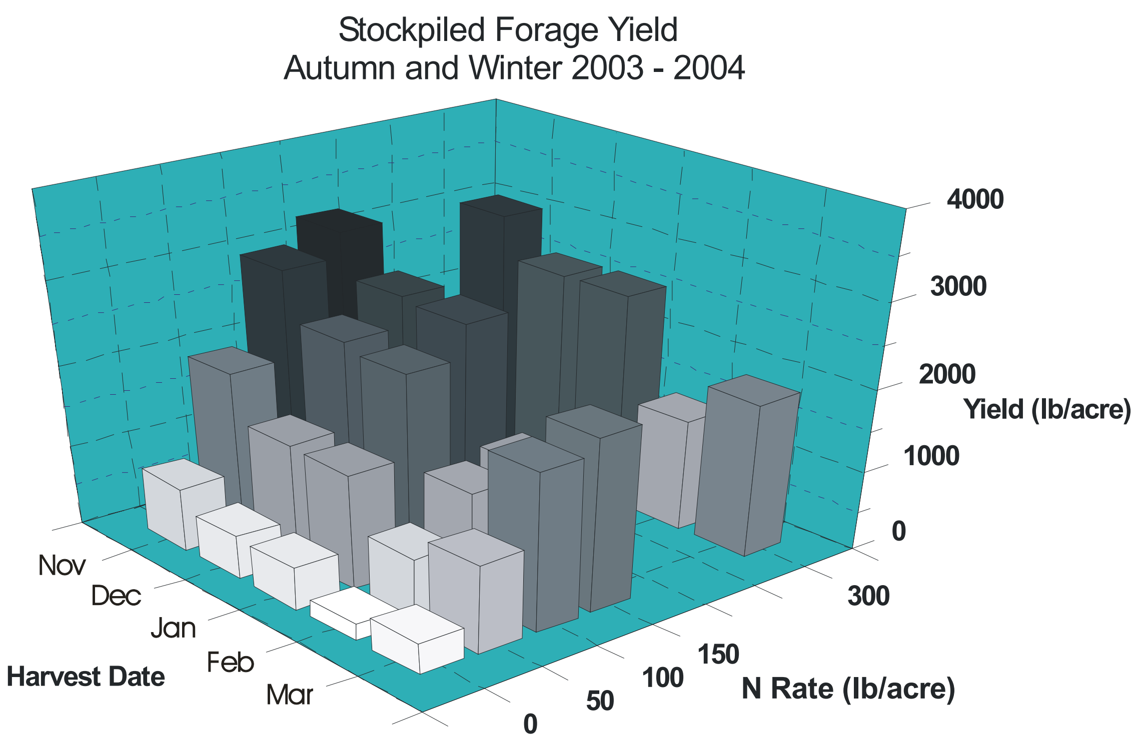
  - Stockpiled forage yields increased substantially when N was applied in August, despite the dry growing conditions in the autumn of 2003 (Fig. 1). Regardless of whether plots contained red clover, a nearly linear response to N rates up to 100 lb. per acre was observed. Rates above 100 lb. per acre showed little increase in stockpiled forage yield. These data suggest at least two things:

    3. Having red clover in stands of tall fescue does not decrease forage yield in autumn, but neither does it improve yields for stockpiling. The amount of red clover in the mixed plots is about 30% in the 0, 50, and 100 lb. per acre N-treatments which is considered ideal for a grazing system. Much less red clover was present in the 150 and 300 lb. per acre N treatments, likely due to competition from the tall fescue. If red clover contributes any nitrogen to improve grass growth in autumn,

then it is likely that the competition from the red clover or the space that the red clover uses offsets any N contribution. Red clover does not maintain its dry matter as well in winter as does tall fescue, and the red clover plants themselves contribute little to yield, especially after mid-December.

4. Although many producers limit late-summer or fall applications of N to 50 or 60 lb. per acre, our data show that even in dry years N rates up to 100 lb. per acre give acceptable yield responses. A preliminary economic analysis for this appears later in this report.

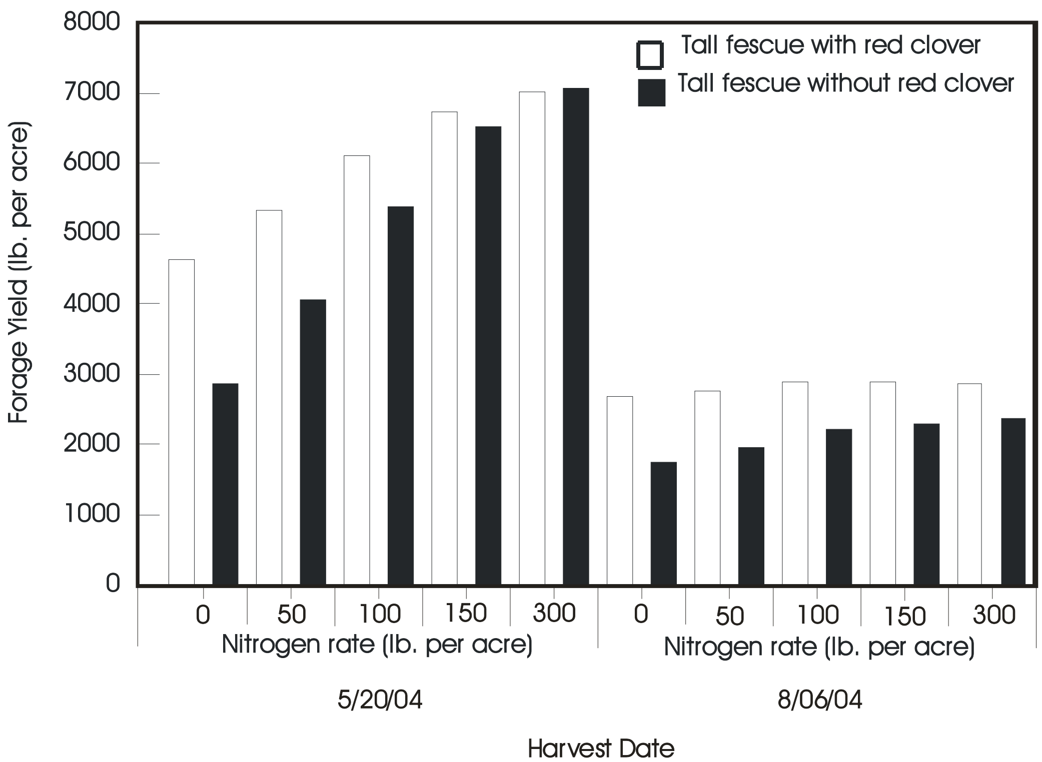
Fig. 1. Stockpiled forage yield in autumn and winter 2003 – 2004. Forage yields for plots with red clover were the same (P>0.05) as those without red clover so data were averaged across pasture types.




- Forage yields in spring and summer:
    - o While the tall fescue responded in autumn to N, there were large carry over effects the following spring (Fig. 2). Yields taken in May of 2004 showed a nearly linear increase in forage yield in response to N applied in autumn although the response was greater for tall fescue without red clover that for tall fescue with red clover. At the three lowest N rates (0, 50, and 100 lb. per acre N) tall fescue with red clover yielded more than plots without red clover but at the two highest N rates the differences were not significant (P>0.05). In July, yields were lower than in spring for all treatments. The addition of red clover improved

yields at all N rates for the July harvest.

Fig. 2. Forage yields in May and July of 2004 from tall fescue with and without red clover and fertilized with 0, 50, 100, 150 or 300 lb. per acre of N the previous August.

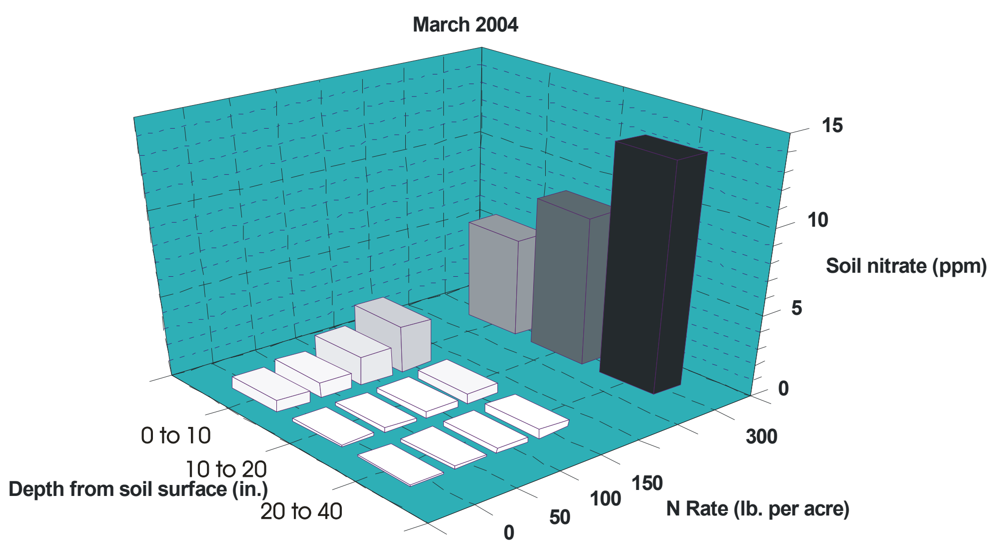



- Red clover stands:
    - Red clover stands were impacted by autumn applied N but red clover stands in all but the 150 and 300 lb. of N per acre treatments were at or above the ideal density of 5 plants per square foot in spring. This along with the yield data discussed above suggests that mixed tall fescue/red clover pastures can benefit from modest rates of autumn applied N without the red clover component being lost. When applying N fertilizer in late summer, rates of 150 or more lb. per acre should be avoided if red clover stands are desired.
- Soil nitrate levels:
    - As expected, soil nitrate levels in March of 2004 were highest in the 300 lb. per acre N treatment (Fig. 3). Soil nitrate levels in the 0 to 10 inch layer were 5 ppm for the 300 lb. per acre N treatment but only 1 ppm or less for all the other treatments. In the 10 to 20 inch layer and the 20 to 40 inch layer, soil nitrate levels were 40 to 70% lower than for the 0 to 10 inch layer for all treatments except the 300 lb. per acre N treatment. For the 300 lb. per acre treatment, soil nitrate levels increased with depth of sampling. In the 20 to 40 inch layer, soil nitrate levels were 13 ppm for the 300 lb. per acre treatment, which

is about 3 times more nitrate than was found in the top 10 inches of the soil profile.

- This suggests that annual applications of 300 lb. per acre of N in August could allow some leaching of nitrogen. We have noted that the grass stands in the 300 lb. per acre treatment have thinned over the course of the experiment. We believe that the abundant growth in this treatment caused excessive shading which in turn caused the stand to thin. This thinner stand was less able to take up N in autumn leaving the potential for unused N to move lower into the soil profile.

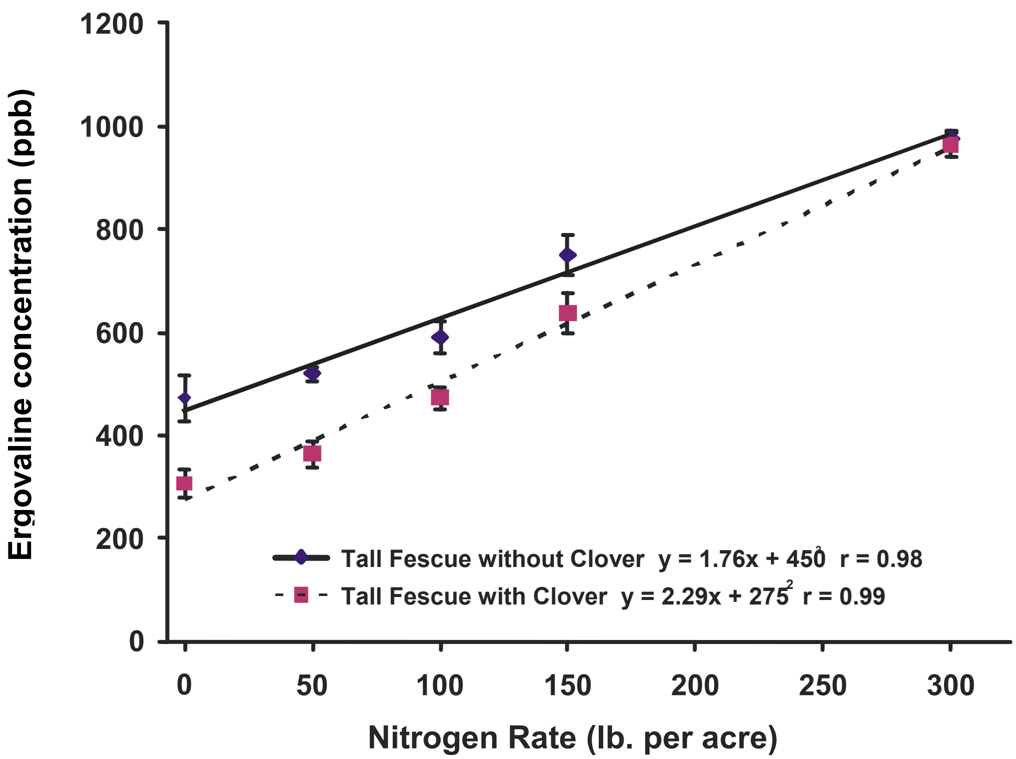
Fig. 3. Soil nitrate levels in March 2004 when fertilized with 0, 50, 100, 150 or 300 lb. per acre of N the previous August.




- These data show that in a healthy grassland system, little nitrate is lost from the system except when 300 lb. per acre of N is applied. Although economic considerations make it unlikely that commercial fertilizer would applied at such a high rate, it does suggest that high N levels from other sources such as manure could pose a nitrate leaching problem.

- Ergovaline concentrations in forage:
  - The ergovaline concentrations we found in stockpiled forage are approximately 25 to 50% lower than those reported by Rottinghaus et al. (1991) for spring-grown tall fescue. However, the ergovaline concentration in all treatments was in excess of the 150 ppb threshold for livestock reported by Stamm et al. (1994). This suggests that while stockpiled forage has lower ergovaline levels than tall fescue during the growing season, it still is a potential problem for livestock owners in winter and that N fertilizer management plays an important role (Fig. 4).

Fig. 4. Ergovaline concentrations in stockpiled tall fescue with and without red clover and fertilized with 0, 50, 100, 150 or 300 lb. per acre of N in August 2002. Samples were collected in November 2002.




- Preliminary economic analysis:
  - When previous moisture conditions cause limited on-farm hay supplies, a late summer N application might be more cost effective than previously thought. A basic economic analysis shows that if ammonia nitrate costs $0.40 per N unit, plus $3 per acre spreading cost and fair quality grass hay is valued at $50.00 per ton that the optimum N fertilization rate in autumn is over 100 lb. per acre (Table 1).

Table 1. Preliminary economic analysis showing the cost and benefit of nitrogen applied in August to tall fescue pastures that are stockpiled. Yields used in the analysis are the average of all winter harvest dates.

| N rate applied in Aug. | Stockpiled forage yield | Fertilizer Cost † | Additional cost per ton of forage ‡ |
|---|---|---|---|
| -------- lb. per acre -------- | | $ per acre | $ per ton |
| 0 | 623 | 0 | - |
| 50 | 1668 | 23.00 | 44.04 |
| 100 | 2761 | 43.00 | 40.23 |
| 150 | 3094 | 63.00 | 50.99 |
| 300 | 2842 | 123.00 | 110.85 |

† Fertilizer costs include ammonia nitrate @ $0.40 per N unit plus $3 per acre for spreading.
‡ Cost compared to 0 N rate.

- More than 500 people have seen this research as part of various extension education programs conducted at the Forage Systems Research Center. In addition, the research plots have been used as part of Dr. McGraw's *Forages* class at the University of Missouri.

**Objectives left to finish:**

- Over the next year we will continue our research on the impact of N on stockpiled tall fescue. As outlined in our original proposal, the tasks in the table below will be conducted over the next year.

| | |
|---|---|
| Continue to harvest appropriate sub-subplots for forage yield and retain subsamples for forage quality and ergovaline analysis (Year 3) | 1/15/05, 2/15/05 and 3/15/05 |
| Seed 5 lb/a of red clover on appropriate plots to maintain grass/legume mix. | 3/1/05 |
| Take soil cores from each sub-plot to determine residual soil N. | 3/19/05 |
| Harvest all sub-subplots for forage yield and retain subsamples for forage quality and ergovaline analysis. (This should measure the residual effects) | 5/19/05 and 7/24/05 |
| Count the legume plants in six, 1.0 $ft.^2$ quadrats in each plot | 5/25/05 and 8/12/05 |
| Analyze samples taken to date for forage quality & ergovaline content | 8/30/05 |
| Prepare final report to Missouri Fertilizer and Lime Council | 12/15/05 |
| Prepare a guidesheet on N fertilization of stockpiled tall fescue | 12/15/05 |
| Work with publications office on articles for the popular press | 12/15/05 |

- In addition to completing the tasks outlined above, we will be analyzing our field data more fully. Specifically, we are interested in determining the rate and extent of forage degradation over winter, with a special focus on ergovaline concentrations. Based on previous data published by Kallenbach et al. (2003), ergovaline levels are expected to drop over winter in stockpiled tall fescue. Although the influence of N rate on this process is unknown, we would like to develop prediction equations that could guide producers, fertilizer dealers, crop consultants and other about the potential toxicity and use of stockpiled tall fescue in winter.
- We will continue to integrate our findings into the curriculum of the Missouri Grazing Schools and the annual Winter Grazing Workshops at Linneus and Mt. Vernon. These outreach efforts can be expected to reach more than 1,000 producers, agency staff, and agri-business personnel. Additionally, as more comprehensive data are collected, we will prepare a new guidesheet about stockpiling tall fescue as well as prepare articles to be published in statewide and national magazines such as Missouri Ruralist, Graze, Stockman Grass Farmer and scientific journals.

**References**

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Rottinghaus, G.E., G.B. Garner, C.N. Cornell, and J.L. Ellis. 1991. HPLC method for quantitating ergovaline in endophyte-infested tall fescue: Seasonal variation of ergovaline levels in stems with leaf sheaths, leaf blades, and seed heads. J. Agric. Food. Chem. 39:112-115.

Stamm, M.M., T. Delcurto, M.R. Horney, S.D. Brandyberry, and R.K. Barton. 1994. Influence of alkaloid concentration of tall fescue straw on the nutrition, physiology, and subsequent performance of beef steers. J. Ani. Sci. 72:1068-1075.

**No additional budget is requested for this year. Since this project starts in August and continues through July of each year, we still have about six more months of data to collect before the project is completed. We only request that we be allowed to carry over the funding already allocated for this project so that we can complete it.**

# Evaluating Fall N Applications for Corn:
## 3-year Summary Report, 2002-2004

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**Objectives:**
The objective of this study is to evaluate fall N applications in production cornfields over several weather years. This includes:

a. Tracking how much fall-applied N is converted to nitrate and how much is lost from production cornfields.
b. Determining how much yield potential is lost.
c. Determining the economics of additional spring N applications.

**Summary of Accomplishments & Conclusions, 2002-2004:**

- A total of fifty experiments were established in production cornfields that had received N applications in fall/winter of 2001, 2002, and 2003 (Figure 1). Most of these experiments were in west-central Missouri, near the Missouri River, and in the claypan region of northeast Missouri. These regions were among the highest in the state for fall application of N. Far northwest and northeast Missouri were also major areas of fall N application, but experiments were not conducted in those areas due to logistics and trying to maximize the number of experiments we could do with project money while still getting a good geographical spread. Several experiments were established in Vernon County because it is a higher-risk area for loss of fall-applied N, though less fall N is applied in that area.
- $NH_3$ was applied after November 1 in all but one of the experimental fields.
- Twenty-one of the 50 fields had N-Serve added to the $NH_3$ (Table 2).
- Reports for individual years contain details of each experimental field.

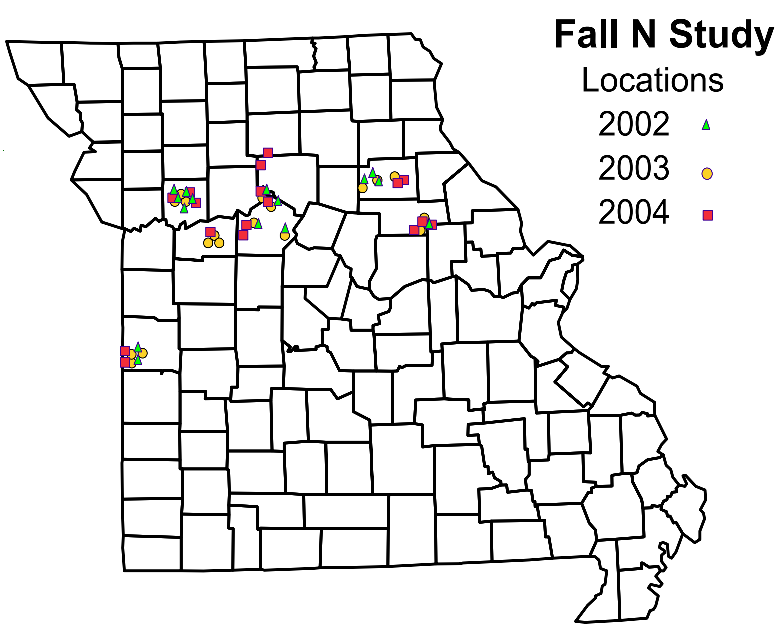


Figure 1. Locations of 50 fall N studies, 2002-2004.

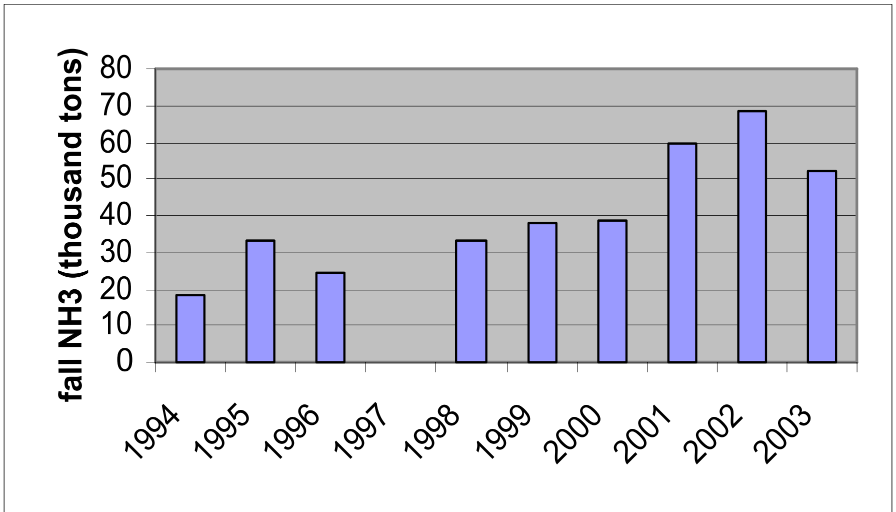


Figure 2. More fall N was applied in Missouri during each of the three years of this study than during any of the seven previous years. Increasing farm size has pressured corn producers to apply N in the fall, leaving more spring work days available for planting and other spring operations.

**Soil samples**

Soil samples were taken in all experiments to a three foot depth in March or April and again in May or June. These samples were analyzed for nitrate and ammonium.

Fertilizer: conversion to nitrate

- All fertilizer N eventually converts to nitrate in the soil. Nitrate is the form of N that is most vulnerable to loss. Anhydrous ammonia converts to nitrate more slowly than any other N fertilizer, which is why it is the only N source that is widely used for fall N applications.
- More than half of fertilizer N had converted to nitrate by the March/April sampling in 28 of 41 fields sampled during these months (nine fields were not sampled until May in 2002, the first year of the study). This indicates fairly high potential for loss of fertilizer N if wet weather occurs after this conversion.
- Conversion to nitrate was greater in 2003 and 2004 than in 2002 (see table), even though 2001-02 was the warmest of the three winters. Warm winters are thought to increase conversion to nitrate, and increase risk of loss. The unusually dry soil conditions due to drought starting in summer 2001 probably slowed down the rate of fertilizer conversion to nitrate, even though soils were unusually warm.

| Year | Month sampled | # Fields sampled | # Fields more than half nitrate | Winter temps | Winter precip |
|---|---|---|---|---|---|
| 2002 | April | 6 | 2 | warm | dry |
| 2003 | April | 18 | 13 | normal | dry |
| 2004 | March | 17 | 13 | normal/cold | normal |

- The amount of N in the nitrate form was related to the date of N application (Figure 3). The later the application date, the lower the percentage of N as nitrate by March or April, and the lower the risk of N loss.

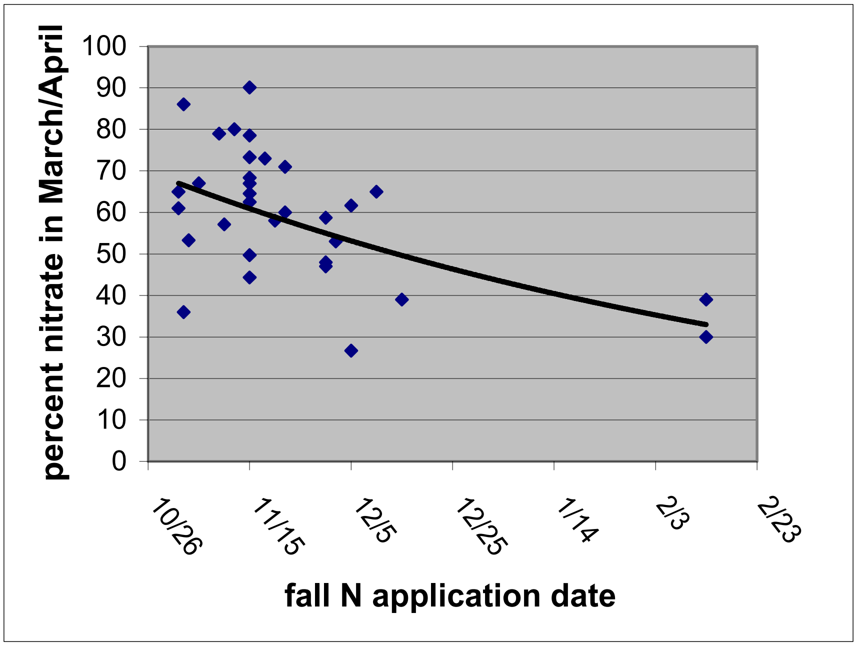


Figure 3. The proportion of anhydrous ammonia that had converted to nitrate by the March/April 2003 & 2004 soil samples was lower for later-applied N. A lower proportion of nitrate means less risk of loss.

● There was some evidence (79% confidence statistically) that N-Serve reduced the percent of N found in the nitrate form in March/April. Fields with N-Serve had an average of 53% of N as nitrate, while fields without had an average of 61% of N as nitrate. This difference carried through to the May/June sampling, but by then soil N was more than 90% nitrate even with N-serve.

Fertilizer loss

- Actual loss of fertilizer N appeared to be minimal in April 2002 and 2003. Both winters were unusually dry, so the nitrate that existed in the soil was not lost.
- Moderate N loss was seen in many fields in March 2004, following a winter with normal precipitation.

**Yield response to supplemental spring N**

Average yield for these 50 experiments was 158 bu/acre. Yield levels were in general good, though yields in some fields were severely drought-limited in 2002 and moderately drought-limited in 2003. Yields in 2004 were excellent in all fields.

When fall-applied N is lost, N availability can limit yields. Each experimental field contained a small yield trial in which some plots received additional spring N. A yield response to these N additions means that yield was N-limited with producer-applied N, and probably that some of the producer-applied N was lost before it could be taken up by the corn.

Average loss of yield potential for a given year was related to weather.

● The winters of 2001-02 and 2002-03 were much drier than normal, with little potential for overwinter loss of N.

- In these two years, spring soil samples showed that N loss was minimal, and yields were increased very little by additional N. The average 3 bu/acre yield increase in 2001-02 came mainly from two fields where the N loss appeared to happen after May 22.

- In 2003-04, winter precipitation was average, spring soil samples showed some loss of N, and average yield response to the N we added was 8 bu/acre (excluding fields which were sidedressed by cooperating producers due to concern for possible N loss).
  - In 2003-04, the convenience of fall N applications was offset by either an average 8 bu/acre yield loss or the need to sidedress additional N to prevent this loss.
- However, sidedressing 50 lb N/acre to all fields would have been only about a break-even proposition.
- In 2003-04, the fields with the greatest loss of yield potential were those that received N the earliest (first week of November).

| Year | Nov-March precip | N loss | Loss of yield potential |
|---|---|---|---|
| | *% of normal* | *(from soil samples)* | *bu/acre* |
| 2001-02 | 47% | minimal | 3 |
| 2002-03 | 30% | minimal | 0 |
| 2003-04 | 104% | moderate | 8 |

- An important question that was not answered during the three years of this project was how much fall-applied N, and how much yield potential, would be lost in a year with above-average winter precipitation.
- Until the answer to this question is known, the overall risk level associated with fall N applications in Missouri will not be understood.

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

Shawn P. Conley
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University of Missouri, Columbia

**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 2003-2004 winter wheat growing season at Columbia, Lamar, and Portageville, MO. 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 acre$^{-1}$. 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$^{-1}$) 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" centers at a seeding rate of 117#'s or 1,500,000 seeds acre$^{-1}$ on October 7$^{th}$, 22$^{nd}$, and 23$^{rd}$, at Columbia, Lamar, and Portageville, respectfully. Wheat followed soybean at Portageville and Columbia and corn at Lamar. 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 (ft.$^{-1}$ row) was taken at green up and jointing. Wheat head number (3 ft.$^{-1}$ row) and crop height (inches) was taken just prior to wheat harvest. Wheat grain yield, test weight, thousand kernel weight, and kernel number head$^{-1}$ were taken at crop physiological maturity and adjusted to 13% moisture.

**Results and Discussion:**

There was a significant location by main effect interaction ($P \leq 0.001$) for grain yield, test weight, thousand kernel weight, and kernel number head$^{-1}$, therefore data was separated by location. Within each location there was not a stand loss by N interaction ($P \geq 0.05$); therefore data were combined over main effects.

Crop tiller number at green up and jointing as well as wheat head number at harvest increased as percent stand loss decreased (Tables 1-3). The application of spring N stimulated wheat tiller formation at Portageville and Columbia, however additional tillers were not formed 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 affect on crop height depending upon location.

At Columbia and Lamar, grain yield decreased as percent crop stand loss increased (Figures 1- 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). Crop test weight response to crop stand loss was variable among locations, however at each location test weight increased as spring nitrogen rate decreased (Tables 1-3). 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 head$^{-1}$ increased as crop stand loss and spring N increased.

Variability in the crop response to stand loss and spring N among locations may be a result of the residual soil N at each location. At Columbia, Lamar, and Portageville the wheat grain yield at the 0 pounds N $acre^{-1}$ treatment were 50.1, 66.6, and 73.4 bu $acre^{-1}$. At Portageville wheat followed an 80 bu $a^{-1}$ soybean crop whereas at Lamar wheat followed a 140.7 bu $a^{-1}$ corn crop. Excess residual soil N may explain the variable crop yield response to spring N at Portageville.

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 | 0.6 | 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 | 7.7 | 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 $P \geq 0.05$.

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

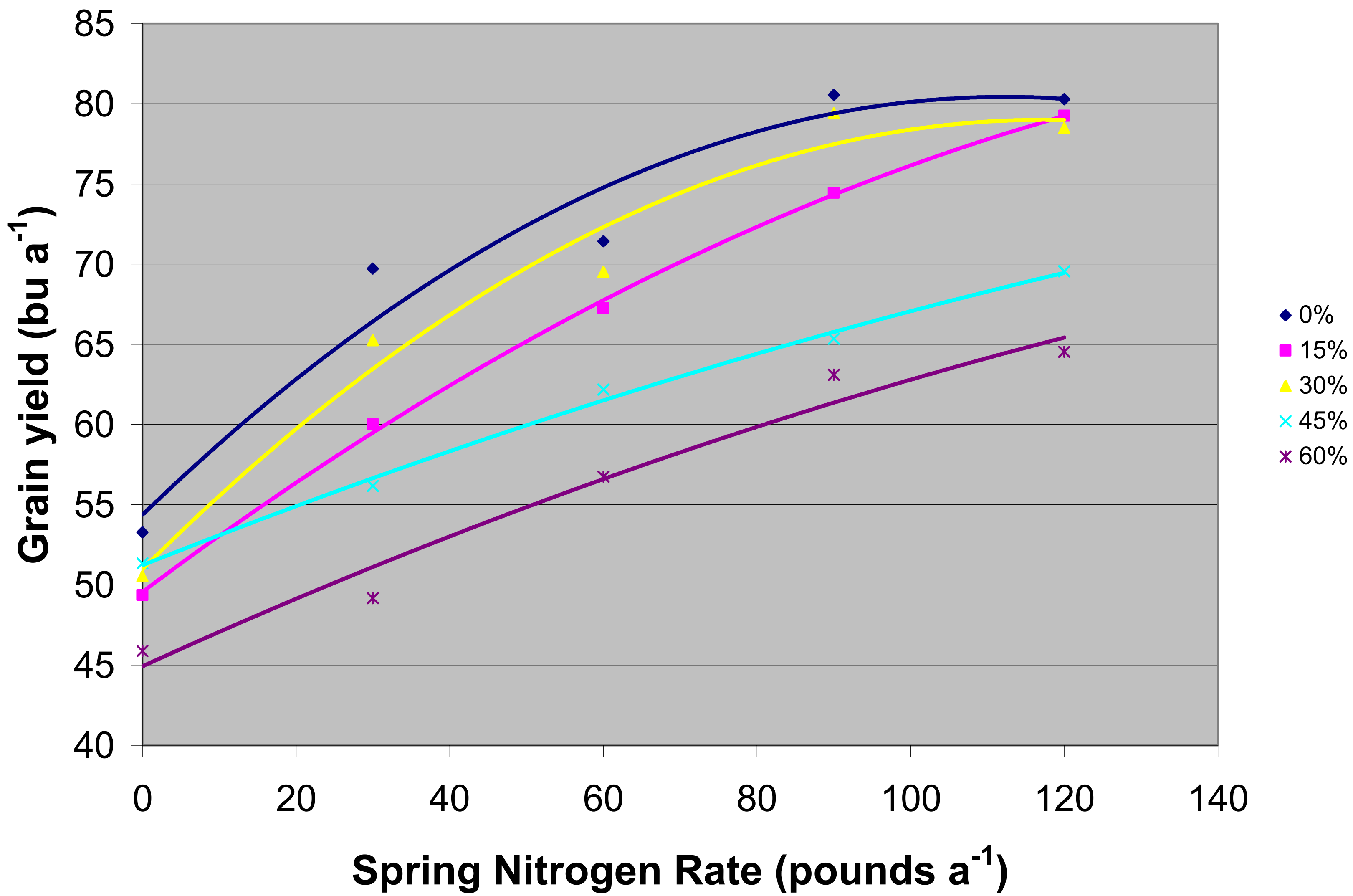


Table 2. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Lamar, MO in the 2003-2004 growing season.

| 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 | 0.5 | 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 | 9.5 | 9.9 | 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 $P \geq 0.05$.

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

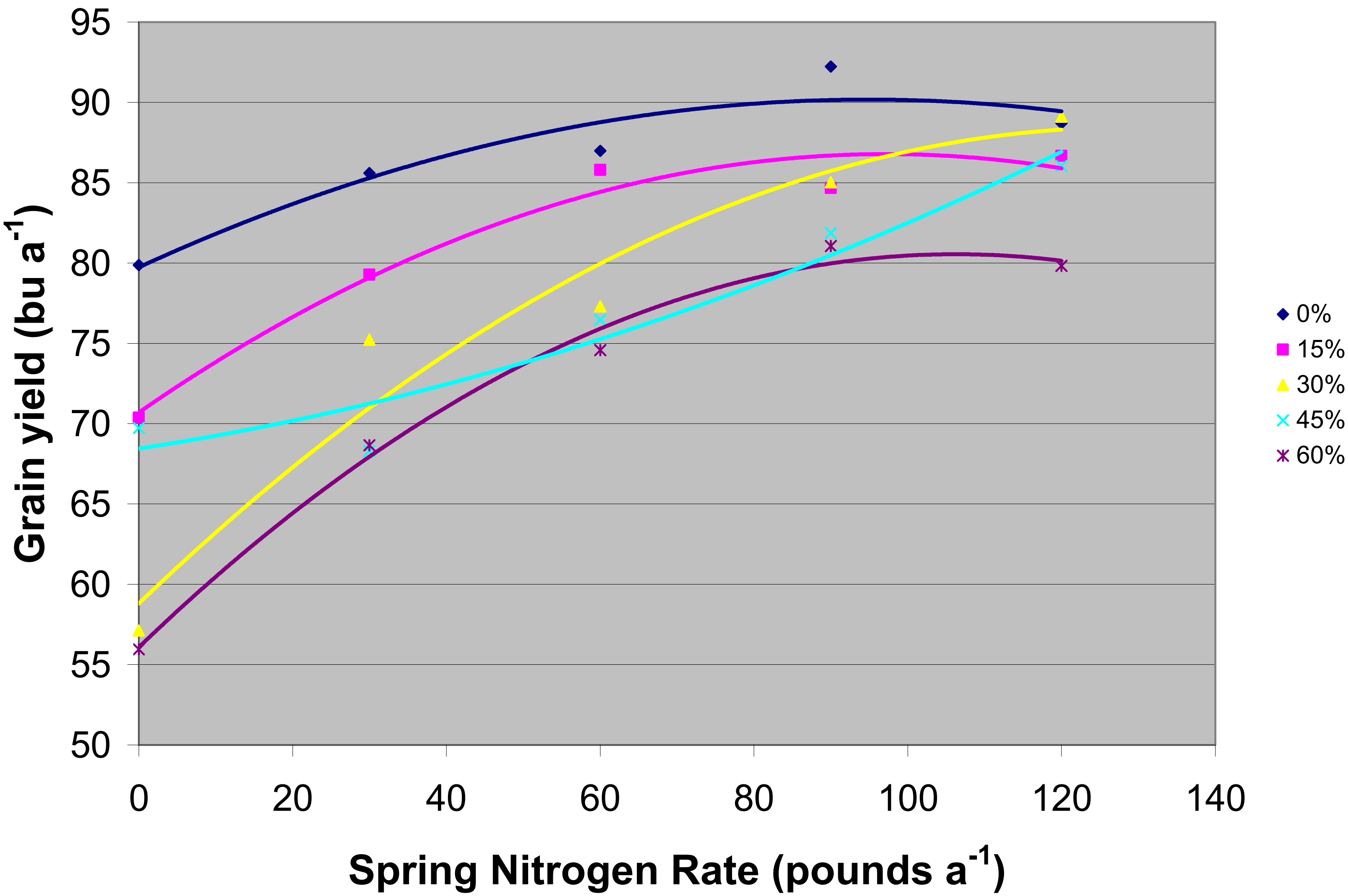
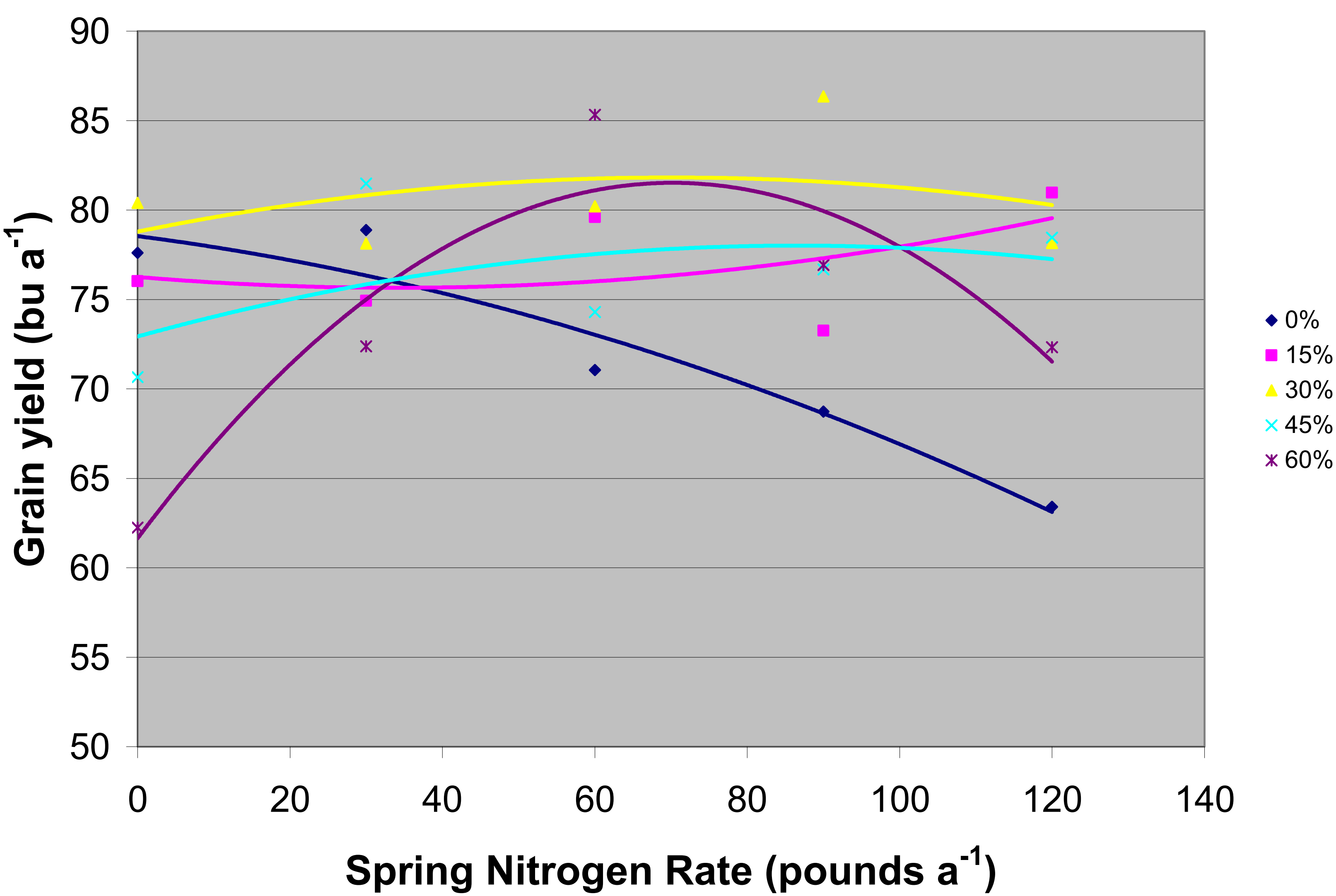


Table 3. Effect of Wheat Stand Loss and Spring Nitrogen Rate on Truman Wheat Yield Components at Portageville, MO in the 2003-2004 growing season.

| 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 | 6.5 | 4.9 | 9.9 | 1.3 | 5.8 | 1.3 | 0.7 | 3.9 |

†Treatment means within the same column and treatment followed by the same letter were not considered different at $P \geq 0.05$.

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



# Grain Sorghum Ratoon Cropping System for SEMO: Final Report

Shawn P. Conley
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University of Missouri, Columbia

**Project Summary Statements:**

- Starter fertilizer did decrease the number of days to 50% bloom in the early season ratoon variety.
- Starter fertilizer did not effect days to 50% bloom in the full season variety.
- Grain yield response to starter was variable among soil types and production system.
- Total grain yield was greater in the grain sorghum ratoon cropping system than in the conventional grain sorghum system.
- Ratoon cropping may prove to be a successful alternative to traditional grain sorghum production systems in SEMO.

**Objectives and Goals:**

The objectives of this research were:

6) To quantify the affect of starter fertilizer on grain sorghum development and grain yield.

To quantify the optimal fertility requirements for a ratoon cropping system.

7) To determine the feasibility of introducing a grain sorghum ratoon cropping system into SE Missouri.

**Procedures:**

- The experiment was located on two soil types in each year in SE Missouri
  - 2003
    - Pemiscot County: The University of Missouri Lee Farm at Portageville
      - Tiptonville silt loam
    - Dunklin County: The University of Missouri Rhodes Farm at Clarkton
      - Malden fine sand
  - 2003
    - Pemiscot County: The University of Missouri Lee Farm at Portageville
      - Tiptonville silt loam
      - Sharkey silty clay

- Experimental Design: Randomized complete block design
  - Seeding rate: 110,000 plants per acre
  - Two cultivars:
    - Early season ratoon: KS-310 (55 to 59 days to 50% bloom)
    - Full season check: KS-955 (74 to 78 days to 50% bloom)
  - Starter treatment:
    - 45# N and 30# $P_2O_5$ applied at planting (dribble placement)
  - First planting Nitrogen rate (pounds per acre):
    - 120 pounds total
  - Ratoon Nitrogen rate (pounds per acre, side-dressed):
    - 0, 30, 60, 90, 120
  - Ratoon Phosphorus rate (pounds per acre, side-dressed):
    - 0 or 30
  - Four replications:
  - Data collected:
    - Days to 50% bloom
    - Maturity and harvest date
    - Grain yield

**Full treatment list:**

| **Treatment** | **Starter** | **Ratoon N rate** | **Ratoon P rate** |
|---|---|---|---|
| Mid to late season cultivar (KS-955) | Y | - | - |
| Mid to late season cultivar (KS-955) | N | - | - |
| Early season cultivar (KS-310) | Y | 0 | 0 |
| Early season cultivar (KS-310) | Y | 30 | 0 |
| Early season cultivar (KS-310) | Y | 60 | 0 |
| Early season cultivar (KS-310) | Y | 90 | 0 |
| Early season cultivar (KS-310) | Y | 120 | 0 |
| Early season cultivar (KS-310) | Y | 0 | 30 |
| Early season cultivar (KS-310) | Y | 30 | 30 |
| Early season cultivar (KS-310) | Y | 60 | 30 |
| Early season cultivar (KS-310) | Y | 90 | 30 |
| Early season cultivar (KS-310) | Y | 120 | 30 |
| Early season cultivar (KS-310) | N | 0 | 0 |
| Early season cultivar (KS-310) | N | 30 | 0 |
| Early season cultivar (KS-310) | N | 60 | 0 |
| Early season cultivar (KS-310) | N | 90 | 0 |
| Early season cultivar (KS-310) | N | 120 | 0 |
| Early season cultivar (KS-310) | N | 0 | 30 |
| Early season cultivar (KS-310) | N | 30 | 30 |
| Early season cultivar (KS-310) | N | 60 | 30 |
| Early season cultivar (KS-310) | N | 90 | 30 |
| Early season cultivar (KS-310) | N | 120 | 30 |

**Results:**

The experiment was planted on April 14$^{th}$, 2003 and April 5$^{th}$, 2004. The early season ratoon variety (KS 310) was first harvested on July 28$^{th}$, 2003 and July 22$^{nd}$, 2004. The ratoon (second cutting) grain sorghum crop was harvested on November 21$^{st}$, 2003 and November 19$^{th}$, 2004. The full-season single crop variety (KS 955) was harvested on August 14$^{th}$, 2003 and August 17$^{th}$, 2004. Based on environmental conditions in 2003 we estimate that we lost two full weeks of growing conditions for the ratoon grain sorghum crop; whereas growing conditions were optimal in 2004.

**Grain Sorghum Bloom Date and Yield Response to Starter Fertilizer**

In each year and on each soil type the addition of starter fertilizer decreased the number of days to 50% bloom by an average of 3 days in the ratoon variety (Figures 1 and 2). However, the addition of starter fertilizer to the ratoon crop (second growth and cutting) did not affect bloom date. Starter fertilizer also did not affect bloom date in the full season check variety.

Starter decreased grain yield in the ratoon variety when grown on the Tiptonville silt loam in 2003 and 2004 (Figures 3 and 4). However, starter did not affect grain yield in the full season check variety on the Tiptonville silt loam in 2003 or 2004.

Starter also did not affect grain yield in either the ratoon or full season check variety when grown on Malden fine sand in 2003. In contrast, starter increased grain yield in both the ratoon and full season check variety when grown on Sharkey silty clay in 2004. Our results suggest that the application of starter fertilizer may prove beneficial in ratoon grain sorghum production systems; whereas data does not support the application of starter to full season grain sorghum varieties.

**Ratoon (Second Cutting) Yield Response to Nitrogen and Cropping System Summary**

Ratoon N rate did not affect the ratoon grain sorghum bloom date in 2003 or 2004 (data not shown). In each year and at each location grain yield increased linearly as nitrogen rate increased (Figures 5-8). Grain yield in the ratoon system ranged from 12 to 60 bushels acre$^{-1}$ depending upon soil type, N rate, and year. In each year and on each soil type grain yield was greater in the ratoon grain sorghum production system when compared to the conventional full season variety production system (Figures 9 and 10). Our results indicate a 44 to 104% increase in grain yield in the ratoon production system.

**Conclusions**

The application of starter fertilizer decreased the number of days to 50% bloom in the early season variety. This may decrease the number of days until harvest and allow growers to capture more growing degree units for the ratoon crop. Starter fertilizer did not affect the 50% bloom date in the full season check variety. Though crop yield was variable among locations; at each location the total crop yield of the ratoon system out performed the full season check system. Our results indicate that the application of starter fertilizer may prove beneficial in a ratoon cropping system and that ratoon cropping may prove to be a successful alternative to conventional grain sorghum production systems in SEMO.

Figure 1. Grain Sorghum Bloom Date Response to Starter Fertilizer in 2003.

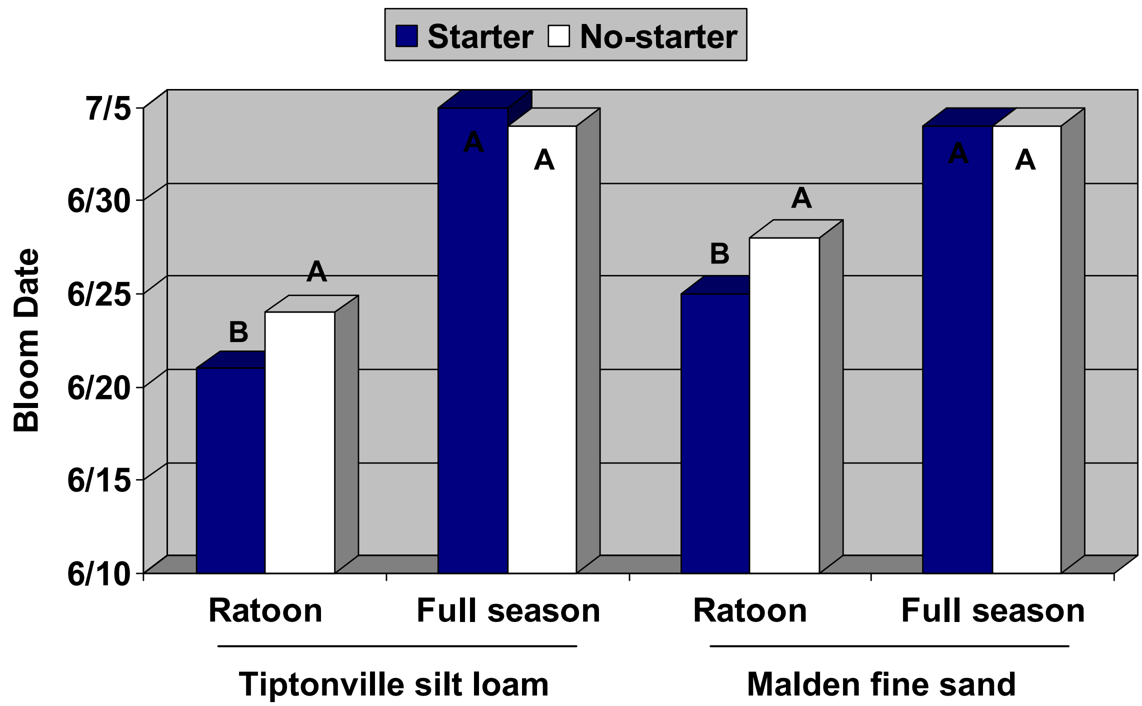



Figure 2. Grain Sorghum Bloom Date Response to Starter Fertilizer in 2004.

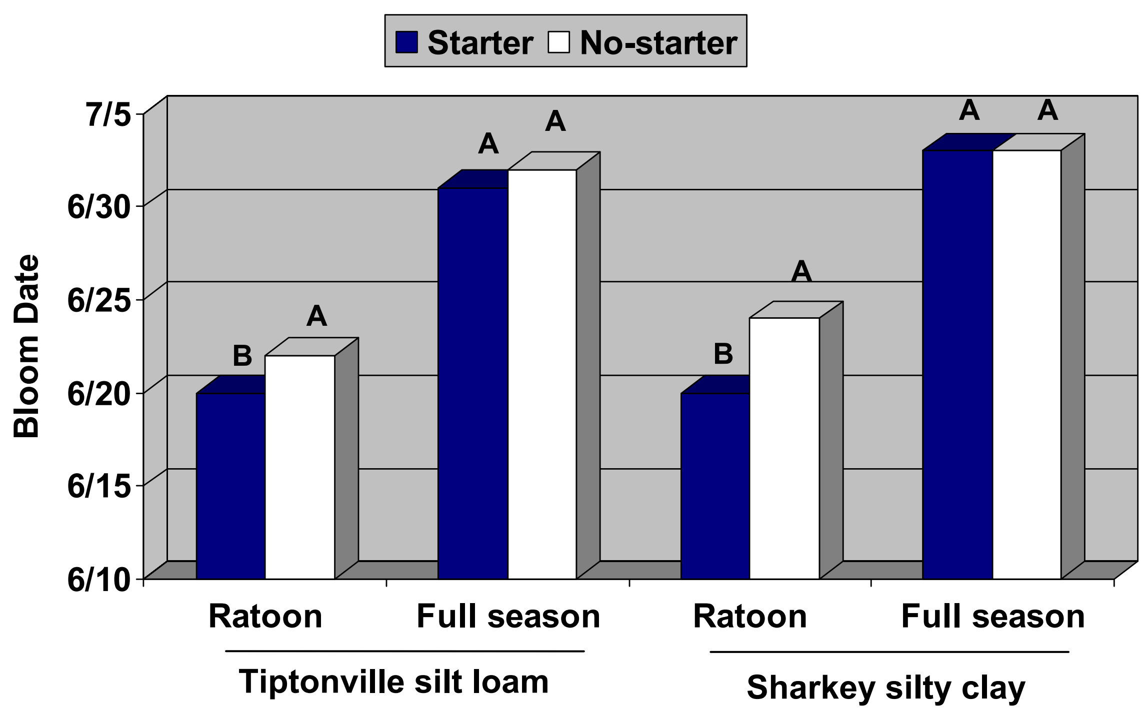


Figure 3. Grain Sorghum Yield Response to Starter Fertilizer in 2003.

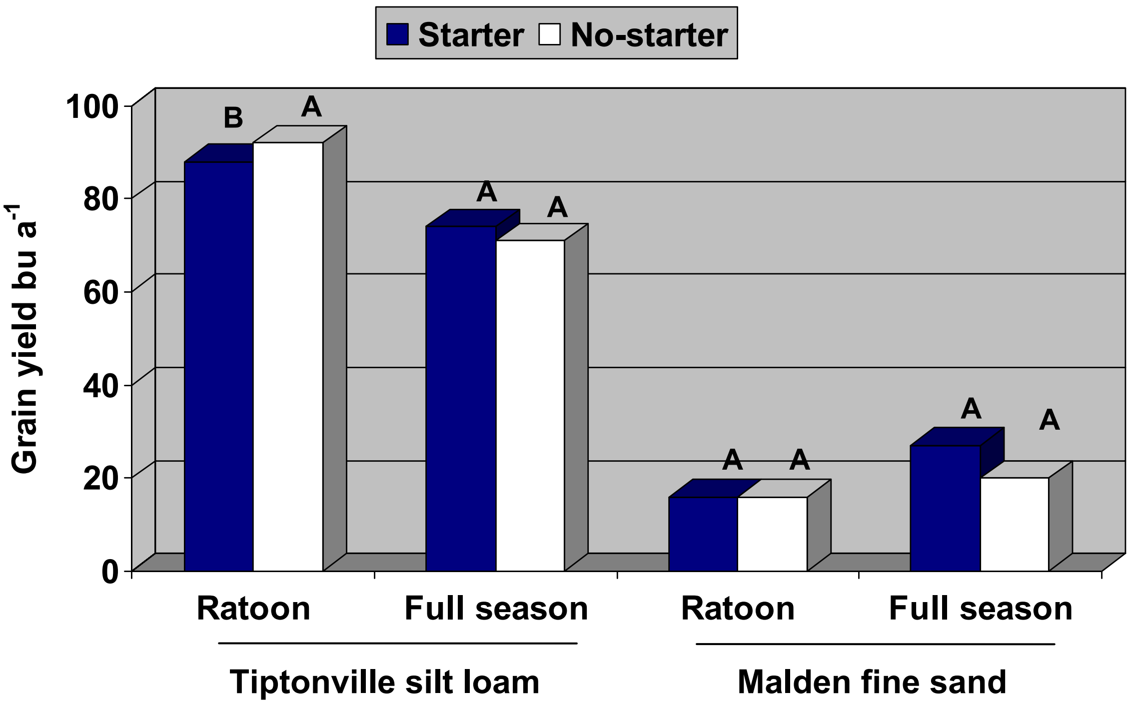



Figure 4. Grain Sorghum Yield Response to Starter Fertilizer in 2004.

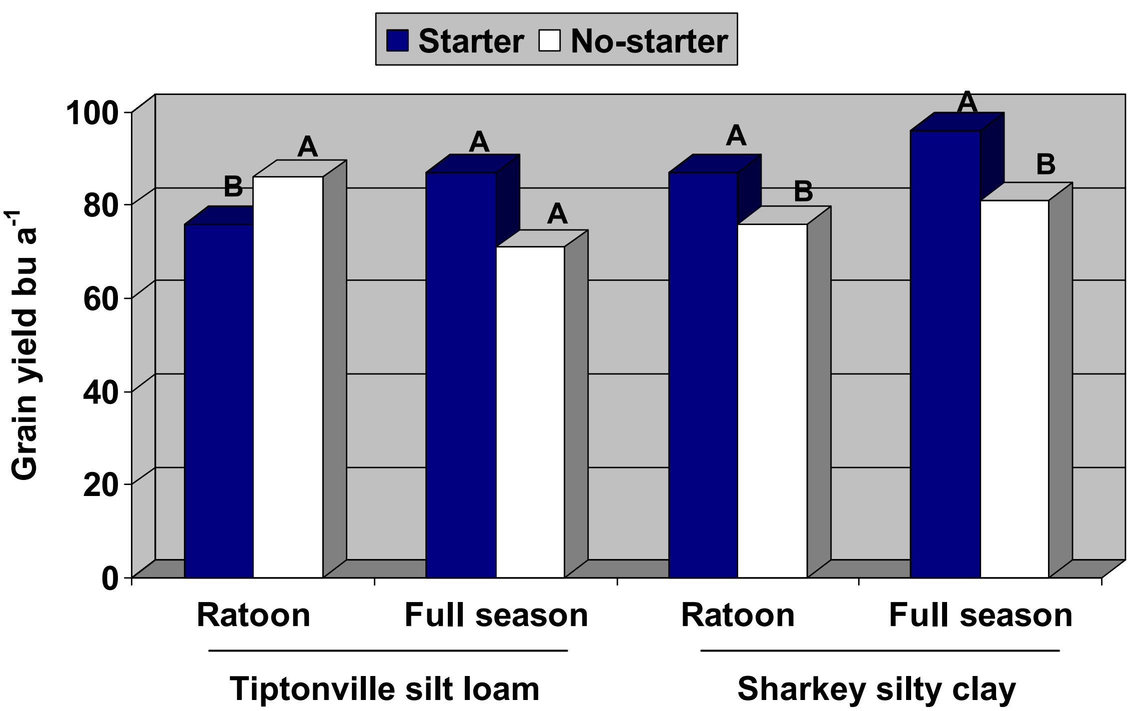


Figure 5. Grain Sorghum Yield Response to Ratoon N on a Tiptonville Silt Loam in 2003.

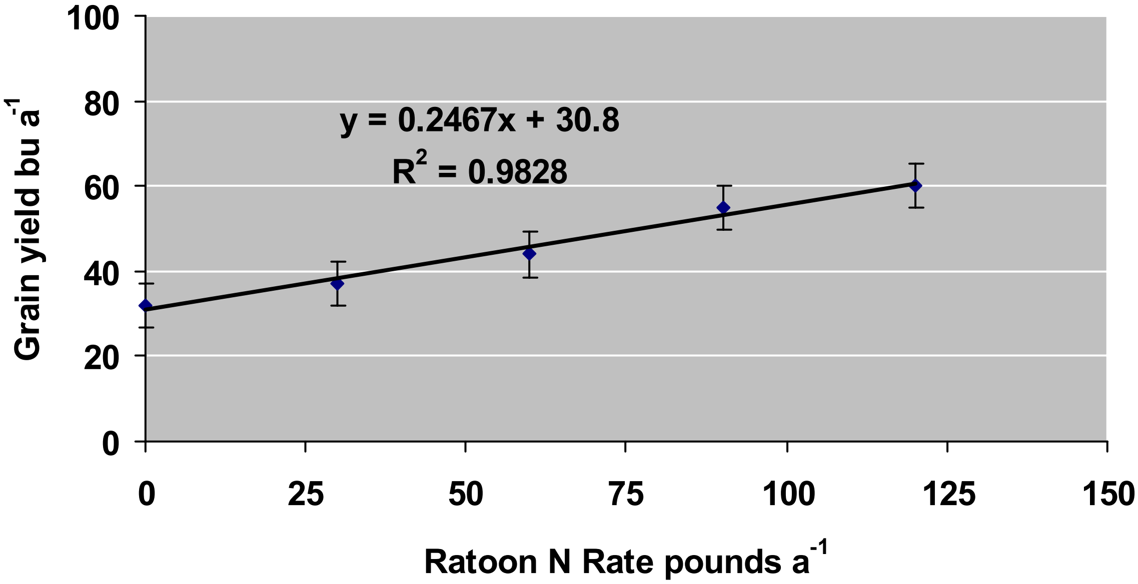



Figure 6. Grain Sorghum Yield Response to Ratoon N on a Malden Fine Sand in 2003

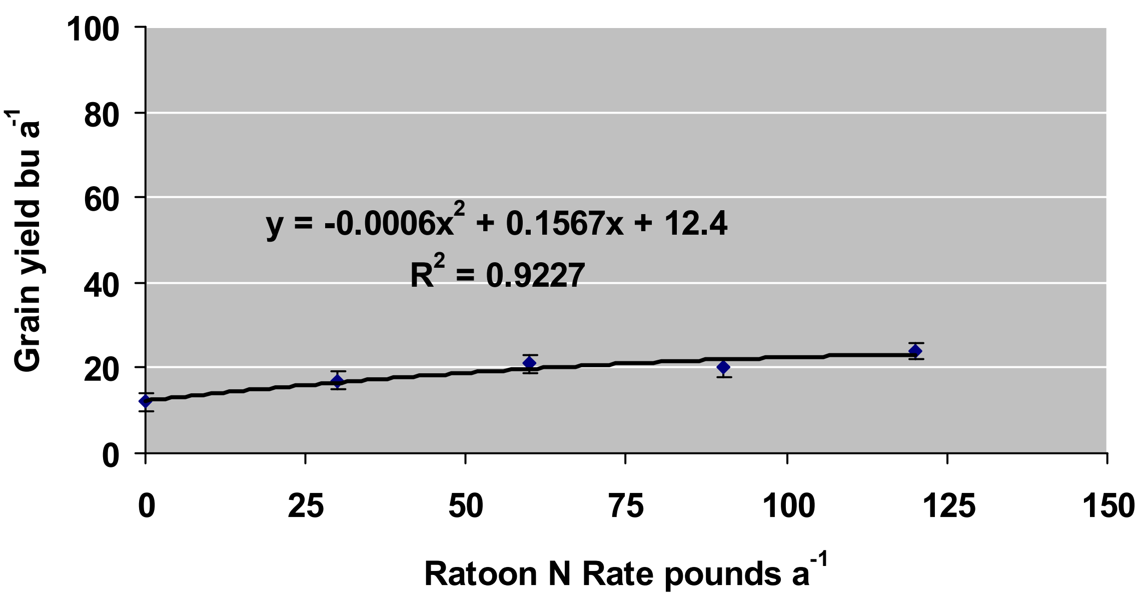


Figure 7. Grain Sorghum Yield Response to Ratoon N on a Tiptonville Silt Loam in 2004

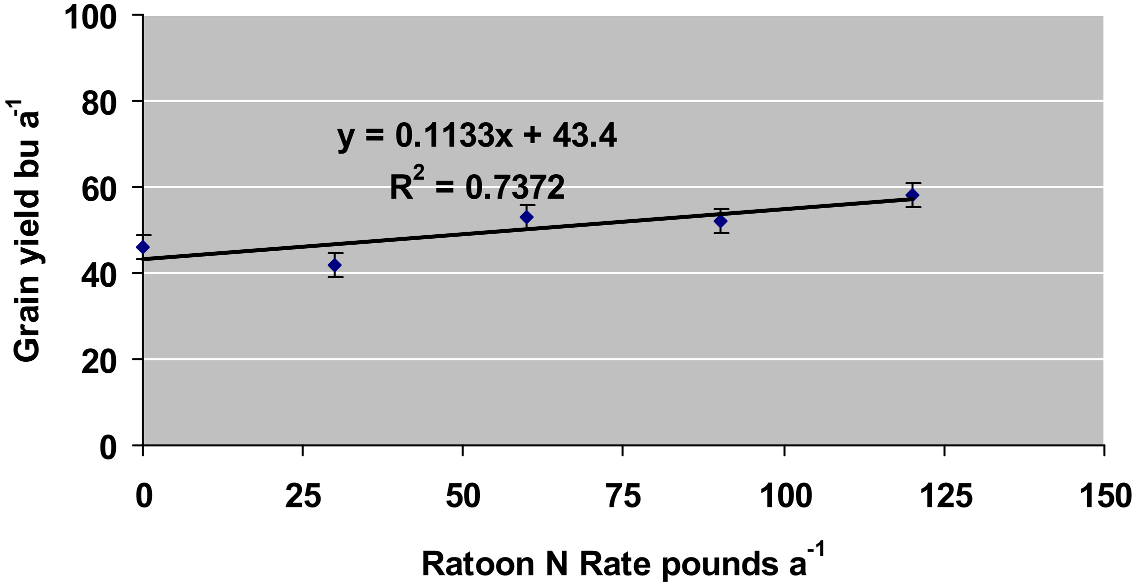



Figure 8. Grain Sorghum Yield Response to Ratoon N on a Sharkey Silty Clay in 2004

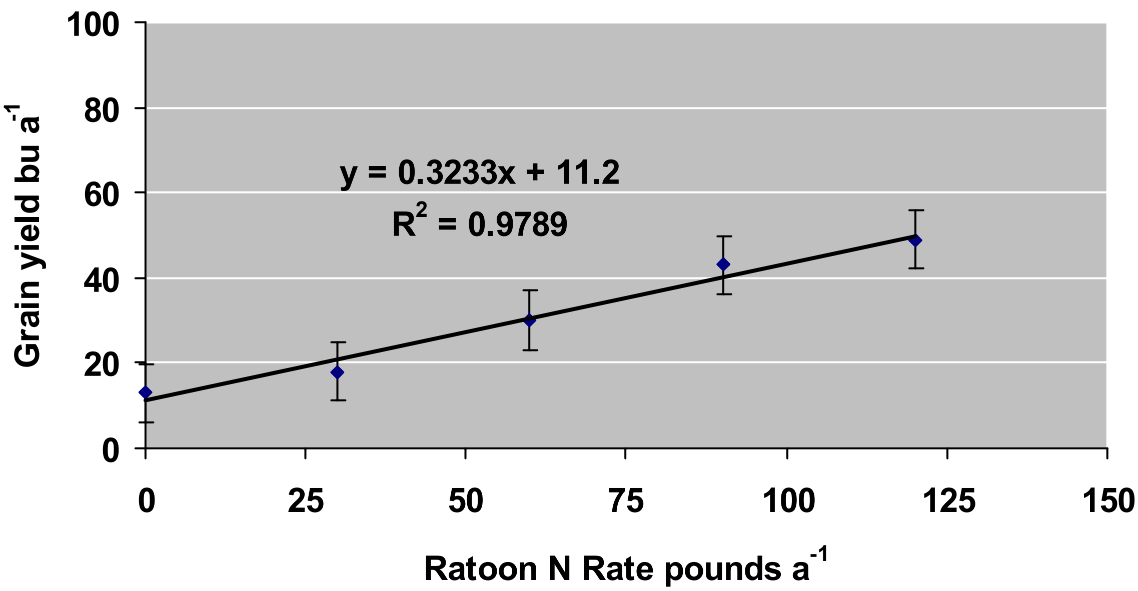


Figure 9. Grain Yield Comparison Between the Ratoon Grain Sorghum Cropping System and the Conventional Full Season Grain Sorghum Production System in 2003.

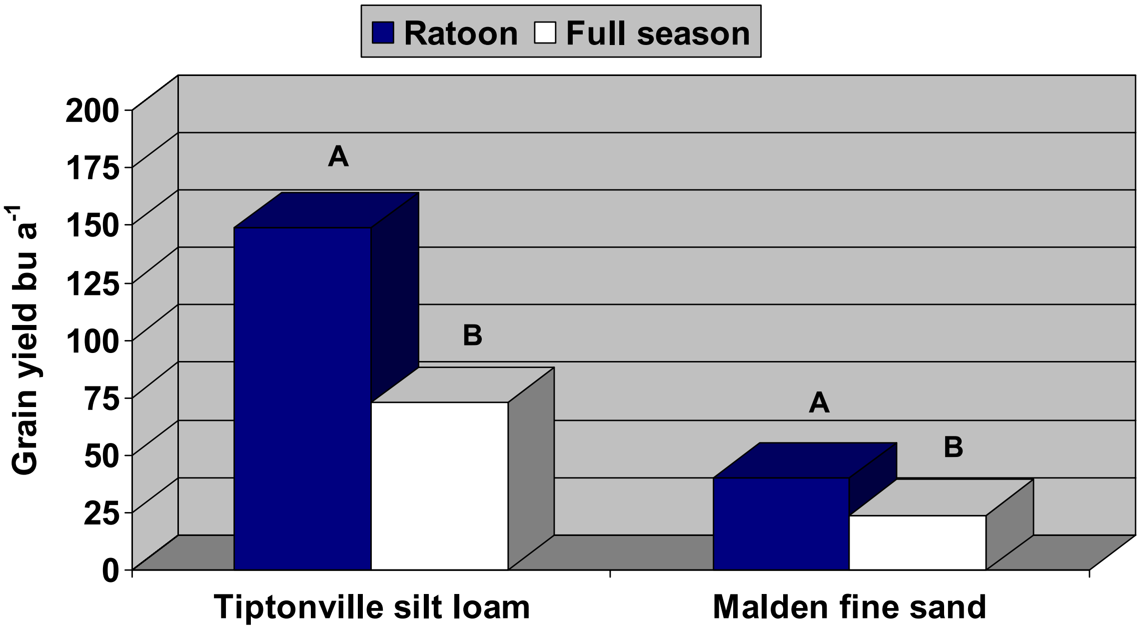
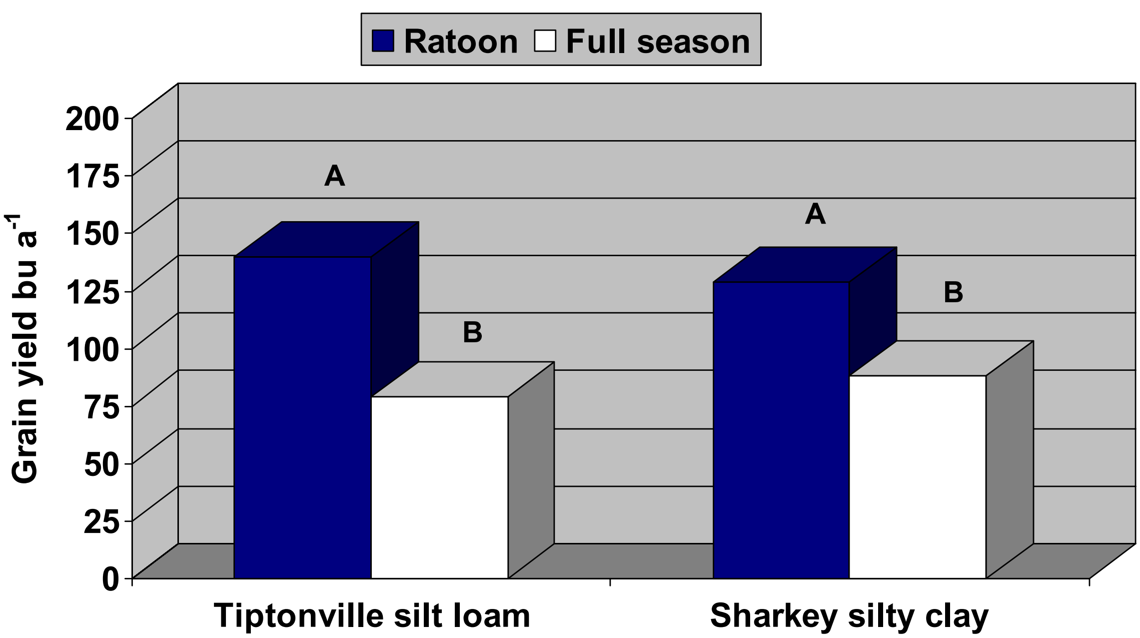



Figure 10. Grain Yield Comparison Between the Ratoon Grain Sorghum Cropping System and the Conventional Full Season Grain Sorghum Production System in 2004.



# Determining the Correct Nitrogen Rate for Cotton Following Soybeans
# Second Year (2004) Progress report

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

## Objectives

3) Determine the optimum rate of nitrogen fertilization for cotton in a cotton/soybean rotation.
4) 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 NO3 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, and trash percentage. The data from the fiber property determinations was not available at the time this report was prepared (12-16-2004). These fiber quality properties are being 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 2003 crop 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 2004**

Data collected in 2004 are presented in Table 1 and Figure 1. The clay soil and the silt-loam sites responded differently to N fertilization in 2003. Nitrogen fertilization significantly increased lint yields at the clay soil site (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. The two-year average yield was also greatest for the highest rate of N application. 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. This would indicate that the previous soybean crop had supplied sufficient N to maximize cotton lint production. In 2004 there were significant differences in gin turn out %, but no consistent trend at either site. This is in contrast to 2003 when increasing nitrogen rates reduced turn out. The data from the fiber property determinations was not available at the time this report was prepared (12-16-2004). When this data is available this report will be amended to include an economic analysis based on returns to producers calculated by using Commodity Credit Corporation Cotton loan rates for 2004 crop White Upland Cotton warehoused in Missouri. Discounts or premiums for fiber properties will be applied to the base rate. Input costs for nitrogen will be computed at a rate of $0.24 per lbs of N and an application cost of $5.00 per acre. Returns for cottonseed will be calculated using a price of $110.00 per ton.

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.

The 2003 data was presented in poster form to cotton producers and researchers at the Belt-Wide Cotton Conferences, in San Antonio, TX January 5,6,7,8,9-2004. The 2003 and 2004 data will be presented in poster form to cotton producers and researchers at the Belt-Wide Cotton Conferences, in New Orleans, LA January 4,5,6,7-2005. Results were also presented to 55 crops researchers at the Southern Plant Nutrition Conference held 10-7,6-03 in Olive Branch, MS. This information was also presented as an oral presentation at the Missouri Cotton Producers Conference in Kennett, MO February 10, 2004.

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

| N Treatment | Cotton lint yields lbs/acre | | | | | | Turn out % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Clay | | | Silt loam | | | Clay | | | Silt loam | | |
| | 2003 | 2004 | Avg | 2003 | 2004 | AVG | 2003 | 2004 | AVG | 2003 | 2004 | AVG |
| 0 | 491d | 315d | 403 | 761a | 825a | 793 | 0.40ab | 0.40b | 0.40 | 0.38a | 0.39a | 0.39 |
| 60 | 750c | 633c | 692 | 680a | 817a | 749 | 0.41a | 0.43a | 0.42 | 0.36b | 0.37ab | 0.37 |
| 85 | 956b | 761b | 859 | 721a | 940a | 831 | 0.40ab | 0.42a | 0.41 | 0.36b | 0.38ab | 0.37 |
| 110 | 1059a | 923a | 991 | 870a | 942a | 906 | 0.39bc | 0.41ab | 0.40 | 0.36ab | 0.36b | 0.36 |
| 135 | 1098a | 934a | 1016 | 764a | 979a | 872 | 0.38c | 0.41ab | 0.40 | 0.36b | 0.37b | 0.37 |
| LSD 0.05 | 94 | 100 | | 244 | 243 | | 0.014 | 0.019 | | 0.0019 | 0.02 | |
| CV % | 7.1 | 9.1 | | 20.4 | 17.54 | | 2.3 | 2.98 | | 3.4 | 3.52 | |

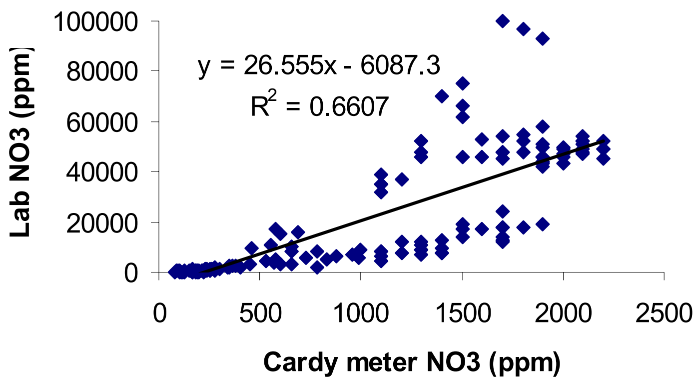



Figure 1 Relationship between laboratory cotton petiole analysis and Cardy meter $NO_3$-N determinations for both sites in 2004.

# RESCUE NITROGEN APPLICATIONS FOR CORN (*ZEA MAYS*)

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Novelty, Columbia, Portageville, and Albany

**Abstract:** Rescue N (nitrogen) applications in a standing corn crop may be necessary when wet conditions prevent preplant N applications or loss of N was suspected due to wet conditions after application. Field research at Albany, Columbia, Novelty, and Portageville in 2003 and 2004 evaluated the impact of AN (ammonium nitrate), UAN (urea ammonium nitrate), urea, and urea plus NBPT (Agrotain®) applied broadcast and between-row (BR) as a preplant or postemergence application to 1, 2, 3, and 4 ft corn. Nitrogen applied BR injured corn on average less than 5% 7 days after treatment except UAN applied to 2 ft tall corn. Broadcast applied N injury was ranked UAN (32-55%) > AN (14-26%) > urea (4-8%) = urea plus NBPT (5-10%). BR application of AN, UAN, or urea plus NBPT to corn 1 to 4 ft tall had optimal grain yields at 60 to 100% of the sites; however, BR application of urea was consistent at 80 to 100% of the sites when applied to 3 to 4 ft tall corn. Broadcast applications of N sources with optimal grain yields at 60 to 100% of the sites included: UAN up to 1 ft tall corn, AN 1 to 2 ft tall corn, and urea or urea plus NBPT 2 to 4 ft tall corn.

## INTRODUCTION

Rescue N applications in a standing corn crop may be necessary when wet conditions prevent preplant N applications or loss of N was suspected due to wet conditions after application. In these situations, either tractor-mounted or high-clearance-mounted applicators can sidedress N fertilizer between corn rows, avoiding leaf burn. These applicators are not always available, or may be configured for other uses such as spraying herbicides, consequently, broadcast applications may be easier to accomplish. In addition, broadcasting N fertilizer by airplane is another option for rescue applications of N when soil conditions are too wet to carry traffic. Broadcast applications of N will cause leaf burn, but little if any research has been conducted to measure how much yield is lost due to leaf injury for various application times and nitrogen forms. The amount of yield recovered may depend on the stage at which N is applied. Understanding yield loss associated with nitrogen burn at different stages of corn development would help corn producers to make informed decisions about whether to attempt rescue N applications and what type of application equipment to use. The objective of this study was to evaluate yield response of corn to rescue N applications, including broadcast applications that cause leaf burn and to evaluate dry and liquid nitrogen sources.

## MATERIALS AND METHODS

Field research was conducted at the University of Missouri Greenley Research Center near Novelty in 2003 and 2004 (40.035997 N, 92.243783 W), Bradford Research and Extension Center near Columbia in 2003 and 2004 (38.894165 N, 92.274145 W), Hundley-Whaley Research Center near Albany in 2003 (40.251282 N, 94.326977 W), and Delta Center near Portageville in 2003 and 2004 (36.427945 N, 89.700234 W). The Albany site experienced a severe hailstorm prior to the 4 ft application timing in 2004 and was abandoned. The soil was a Putnam silt loam (fine, montmorillonitic, mesic Mollic Albaqualf), Mexico silt loam (fine, montmorillonitic, mesic Vertic Albaqualfs), Grundy silt loam (fine, montmorillonitic, mesic Aquic Argiudolls), and Tiptonville sandy loam (fine-silty, mixed, thermic Typic Argiudolls) at Novelty, Columbia, Albany, and Portageville, respectively. Researchers at each site utilized management practices commonly used by farmers in the area. Field information about the locations and selected management practices is shown in Table 1.

Research was arranged as a randomized complete block design with four replications at Novelty, Columbia, and Portageville and three replications at Albany. Ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, or urea plus NBPT at 1 qt/ton was applied broadcast or between the row at 150 lb N/acre preplant and to 1, 2, 3, and 4 ft tall corn except between-row (BR), preplant urea and urea plus NBPT at 1 gallon/ton; 1 ft corn treated with urea at Novelty, Columbia, and Albany; and 3 ft corn treated with urea and urea plus NBPT at Novelty, Columbia, and Albany. NBPT is a urease inhibitor and is n-(n-butyl) thiophosphoric triamide (Agrotain®) combined with the solvent n-methyl pyrrolidone. Corn injury from 0 (no visual crop injury) to 100% (complete crop death) was evaluated 7 and 14 days after treatment based on the combined visual effects of N source on necrosis, chlorosis, and stunting. Corn was harvested with a small-plot combine and final weight adjusted to 15% moisture.

Injury data were subjected to ANOVA and reported by location due to interactions between locations and different environmental conditions. Yield data were grouped and discussed according to low, medium, and high yield environments. Data were subjected to an analysis of variance and means separated using Fisher's Protected LSD at p = 0.05.

## RESULTS

***Injury.*** Preplant N at 150 lb/a did not injure corn (data not presented). Nitrogen applied between the rows injured corn on average less than 5% 7 DAT except UAN applied to 2 ft tall corn (Table 2). However, injury was less than 4% for all N sources 14 DAT. Broadcast applied N injury was ranked UAN > AN > urea = urea plus NBPT. Average broadcast N injury was 32-55%, 14-26%, 4-8%, and 5-10% for UAN, AN, urea, and urea plus NBPT 7 DAT, respectively, depending on the application timing. Complete recovery was evident by 28 DAT for all N sources except UAN applied broadcast to corn that was 2, 3, or 4 ft tall and AN applied broadcast to 3 or 4 ft tall corn (visual observation).

***Yield response.*** Grain yield was affected by the yield potential of the environment, injury, N source, and application timing. Data were presented separately for each location except Columbia and Albany in 2003 since both locations experienced drought conditions. All rescue N application treatments had grain yields similar to preplant N except UAN applied broadcast to 4 ft corn which reduced grain yield 34 and 23 bu/a when compared to UAN applied preplant and the untreated control, respectively (Table 3). Preplant, broadcast applied urea plus NBPT, urea plus NBPT applied broadcast to 2 ft tall corn, urea applied BR to 2 ft tall corn, and AN applied BR to 2 ft tall corn had grain yields 17 to 21 bu/a greater than the untreated control.

The Novelty site in 2003 was a medium grain yield environment (Table 3). All treatments increased corn grain yield when compared to the untreated control. All rescue N application treatments had grain yields similar to or greater than the preplant N applications except UAN applied broadcast to 4ft corn. Corn grain yield was probably reduced due to injury at this application timing. Urea applied broadcast to 3 and 4 ft corn, AN applied BR to 3 and 4 ft corn, and UAN applied BR to 3 and 4 ft corn increased grain yield 15 to 23 bu/a when compared to preplant N applications. UAN applied broadcast to 4 ft corn reduced grain yield 18 bu/a when compared to UAN applied preplant.

Rainfall and temperature were optimal for corn in 2004. The Columbia and Novelty sites were in high yield environments (Table 4). Grain yields at Columbia were maximized at the 1 ft application timing when compared to other application timings. Corn grain yield, when AN was applied broadcast or BR at the 1 and 2 ft corn timings, was similar to the preplant control. UAN applied broadcast to 1 ft tall corn had grain yields similar to UAN applied preplant treatment; however, corn treated BR up to

2 ft tall or 4 ft timing had grain yields similar to the preplant control. A broadcast application of urea or urea plus NBPT up to 3 ft tall corn had grain yields similar to preplant treatments. Grain yield for urea and urea plus NBPT was 23 and 26 bu/a greater at the 1 ft timing than preplant urea and urea plus NBPT controls, respectively. At Novelty, the 2 ft N applicationg timing had the highest grain yields. AN applied broadcast or BR to corn 1 to 4 ft tall had grain yields similar or up to 34 to 36 bu/a greater than the preplant timing. A broadcast or BR application of UAN to corn 1 to 3 ft tall had grain yields similar to the preplant control. Corn grain yield in urea or urea plus NBPT applied broadcast or BR up to 2 ft tall was similar to the preplant control; however, grain yields were similar to the untreated control at the 3 and 4 ft application timings.

The Portageville site had a high yield environment in 2003 and a medium yield environment in 2004 (Table 5). The preplant and 1 ft tall corn application timings had the greatest corn grain yields at Portageville in 2003 and 2004. Corn grain yield was similar to the preplant control when AN was applied broadcast and UAN was applied BR up to 1 ft tall corn; UAN was applied broadcast, urea plus NBPT applied broadcast or BR up to 2 ft tall corn; and AN was applied BR up to 4 ft tall corn. Corn plant population was reduced in 2004 by birds that reduced overall grain yields and increased variability. The 1 ft tall corn application timing of broadcast and BR UAN or urea plus NBPT had grain yields 32 to 45 bu/a greater than the preplant timing. UAN applied broadcast to 3 and 4 ft tall corn and AN applied BR to 3 ft tall corn had grain yields 69 to 112 bu/a lower than the preplant controls.

## SUMMARY AND RECOMMENDATIONS

Rescue N applications to corn 1 to 4 ft tall with different N sources had grain yields similar or greater than preplant timings depending on the application method and N source. Corn with delayed N applications due to wet conditions may have the same yield potential as a preplant application. Crop response to rescue N applications depended on the N source and whether the source was applied broadcast or BR. Recommendations on rescue N application methods and sources depend on a consistent, high yield response (Table 6). Urea and urea plus NBPT were the least injurious N sources when applied broadcast or BR. Urea or urea plus NBPT broadcast applied from 2 to 4 ft tall corn had corn grain yields similar to the highest yielding N application at that timing 60 to 100% of the sites. A BR application of urea was the most consistent at the 3 and 4 ft tall corn application timings. Urea plus NBPT, AN, and UAN applied BR from 1 to 4 ft tall corn had high grain yields at 60 to 100% of the sites evaluated. AN may be broadcast applied to corn up to 2 ft tall. AN may concentrate in the whorl or on the leaf and cause necrosis of the plant tissue. An early broadcast application of AN provided sufficient time for the corn plant to recover from leaf burn. UAN applied broadcast may be utilized on 1 ft tall corn, but did not provide consistent yields at the 2 ft application timing. Necrosis of corn leaf tissue on plants 3 to 4 ft tall reduced grain yield when compared to other N sources. Based on this research, Figure 1 summarizes the recommended application timing for different N sources and application method.

Table 1. Field information and selected management practices for Novelty, Albany, Portageville, and Columbia in 2003 and 2004.

| | Novelty | | Albany | Portageville | | Columbia | |
|---|---|---|---|---|---|---|---|
| | 2003 | 2004 | 2003 | 2003 | 2004 | 2003 | 2004 |
| Planting Date | 19-May | 9-Apr | 7-May | 2-Apr | 5-Apr | 23-Apr | 26-Apr |
| Hybrid | Pioneer 33P67 | Pioneer 33P67 | DKC60-19 | Cropland 818BT | Dyna-Gro 57P35 | Asgrow RX 7118RR | DK C60-19 |
| Seeding rate (seeds/a) | 29,900 | 29,900 | 28,500 | 30,000 | 30,000 | 29,100 | 30,200 |
| Tillage | No-till | No-till | Minimum | Disk, bed, harrow | Disk, bed, harrow | Field cultivate, mulch | No-till |
| Harvest Date | 22-Oct | 22-Sep | 30-Sep | 15-Sep | 9-Sep | 26-Sep | 23-Sep |

Table 2. Average broadcast and between-row (BR) ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus NBPT injury to corn 7 and 14 days after treatment (DAT) for 1, 2, 3, and 4 ft corn application timings in 2003 and 2004. Data were averaged over all seven site years. All nitrogen sources were applied at 150 lb N/acre. NBPT was applied at 1 qt/ton.

| | 1 ft | | 2 ft | | 3 ft | | 4 ft | |
|---|---|---|---|---|---|---|---|---|
| | 7 DAT | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT | 7 DAT | 14 DAT |
| Untreated | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Between-row (BR) | | | | | | | | |
| AN | 1 | 0 | 2 | 1 | 1 | 0 | 1 | 0 |
| UAN | 2 | 1 | 12 | 3 | 5 | 2 | 4 | 4 |
| Urea | 0 | 0 | 1 | 1 | 2 | 0 | 2 | 0 |
| Urea + NBPT | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 |
| Broadcast | | | | | | | | |
| AN | 15 | 6 | 22 | 12 | 26 | 20 | 14 | 9 |
| UAN | 32 | 16 | 41 | 20 | 53 | 32 | 55 | 44 |
| Urea | 4 | 1 | 8 | 3 | 7 | 2 | 5 | 1 |
| Urea + NBPT | 5 | 1 | 10 | 3 | 8 | 2 | 5 | 2 |

Table 3. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus NBPT applied broadcast and between-row (BR) as preplant and sidedress to 1, 2, 3, and 4 ft corn in low (Columbia and Albany, 2003) and medium (Novelty, 2003) yield environments.

| | Columbia and Albany, 2003 | | | | | Novelty, 2003 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
| Treatment | Yield (bu/a) | | | | | | | | | |
| Untreated | 70 | | | | | 58 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 86 | 82 | 76 | 78 | 86 | 115 | 122 | 112 | 113 | 110 |
| UAN | 81 | 74 | 79 | 67 | 47 | 108 | 114 | 110 | 106 | 90 |
| Urea | 81 | 81 | 84 | 75 | 77 | 105 | 115 | 118 | 128 | 125 |
| Urea + NBPT | 87 | 81 | 87 | 79 | 80 | 111 | 116 | 126 | 120 | 120 |
| Between-row (BR) | | | | | | | | | | |
| AN | 80 | 85 | 83 | 91 | 86 | 110 | 112 | 118 | 126 | 125 |
| UAN | 86 | 84 | 77 | 80 | 80 | 105 | 114 | 118 | 124 | 125 |
| Urea | — | — | 90 | — | 69 | — | — | 110 | — | 120 |
| Urea + NBPT | — | 80 | 80 | — | 83 | — | 118 | 121 | — | 120 |
| LSD ($p \leq 0.05$) | 17 | | | | | 15 | | | | |

Table 4. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus NBPT applied broadcast and between-row (BR) as preplant and sidedress to 1, 2, 3, and 4 ft corn in high (Columbia and Novelty, 2004) yield environments.

| | Columbia, 2004 | | | | | Novelty, 2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
| Treatment | Yield (bu/a) | | | | | | | | | |
| Untreated | 106 | | | | | 86 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 236 | 239 | 209 | 182 | 174 | 226 | 240 | 243 | 219 | 225 |
| UAN | 205 | 214 | 155 | 106 | 80 | 185 | 175 | 207 | 175 | 130 |
| Urea | 217 | 240 | 210 | 209 | 195 | 164 | 204 | 238 | 84 | 99 |
| Urea + NBPT | 225 | 251 | 227 | 211 | 188 | 214 | 210 | 243 | 83 | 96 |
| Between-row (BR) | | | | | | | | | | |
| AN | 217 | 237 | 226 | 193 | 202 | 218 | 227 | 252 | 254 | 237 |
| UAN | 217 | 217 | 209 | 192 | 203 | 198 | 201 | 250 | 227 | 206 |
| Urea | — | — | 194 | — | 196 | — | — | 245 | — | 99 |
| Urea + NBPT | — | 235 | 227 | — | 197 | — | 200 | 247 | — | 96 |
| LSD ($p \leq 0.05$) | 21 | | | | | 27 | | | | |

Table 5. Corn grain yield and gross margin as affected by ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus NBPT applied broadcast and between-row (BR) as preplant and sidedress to 1, 2, 3, and 4 ft corn in high (Portageville, 2003) and medium (Portageville, 2004) yield environments.

| | Portageville, 2003 | | | | | Portageville, 2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Preplant | 1 ft | 2 ft | 3 ft | 4 ft | Preplant | 1 ft | 2 ft | 3 ft | 4 ft |
| Treatment | Yield (bu/a) | | | | | | | | | |
| Untreated | 102 | | | | | 88 | | | | |
| Broadcast | | | | | | | | | | |
| AN | 177 | 178 | 136 | 84 | 93 | 113 | 107 | 108 | 96 | 100 |
| UAN | 162 | 181 | 130 | 114 | 56 | 88 | 120 | 113 | 55 | 50 |
| Urea | 208 | 155 | 160 | 159 | 134 | 120 | 117 | 125 | 114 | 99 |
| Urea + NBPT | 187 | 154 | 171 | 117 | 140 | 100 | 137 | 113 | 111 | 95 |
| Between-row (BR) | | | | | | | | | | |
| AN | 170 | 202 | 141 | 143 | 152 | 139 | 112 | 115 | 101 | 112 |
| UAN | 181 | 176 | 141 | 121 | 128 | 100 | 140 | 96 | 125 | 106 |
| Urea | — | 143 | 155 | 146 | 128 | — | 125 | 95 | 114 | 100 |
| Urea + NBPT | — | 178 | 175 | 141 | 117 | — | 145 | 108 | 112 | 114 |
| LSD ($p \leq 0.05$) | 33 | | | | | 29 | | | | |

Table 6. Rescue N application recommendations for ammonium nitrate (AN), urea ammonium nitrate (UAN), urea, and urea plus NBPT applied broadcast and between-row (BR) to 1, 2, 3, and 4 ft corn. Number of sites with grain yields similar to the highest yielding treatment at the specified application timing[a].

| | Corn height at application | | | |
|---|---|---|---|---|
| N application method and source | 1 ft | 2 ft | 3 ft | 4 ft |
| Broadcast | | | | |
| AN | 4 of 5 | 4 of 5 | 1 of 5 | 2 of 5 |
| UAN | 3 of 5 | 1 of 5 | NR[b] | NR[b] |
| Urea | 2 of 5 | 5 of 5 | 4 of 5 | 4 of 5 |
| Urea + NBPT | 2 of 5 | 5 of 5 | 3 of 5 | 4 of 5 |
| Between-row (BR) | | | | |
| AN | 4 of 5 | 4 of 5 | 5 of 5 | 5 of 5 |
| UAN | 3 of 5 | 3 of 5 | 3 of 5 | 4 of 5 |
| Urea | 1 of 2[c] | 2 of 5 | 2 of 2[c] | 4 of 5 |
| Urea + NBPT | 4 of 5 | 5 of 5 | 2 of 2[c] | 3 of 5 |

[a]Site-years with grain yields similar to the highest yielding rescue N application treatment at Novelty in 2003 and Portageville in 2004 (medium yield environments), and Portageville in 2003, Columbia in 2004, and Novelty in 2004 (high yield environments).
[b]NR, not recommended.
[c]Portageville only.

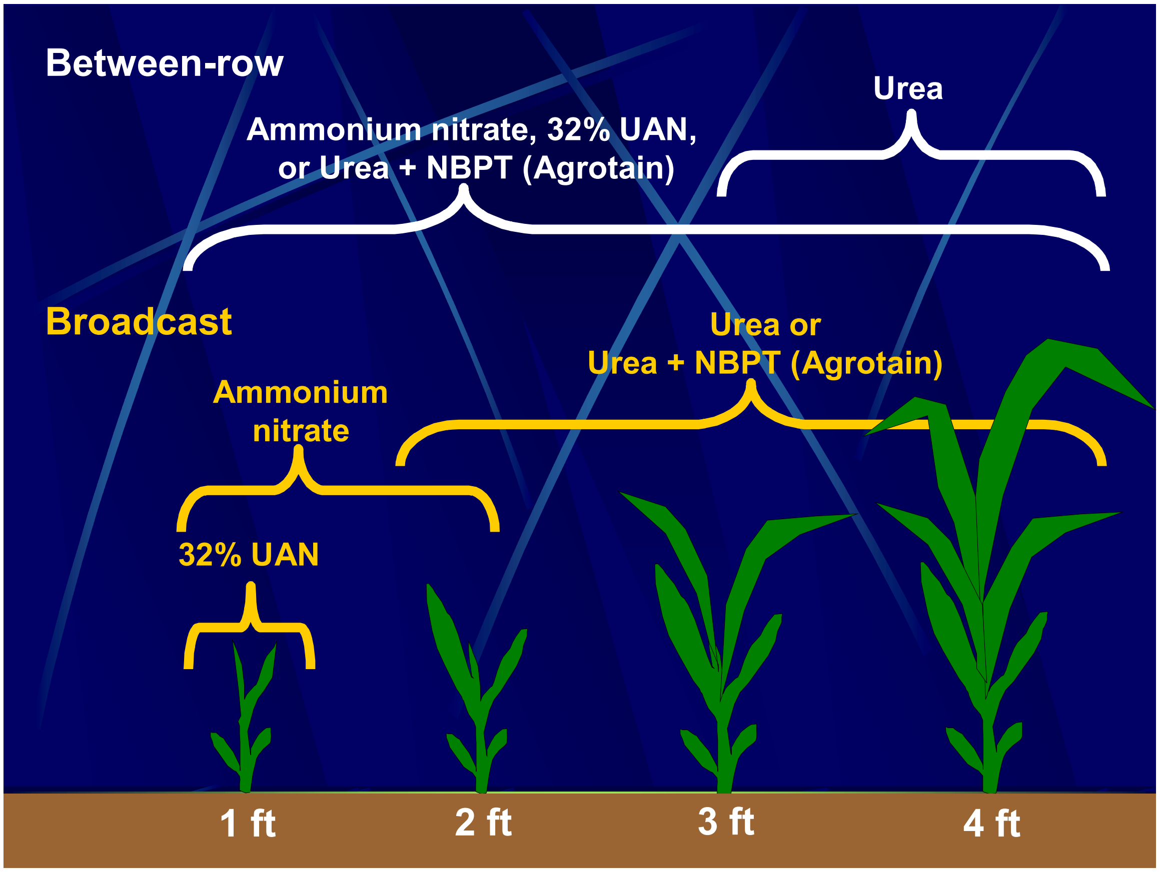


Figure 1. Rescue N application recommendations for N sources applied to 1 to 4 ft tall corn between the row or broacast.

# Making Urea Work in No-till

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**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 2004:**

- Two experiments were conducted in 2004 on Bradford Research Farm near Columbia–one in corn and another in wheat.
- Treatments were nitrogen fertilizer sources and placement.
  - All treatments were applied at rates of 140 lb N/ac for corn, 80 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 corn:**

- Average corn yield (excluding the unfertilized check treatment) was 144 bu/acre, which is higher than average for Missouri but near the state average for the outstanding production conditions that we had in 2004. Regular rainfall and cool nights contributed to what is projected to be a state record harvest and average yield, if the harvest can be completed.
  - This experiment was conducted on land that was newly acquired by the Bradford Research Center in February 2004.
  - We observed slow growth, purpling, and stress appearance during the early growing season. When we inquired into possible reasons, we discovered that this land had received a fall application of Canopy XL prior to its acquisition for the research farm. This stress probably limited yields in this experiment.

**Table 1. Corn yields in 2004 for different N fertilizer sources & placements.**

| Fertilizer treatment | Yield |
|---|---|
| Anhydrous ammonia (knife) | 162 |
| Ammonium nitrate (broadcast) | 162 |
| Ammonium nitrate (knife) | 161 |
| Urea + Agrotain (broadcast) | 149 |
| Urea (broadcast + till) | 146 |
| SuperU (broadcast) | 144 |
| Urea (broadcast) | 143 |
| Gel-coated urea (broadcast) | 142 |
| UAN solution (knife) | 142 |
| Polymer-coated urea (broadcast) | 140 |
| Urea (knife) | 138 |
| UAN solution + Agrotain (broadcast) | 135 |
| UAN solution + Agrotain + DCD (broadcast) | 127 |
| UAN solution (broadcast) | 122 |
| Unfertilized check | 61 |

**Least Significant Difference (95% confidence) between yields = 16 bu/acre**

- Anhydrous ammonia and both ammonium nitrate treatments had the highest average yields in the experiment (Table 1). Yields for these treatments were significantly higher (95% confidence) than for broadcast urea, and yield response to N was about 100 bu/acre relative to the unfertilized check.
- None of the six management strategies designed to improve urea performance yielded significantly better than broadcast urea, and the average of the six was exactly the same as the yield with broadcast urea. This is not too surprising, since a 0.8 inch rain fell within 36 hours of treatment application, and 1.4 inches within 4 days. This rainfall would have been expected to move the urea into the soil and eliminate the ammonia volatilization losses that this project is intended to solve. If there was no ammonia volatilization, treatments to eliminate volatilization would not be expected to be effective.

- What was surprising is that all of the urea-based treatments, as a group, yielded less than the ammonium nitrate and anhydrous ammonia treatments. This is a difficult result to explain. One possibility is that the urea was actually washed too deep into the soil. Fred Blackmer at Iowa State University has told me that he has observed poor performance in fields that have received urea applications followed shortly by heavy rains. Normally we want rain in this situation, in order to transport the urea into the soil. But urea is uncharged and can move through the soil as fast as the water. Once the urea breaks down to ammonium, the charge on the ammonium is attracted to opposite charges on soil particles and movement is limited.
- However, this explanation would not seem to apply to the coated urea products and so it's doubtful that this is the real reason.
- Two of the UAN solution treatments (broadcast UAN, and UAN + Agrotain + DCD) yielded significantly less than the broadcast urea treatment. This means that N availability was lower in these treatments. The experiments were conducted in a field that had been no-till cropped for at least four years, mainly to soybean. The most likely explanation is that some of the N in the solution got tied up on the residue when UAN was broadcast. UAN solution is more susceptible to tie-up on residue than other forms of fertilizer because of the even distribution of small droplets that can adhere to the residue. When this happens, we would expect that knife placement would solve the problem, and it did. Knifed UAN solution yielded significantly higher than broadcast UAN solution.
- Yields were not statistically increased by any of the treatments for improving urea performance in no-till, however, average yields were higher than broadcast urea for several of these treatments. These yield increases may be real, or may be a by-product of unavoidable variability in the experiment. Even if they are real, the only treatment that was economically favorable was the Agrotain treatment, which yielded 6 bu/acre more than broadcast urea. At a corn price of $2.00/bu, this would amount to $12/acre, while the cost of Agrotain is about $8/acre, leaving a small net gain of $4/acre.

**Results for wheat:**

- Wheat yields were low, averaging about 37 bu/acre. The reason for this is not known. Planting was timely, and the crop looked good and was well-tillered in early March. Fertility status was good. No disease or insect problems were observed. There were problems with grass weeds in some plots, and ratings of grass infestation were taken. Statistical analysis confirmed that grass weeds reduced yields in plots where they were seen, but even in plots with no weeds, yields were low. Spring growth was just not vigorous, and the canopy looked thin even after head emergence.

**Table 2. Wheat yields in 2004 for different broadcast spring N fertilizer sources.**

| Fertilizer treatment | Yield |
|---|---|
| Urea + Agrotain + DCD | 41 |
| Ammonium nitrate | 40 |
| Urea + Agrotain | 40 |
| Urea | 39 |
| Gel coated urea | 36 |
| UAN solution + Agrotain | 34 |
| UAN solution | 34 |
| Polymer coated urea | 32 |
| UAN solution + Agrotain + DCD | 32 |
| Unfertilized check | 22 |

**Least Significant Difference (95% confidence) between yields = 5 bu/acre**

- No fertilizer treatment produced yields significantly higher than broadcast urea. Although conditions were favorable for volatilization losses of N (fairly warm and no rain for ten days after treatment application), the low yields meant that there was not much pressure on the fertilizer treatments to supply N. The largest yield response to N, relative to the unfertilized check, was 19 bu/acre. This amount of grain would be expected to contain about 20 lb N/acre. Since 80 lb N/acre was applied with each treatment, even with low efficiency it seems that N should not limit yield.
- Even so, some treatments produced yields lower than those produced by broadcast urea. These included:
  - All UAN solution treatments
  - Polymer-coated urea
    - Treatments were applied shortly before jointing, which may not have allowed enough time for urea to diffuse through the polymer coating.

**Summary**

- In the first year of this study, none of the treatments that were designed to avoid volatilization losses from urea improved yields in either corn or wheat.
- Chances for urea treatments to increase yield were limited by rain shortly after treatment application in the corn experiment, and by low yields in the wheat experiment.
- Several broadcast UAN solution treatments gave lower yields than broadcast urea in both corn and wheat. This was probably due to N tie-up on residue.

**Objectives for year 2:**

- Objectives for year 2 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.
- Treatments will be added to the wheat experiment to give the coated urea products a better chance by adding earlier application times. One advantage of these products is that they may be fairly safe for use in late-winter (January & February) topdressing, which can be risky with other N sources because of the extended time before uptake will occur.

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

Peter Motavalli, Kelly Nelson, Steve Anderson and John Sadler

Accomplishments for First Year:

Research was initiated in 2004 to examine the agronomic performance and cost-effectiveness of polymer-coated urea compared to conventional N fertilizer sources under different soil moisture and drainage conditions and to assess environmental N losses under these conditions. 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) 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. $N_2O$ 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.

Rainfall during the 2004 cropping year was above average in the spring and consistent throughout the summer (Fig. 1). Due to timely rainfall, corn grain yields were above average and corn yield response to added N fertilizer averaged approximately 94 bu/acre higher than the check plots receiving no N fertilizer (Fig. 2). In addition, the plots 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 were primarily observed in the plots with no drainage or supplemental irrigation and ranged from an average of 14 to 20 bu/acre (Fig. 2).

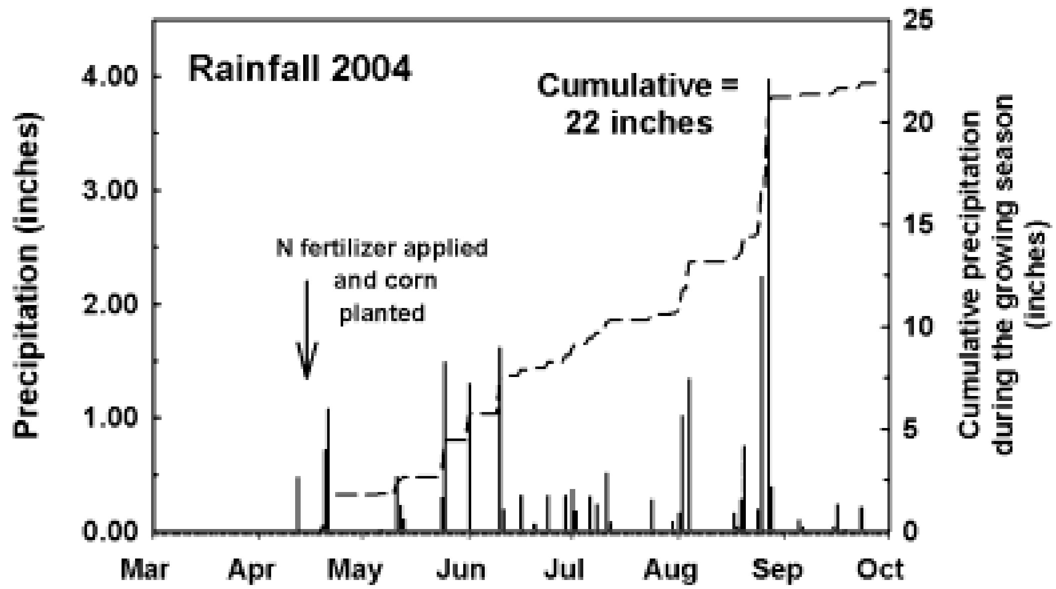



Fig. 1. Daily and cumulative rainfall at the Ross Jones Farm during the 2004 cropping season.

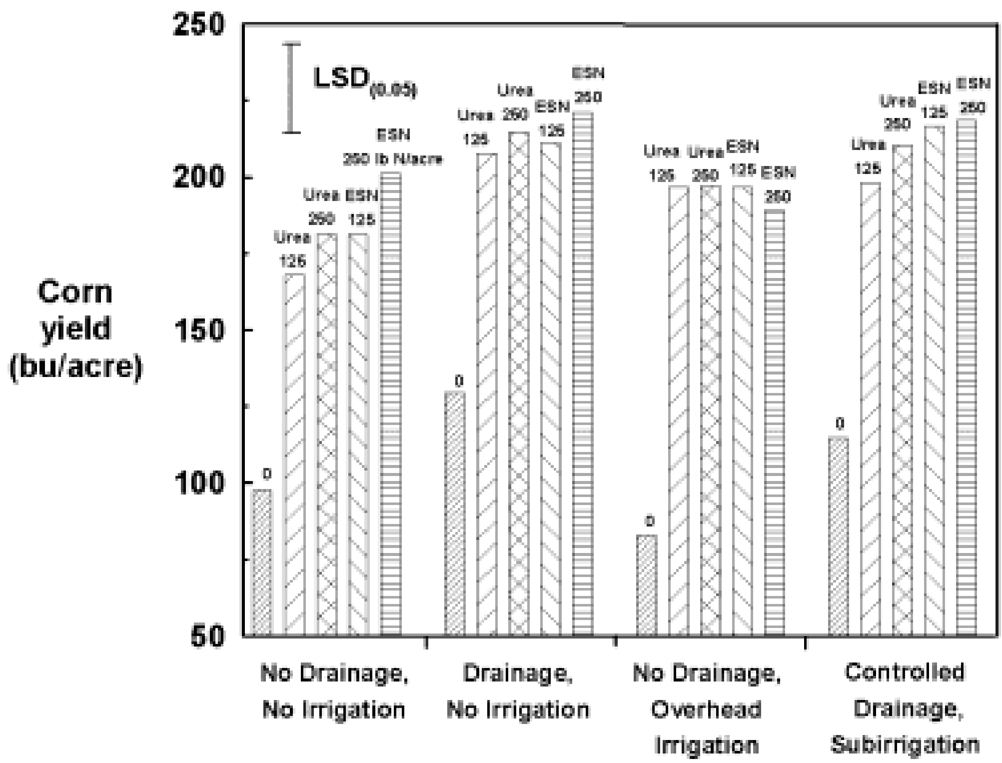



Fig. 2. Corn grain yield response in 2004 to applications of conventional and polymer-coated urea (ESN) under different drainage and irrigation treatments.

Nitrate-N levels contained in suction lysimeter water samples 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. 3). 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).

Table 1 shows gaseous $N_2O$ loss or flux resulting from the different drainage/irrigation and N fertilizer treatments at 3 of the 11 dates sampled during the growing season. 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. Gas measuring chambers were placed between tile drainage lines to avoid differences in soil water content over and between the tile lines within each plot. Due to the high variation in the measured flux, few statistical differences were observed although the polymer-coated ESN N source tended to reduce $N_2O$ flux in the no drainage/overhead irrigation treatment 5 and 63 days after N application.

Table 1. Nitrous oxide gas flux over the growing season resulting from applications of conventional and polymer-coated urea under different drainage and irrigation treatments.

| Drainage/ | N | Days after N application | | |
|---|---|---|---|---|
| **Irrigation** | **fertilizer** | **5** | **63** | **168** |
| | **lb N/acre** | **----------------- g $N_2O$-N/ha/day ------------------------** | | |
| **No drainage/** | **Check** | **7.2** | **10.1** | **2.7** |
| **No irrigation** | **250 Urea** | **21.5** | **29.3** | **12.3** |
| | **250 ESN** | **19.6** | **61.4** | **7.5** |
| **Drainage/** | **Check** | **10.6** | **49.7** | **7.2** |
| **No irrigation** | **250 Urea** | **19.0** | **50.1** | **10.2** |
| | **250 ESN** | **5.0** | **20.6** | **11.5** |
| **No drainage/** | **Check** | **36.1** | **60.1** | **13.2** |
| **Overhead** | **250 Urea** | **49.2** | **573.6** | **71.3** |
| **irrigation** | **250 ESN** | **10.0** | **199.7** | **95.6** |
| **Drainage/** | **Check** | **32.0** | **29.7** | **3.9** |
| **Subirrigation** | **250 Urea** | **31.7** | **31.7** | **4.6** |
| | **250 ESN** | **36.6** | **62.2** | **23.7** |
| | **DMRT $_{(0.05)}$** | **30.4** | **NS** | **92.8** |

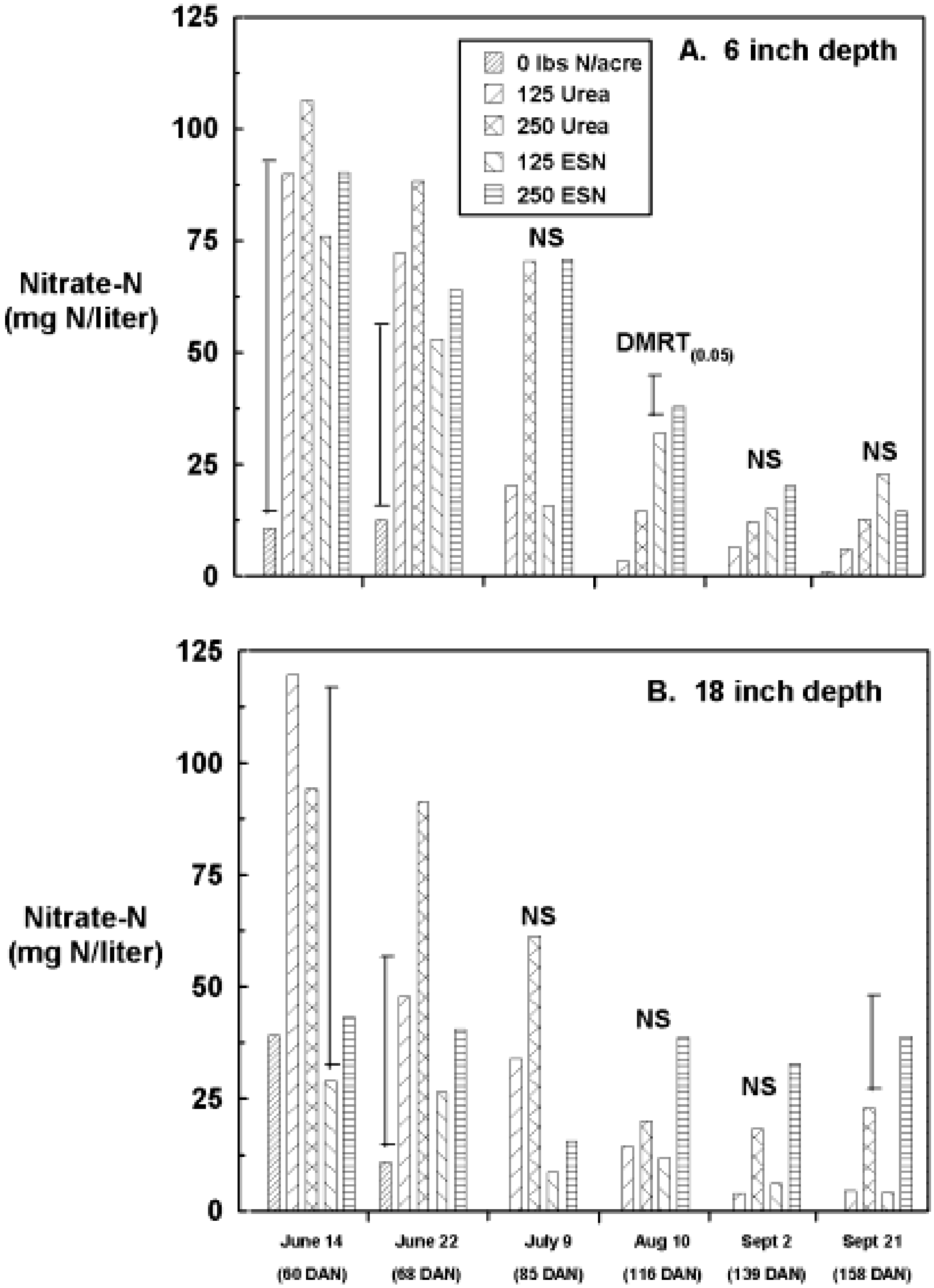



Fig. 3. Nitrate-N contained in water samples collected from suction lysimeters installed at A) the 6 inch depth and B) the 18 inch depth in plots receiving different rates of conventional or polymer-coated urea (ESN). The values are averaged over the drainage/irrigation treatments. DAN = days after N fertilizer applied.

**Two graduate students (one M.S. and one Ph.D. student) are receiving their training working on this project for their thesis research in soil science. The research results were also presented to growers and agricultural professionals at the 2004 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 the effects of spatial and climatic variation in soil water content and soil drainage on crop response and soil N loss from N fertilizer applications.
2. To examine the use of slow release N fertilizer to reduce N loss under different soil moisture conditions.
3. To evaluate the cost-effectiveness of applying slow release fertilizer compared to pre-plant applications of conventional urea fertilizer.

The field study will be repeated for a second year to assess variation in climate on crop performance and N use efficiency in response to the drainage/irrigation and N fertilizer treatments. In addition, the Ph.D. student is working on using the data from the first year results to validate computer simulation models which may assist in predicting the fate of applied N fertilizer under different soil moisture conditions. A laboratory experiment will also be conducted by the M.S. student to examine the effects of differences in soil water content on denitrification losses from applied urea and polymer-coated urea. An economic analysis will be determined using the results from the field study at the end of the second year of research to compare the cost-effectiveness of the two N fertilizer sources over the two years of the study.

# Evaluating Fall N Applications for Corn

Peter Scharf and Larry Mueller
Agronomy Department, University of Missouri

**Objectives:**

The objective of this study is to evaluate fall N applications in production cornfields over several weather years. This includes:

a. Tracking how much fall-applied N is lost from production cornfields.
b. Determining how much yield potential is lost.
c. Determining the economics of additional spring N applications.

**Accomplishments for 2004:**

- Seventeen experiments were established in production cornfields that had received N applications in fall/winter 2003 (Figure 1 and Table 1). Most of these experiments were in west-central Missouri, near the Missouri River, and in the claypan region of northeast Missouri. Fall 2003 applications of $NH_3$ in Missouri were down from the previous two years, but were still higher than any year before 2001 (Figure 2), and these regions were among the highest in the state. Two experiments were established in Vernon County because it is a higher-risk area for loss of fall-applied N, though less fall N is applied in that area. $NH_3$ was applied after November 1 in all experimental fields (Table 2). Eight of the seventeen fields had N-Serve added to the $NH_3$ (Table 2).

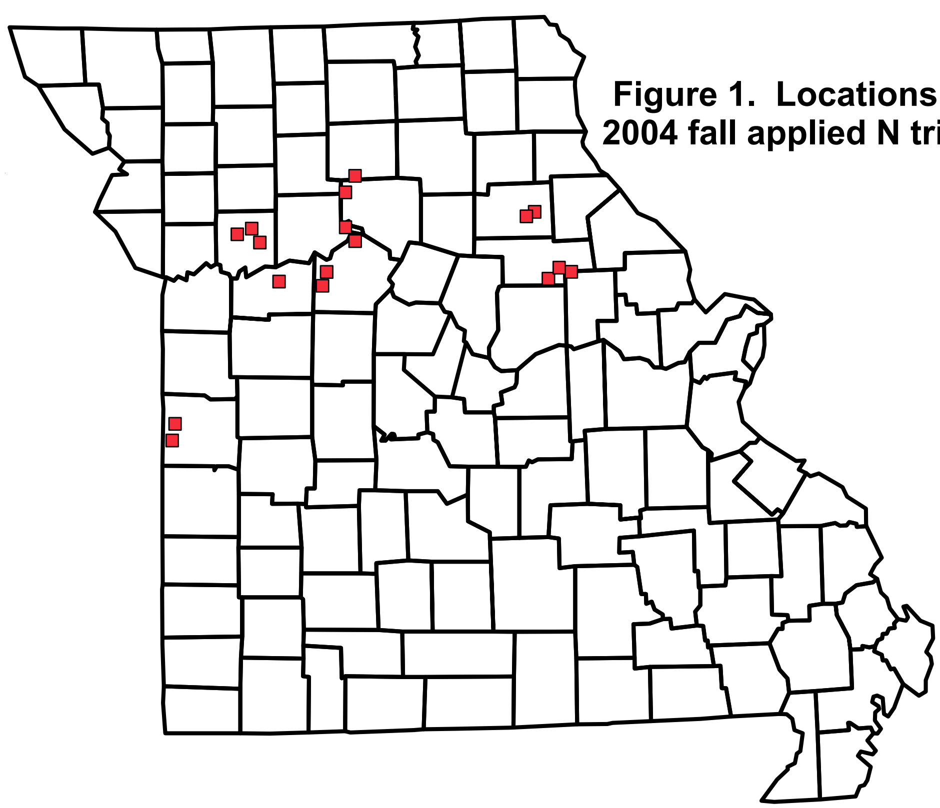


**Figure 1. Locations for 2004 fall applied N trials.**

**Table 1. 2004 LOCATIONS FOR FALL APPLIED NITROGEN TRIALS.**

| COUNTY | LOCATION | SOIL SERIES | HYBRID |
|---|---|---|---|
| Vernon | Deerfield | Barden Silt Loam | Pioneer 34P14 |
| Vernon | Hong | Parsons Silt Loam | NC+5411P |
| Linn | Brookfield | Lagonda Silt Loam | ?RR |
| Chariton | Minden | Grundy Silt Loam | Asgrow RX 752 YG |
| Carroll | DeWitt | Gilliam Silty Clay | Dekalb DKC 63-50 |
| Saline | Miami | Leslie Silt Loam | Mycogen 2A775 |
| Saline | Elmwood | Higginsville Silt Loam | Asgrow RX 752 RR YG |
| Saline | Blackburn | Sibley Silt Loam | Asgrow RX 752 RR YG |
| Lafayette | Higginsville | Marshall Silt Loam | Pioneer 32A85 [A] |
| Ray | Dockery | Grundy Silt Loam | Stone E33D |
| Ray | Morton 1 | Sibley Silt Loam | Pioneer 33P67 [B] |
| Ray | Morton 2 | Sibley Silt Loam | NC+4880 |
| Monroe | Paris 1 | Putnam Silt Loam | Golden Harvest 9461 |
| Monroe | Paris 2 | Putnam Silt Loam | Golden Harvest 9229 |
| Audrain [C] | Martinsburg 1 | Putnam Silt Loam | Na |
| Audrain | Martinsburg 2 | Putnam Silt Loam | Na |
| Audrain | Martinsburg 3 | Mexico Silt Loam | Na |

[A] White corn
[B] 6 Rows Pioneer 33P67 & 2 rows Pioneer 33D31
[C] Irrigated Site

# Table 2. Fall N applications and spring N samples for 2004 experiments

| COUNTY | LOCATION | NITROGEN APPLIED SOURCE [A] | N RATE LBS/AC | DATE [B] | N SERVE | SOIL SAMPLE DATE | $NH_4$ AMMONIUM 0-36" LBS/AC | $NO_3$ NITRATE 0-36" LBS/AC | TOTAL N 0-36' LBS/AC |
|---|---|---|---|---|---|---|---|---|---|
| Vernon | Deerfield | $NH_3$ | 150 | 12/5/2003 | YES | 2/26/2004 | 54 | 90 | 144 |
| | | w/starter | 27 | Planting | - | 6/1/2004 | 26 | 219 | 245 |
| Vernon | Hong | $NH_3$ $NO_3$ | 102 | 11/15/03 | YES | 2/26/2004 | 43 | 118 | 161 |
| | | DAP | 24 | Na | - | 6/1/2004 | 18 | 211 | 229 |
| Linn | Brookfield | $NH_3$ $NO_3$ | 185 | 11/15/2003 | YES | 3/19/2004 | 103 | 82 | 185 |
| | | - | - | - | - | 6/8/2004 | 35 | 259 | 294 |
| Charition | Minden | $NH_3$ | 185 | 11/15/2003 | YES | 3/18//2004 | 44 | 95 | 139 |
| | | - | - | - | - | 6/8/2004 | 8 | 210 | 218 |
| Carroll | DeWitt | $NH_3$ | 200 | 11/15/2003 | YES | 3/19/2004 | 26 | 95 | 121 |
| | | UAN/UAN | 40/100 | PP/SD | - | 6/4/2004 | 95 | 400 | 495 |
| Saline | Miami | $NH_3$ | 185 | 12/05/2003 | YES | 3/18/2004 | 46 | 74 | 120 |
| | | w/starter | 26 | Planting | - | 6/4/2004 | 59 | 268 | 327 |
| Saline | Elmwood | $NH_3$ | 180 | 11/15/2003 | NO | 3/18/2004 | 35 | 71 | 106 |
| | | w/herbicide | 20 | Spring | - | 6/4/2004 | 15 | 186 | 201 |
| Saline | Blackburn | $NH_3$ | 180 | 11/30/2003 | NO | 3/18/2004 | 78 | 72 | 150 |
| | | w/herbicide | 20 | Spring | - | 6/4/2004 | 20 | 344 | 364 |
| Lafayette | Higginsville | $NH_3$ | 160 | 11/10/2003 | YES | 3/126/2004 | 60 | 80 | 140 |
| | | UREA | 20 | Fall | - | 6/1/2004 | 33 | 225 | 2 |
| Ray | Dockery | $NH_3$ | 135 | 11/15/2003 | NO | 3/11/2004 | 86 | 85 | 171 |
| | | AN/Starter | 10/10 | Fall/Planting | - | 6/2/2004 | 15 | 259 | 274 |
| Ray | Morton1 | $NH_3$ | 165 | 11/03/2003 | NO | 3/11/2004 | 50 | 57 | 107 |
| | | DAP | 30 | Fall | - | 6/2/2004 | 11 | 132 | 143 |
| Ray | Morton 2 | $NH_3$ | 195 | 11/5/2003 | NO | 3/11/2004 | 61 | 124 | 185 |
| | | DAP | 23 | Na | - | 6/2/2004 | 5 | 113 | 118 |
| Monroe | Paris 1 | $NH_3$ | 135 | 11/30/2003 | NO | 3/21/2004 | 64 | 91 | 155 |
| | | AN | 13 | Na | - | 6/8/2004 | 4 | 195 | 199 |
| Monroe | Paris 2 | $NH_3$ | 135 | 11/30/2004 | NO | 3/21/2004 | 141 | 126 | 266 |
| | | AN | 17 | Na | - | 6/8/2004 | 11 | 268 | 279 |
| Audrain | Martinsburg 1 [C] | $NH_3$ | 180 | 11/5/2003 | YES | 3/19/2004 | 19 | 173 | 192 |
| | | DAP/Urea | 25/40 | Fall/SD | - | 6/16/2004 | 13 | 262 | 275 |
| Audrain | Martinsburg 2 | $NH_3$ | 150 | 11/5/2003 | NO | 3/21/2004 | 90 | 164 | 254 |
| | | DAP/Urea | 30/40 | Fall/SD | | 6/16/20045 | 11 | 185 | 196 |
| Audrain | Martinsburg 3 | $NH_3$ | 160 | 11/5/2003 | NO | 3/19/2004 | 54 | 90 | 144 |
| | | DAP/$NH_3$ | 36/50 | Fall/SD | - | 6/16/2004 | 55 | 217 | 272 |

[A] $NH_3$ - Annhydrous Ammonia, AN - Ammonium Nitrate, UAN-Liquid N
[B] When application dates were given as ranges the midpoint was used, PP-Preplant, SD-Side Dressed
[C] Irrigated Site

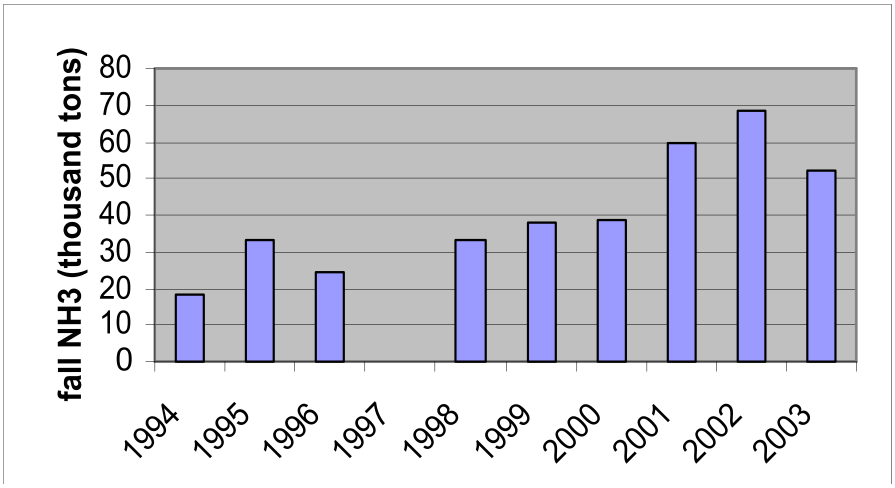



Figure 2. More fall N was applied in Missouri during each of the three years of this study than during any of the seven previous years. Increasing farm size has pressured corn producers to apply N in the fall, leaving more spring work days available for planting and other spring operations.

**Results:**

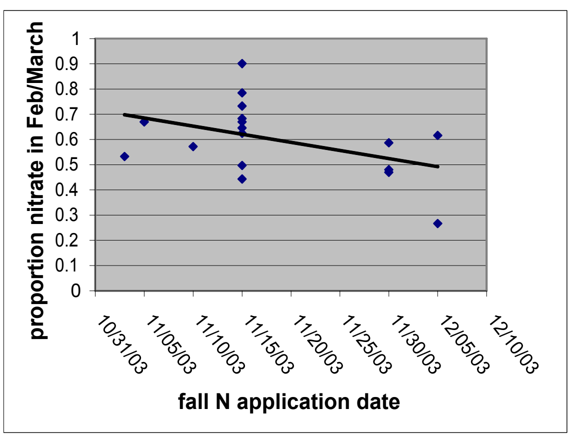
**Soil sample results**

Soil samples were taken in all experiments to a three foot depth in February or March and again in June. These samples were analyzed for nitrate and ammonium (Table 2).

- Many fields had results in March that seemed to show a moderate level of N loss between application and the March sampling. However, the values for many fields went up dramatically for the samples taken in June. We normally expect soil organic matter to release N during the March to June period, but not as much as was observed at many of these locations. Four of the producers applied sidedress N to these fields, which is responsible for the increased soil N levels in those fields, but still some of the values for June seem too high to be true. Thus we are cautious about trusting the numbers reported in Table 2 too much until they have been double-checked. We have stored these soil samples in the freezer, and several months ago submitted some of them again to see whether the results come back the same, but are still waiting on those results.
- Precipitation for northern Missouri was near normal for November to March, and much higher than the previous two winters. Little loss of fertilizer N was seen in the previous two years of the study, but with the added precipitation it seems possible that some N may have been lost during the winter, as indicated by the results from the samples taken in March.
- More than half of the N found in the March samples was in the nitrate form for 13 of the 17 fields studied. This indicates that most of the fall-applied ammonia had been converted to nitrate by this time, which is the form of N most susceptible to loss.
- The amount of N in the nitrate form was related to the date of N application (Figure 3). Producers applied N between November 1 and December 5. On average, for N applied around November 1, 70% had been converted to

the nitrate form by March, but only 50% had been converted for applications in

- N-Serve did not statistically affect the amount of N found in the nitrate form in March, but fields with N-Serve had an average of 46% of N as nitrate, while fields without had an average of 58% of N as nitrate.
- N-Serve did statistically affect the amount of N found in the nitrate form in June: fields with N-Serve had an average of 90% of N as nitrate, while fields without N-Serve had an average of 95% of the N as nitrate. This is a small difference that does not make much difference from a practical standpoint, but it suggests that the slightly larger difference seen in March is also real.
- Apparent N loss in March was statistically higher for fields with more N in the nitrate form, and for fields that received higher N rates.




early December (based on line in Figure 3).

- Apparent N loss in March was statistically higher for fields in the deep loess and loess and drift soil regions, and lower for fields in the claypan and southwest/Osage plain regions. This is probably related to the slow permeability and low leaching potential of soils in the claypan and Osage plain regions.

Figure 3. The proportion of anhydrous ammonia that had converted to nitrate by the time of our February/March soil samples was lower for later-applied N. A lower proportion of nitrate means less risk of loss.

**Yield response to supplemental spring N**

Average yield for these 17 experiments was 214 bu/acre. Yield levels were the highest ever seen for corn in Missouri. Frequent rain and relatively cool night temperatures created ideal conditions for corn growth.

When fall-applied N is lost, N availability can limit yields. In this case, there is potential for yield response to supplemental spring N. We applied either 0, 50, or 100 lb N/acre to small plots in the experimental fields when the corn was 12 to 18 inches tall. In each field, six plots received no spring N, six received the 50 lb N/acre rate, and three received the 100 lb N/acre rate. Also, three additional plots received zinc fertilizer to test for the possibility of yield response to zinc. These small-plot experiments were hand-harvested before the cooperating producers harvested the surrounding field.

In four of the fields, producers sidedressed N due to concerns that N might have been lost. In these fields, N availability would not be expected to limit yield, and these fields were omitted when calculating average yield response to our N additions.

Average yield response

- On average, there was a 8 bu/acre yield response to additional spring-applied N (with 99% confidence). This suggests that some of the fall-applied N may have been lost, as was also suggested by the February/March soil samples.
    - The cost of applying 50 lb of N is about the same as the cost of 8 bu of corn, so sidedressing 50 lb on the 15 fields that were not sidedressed by the cooperating producers would have been about a break-even proposition.
    - The 8 bu/acre of lost yield potential can be used in making economic comparisons to spring N management options, many of which would not have resulted in this loss of yield potential. This year, the average cost of the convenience of fall N application was 8 bu/acre.

Statistics of yield response for individual fields

- Statistical analysis indicated that there were five locations with a high (> 80%) probability that yield responded to additional N (Table 3).
    - At three of these five locations, yield response to both the 50 and 100 lb N rates was statistically significant.
    - At the other two locations, only the yield response to the 100 lb N rate was statistically significant, but the yield with the 50 lb N rate was intermediate, and regression analysis was statistically significant, indicating a true yield response for both the 50 and 100 lb N rates.
    - Many other locations had higher average yields with additional N than without, but statistical confidence that these were real was below 80%.

Yield response to additional N was related to check yield with no additional N.

- For fields with yields above 220 bu/acre without additional N, no response to the N that we applied was seen.
- For fields with yields less than 220 bu/acre in our check plots, average yield response to additional N was 10 bu/acre, bringing average yield in these fields to 218 bu/acre.
- I find it more helpful to think of it this way: many fields had 220 bu yield potential in this exceptional year, but some fields fell a little short of achieving this potential due to slight N limitations, which we could overcome by adding more N to get them to the 220 bu level.

Yield response to additional N was highest in fields where N was applied earliest

- The two largest yield responses to additional N were seen on the two fields that had received the earliest N applications in the fall out of the 17 fields (Figure 4).
- Applications in these two fields were made on November 3 and November 5, 2003.
- These two fields were only slightly above average in fertilizer conversion to nitrate by March (Figure 3), however they were sampled about a week before most other fields. Additional conversion to nitrate would have occurred during that week.

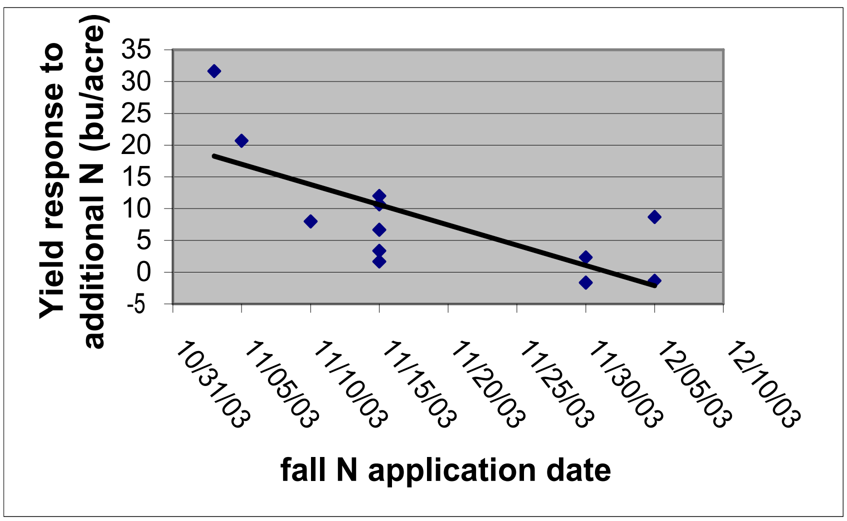



Figure 4. Yield response to additional N was greatest in the two fields which had received the earliest fall N applications. Anhydrous ammonia was applied the first week of November in these two fields. The last fields had N applied in the first week of December.

Both fields were on well-drained soils in Ray County, and had received fall N earlier than any other fields.

- Heavy May-June rains, especially in northwest Missouri, may have contributed to the low soil nitrate levels seen in the top foot of soil in these fields (Figure 6).

Low soil nitrate in June predicted yield response to additional N

- Soil nitrate to a 12 inch depth, sampled in June, was the best predictor of yield response to N among the soil N measurements that we made (Figure 5). This was mainly due to two fields which had the lowest soil nitrate values and also had the largest yield responses to additional N.

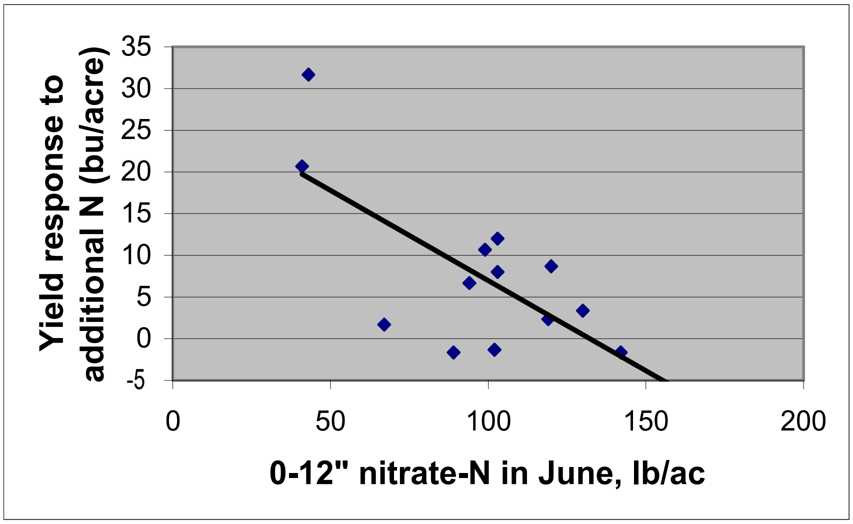



Figure 5. Among all soil N measurements that we made, soil nitrate to a 12" depth in June was the best predictor of yield response to N. This was because the two fields that got the earliest N applications (Figure 4) had the lowest nitrate levels by June, and the largest yield response to additional N.

<u>Geographical location was related to yield response to additional N</u>

- Fields with apparent yield response to N of 5 bu/acre or more were mainly concentrated in western Missouri (Figure 6), especially northwestern Missouri. This is probably related to rainfall patterns, which were heavier in northwestern Missouri in May and in southwestern Missouri in March.
- Areas with heavier rainfall probably had greater leaching losses of nitrate-N.
- Numerous fields with patches or streaks of N deficiency were seen in northwest Missouri in 2004 in an aerial survey (Figure 7).

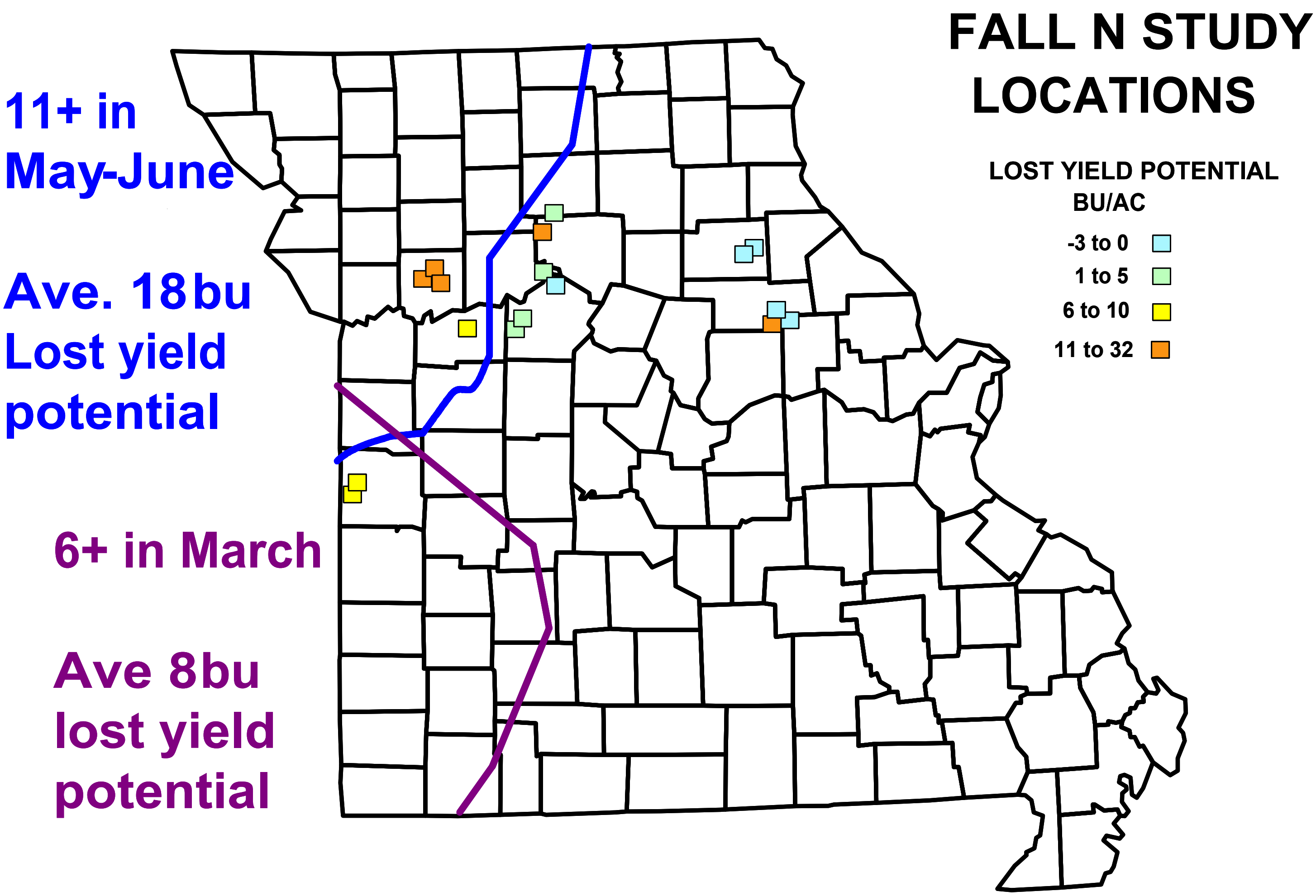



Figure 6. Spring precipitation was heaviest in western Missouri, and the largest yield responses to our N applications were also seen there. Northwest of the blue line, more than 11 inches of rain fell during May and June, mainly in May. This was also the geographical area where the largest yield response to additional N was seen, with an average of 18 bu/acre. The two fields south of Kansas City lost an average of 8 bu/acre of yield potential, likely due to heavy rains in this area in March.

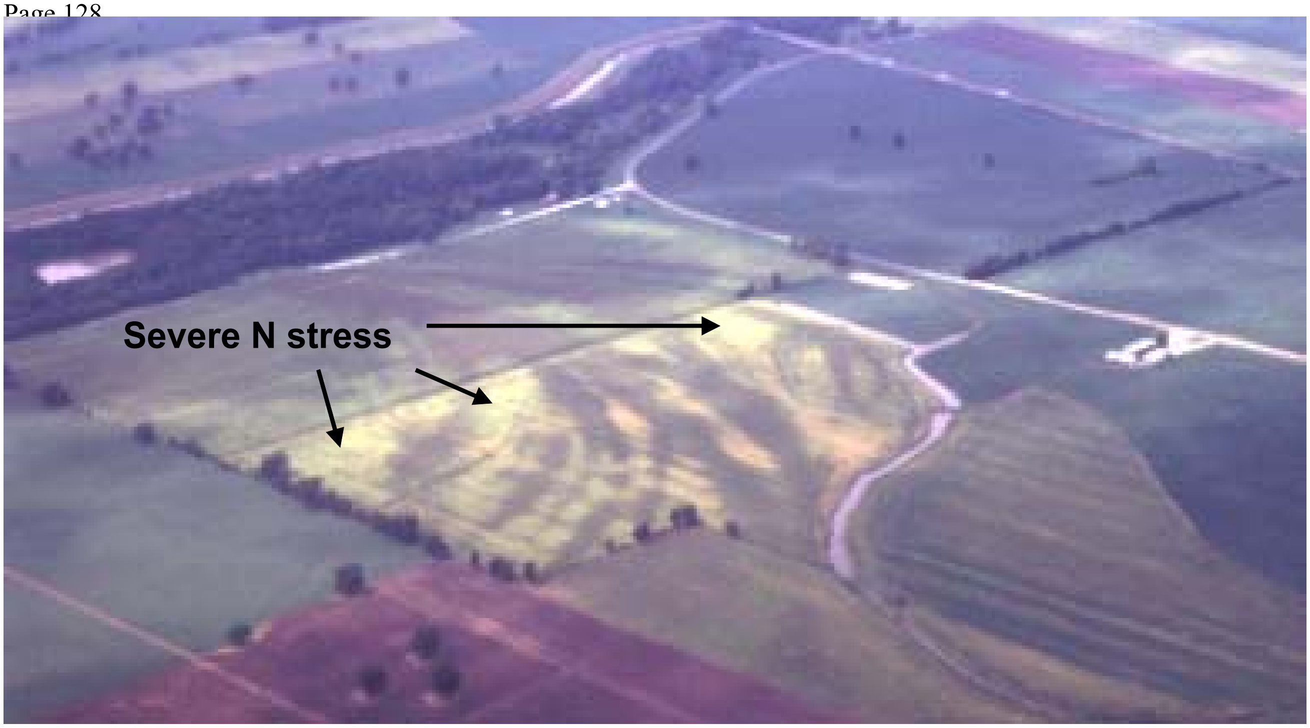



Figure 7. Aerial surveys revealed substantial N stress in northwestern Missouri in mid- August. My estimate was that one out of three corn fields in the area showed enough N stress to correspond to a field-average yield potential loss of 10 bu/acre or more. I would estimate lost yield potential in the field shown here at 30 to 40 bu/acre.

<u>Yield response to additional N was greatest in the fields with the best soil drainage</u>

- Yield response to additional N was statistically related to soil drainage class for the fields in this study, as shown in the table below.
- Nitrogen losses were probably mainly due to leaching of the nitrate form of N. Water moves more easily downward in well-drained soils, taking nitrate with it. In my experience, poorly-drained soils are most susceptible to N losses when they are wet in June, when a combination of warm and wet conditions can lead to high nitrate losses through the denitrification process.

| Soil drainage class | # of fields | Average yield response to additional N (bu/acre) |
|---|---|---|
| Well-drained | 4 | 16 |
| Moderately well-drained | 1 | 9 |
| Somewhat poorly drained | 8 | 6 |
| Poorly drained | 4 | 0 |

**Table 3. Yields From 2004 Fall Applied Nitrogen Trials**.

| COUNTY | LOCATION | YIELD WITH FERTILIZER TREATMENT: | | | |
|---|---|---|---|---|---|
| | | CHECK | + 50 N | + 100 N ADDED | ZN |
| Vernon | Deerfield | 208 | 216 * | 218 * | 210 |
| Vernon | Hong | 191 | 194 | 205 § | 180 |
| Ray | Dockery | 212 | 221 | 226 | 223 |
| Ray | Morton 1 | 198 | 226 ** | 237 ** | 219 † |
| Ray | Morton 2 | 202 | 221 ** | 226 ** | 204 |
| Lafayette | Higginsville | 219 | 227 | 227 | 220 |
| Saline | Elmwood | 220 | 223 | 219 | 226 |
| Saline | Blackburn | 221 | 226 | 218 | 223 |
| Saline | Miami | 218 | 215 | 220 | 211 |
| Carroll | DeWitt [SD] | 246 | 246 | 253 | 254 |
| Chariton | Minden | 198 | 206 | 218 † | 183 |
| Linn | Brookfield | 211 | 216 | 211 | 221 § |
| Monroe | Paris 1 | 249 | 246 | 250 | 242 |
| Monroe | Paris 2 | 217 | 218 | 210 | 218 |
| Audrain | Martinsburg 1 [SD, Irr A]†‡§¶[A A A] GGGG | 242 | 241 | 235 | 235 |
| Audrain | Martinsburg 2 [SD] | 216 | 226 | 228 | 220 |
| Audrain | Martinsburg 3 [SD] | 172 | 171 | 169 | 180 |
| Average | | 214 | 220 | 222 | 216 |

** This yield is statistically different from yield of the check with > 99% confidence.

* This yield is statistically different from yield of the check with 95 to 99% confidence.

† This yield is statistically different from yield of the check with 90 to 95% confidence.

§ This yield is statistically different from yield of the check with 80 to 90% confidence.

Irr Irrigated site

SD This field was sidedressed by the cooperating producer, and omitted from averages.

Yield response to zinc

Zinc treatments were also included in these experiments because of promising results in 2001 in another set of experiments. There were two of these 17 fields with some evidence of yield response to zinc. Over all 17 experiments, average yield response to zinc was 1.7 bu/acre, but this was not statistically different than zero. Averaged over 69 experiments from 2001 to 2004, yield response to zinc was 0.0 bu/acre.

**Summary and Conclusions:**

- Despite a normal-to-cold winter, fall $NH_3$ applications had more than half-converted to the nitrate form by March in 13 of the 17 experimental fields.
  - Conversion to nitrate created a situation with risk for N loss.
- Winter precipitation was normal, and there appeared to be moderate loss of fertilizer N by March.
- In the previous two years, we had seen that much of the fertilizer had converted to nitrate, but that little was lost due to unusually dry winters.
- Wet weather in March and May created the potential for additional loss of N in some areas.
- Average yield response to our additional N applications (in the 13 fields that were not sidedressed by producers) was 8 bu/acre. This represents the average loss of yield potential due to loss of fall N for our 2003-04 experiments. In this year, the convenience of fall N applications was offset by either an average 8 bu/acre yield loss or the need to sidedress additional N to prevent this loss.
- Loss of yield potential was higher in fields with the following conditions:
  - Fields receiving the earliest N applications (first week of November).
  - Fields in western Missouri, which received more rain in March and May than the fields in central and eastern Missouri.
  - Fields with well-drained soils. This suggests that N loss was mainly by leaching in 2004.
  - Fields with the above conditions also had the lowest soil nitrate values when sampled in June, confirming that the response to our additional N treatments was due to loss of fall-applied N.

# Nitrogen fertilization strategies for annual ryegrass pasture

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**Accomplishments for Year 1:**

- A three-year field trial studying the effects of nitrogen rate and date of application on the yield and quality of annual ryegrass began in August, 2002. This replicated (4x) experiment has 16 treatments; four N rates in autumn (0, 50, 100, and 150 lb. per acre of N at planting) followed by the either 0, 50, 100, or 150 lb. per acre of N in early spring. The table below describes the rate and date of N applications for treatments.

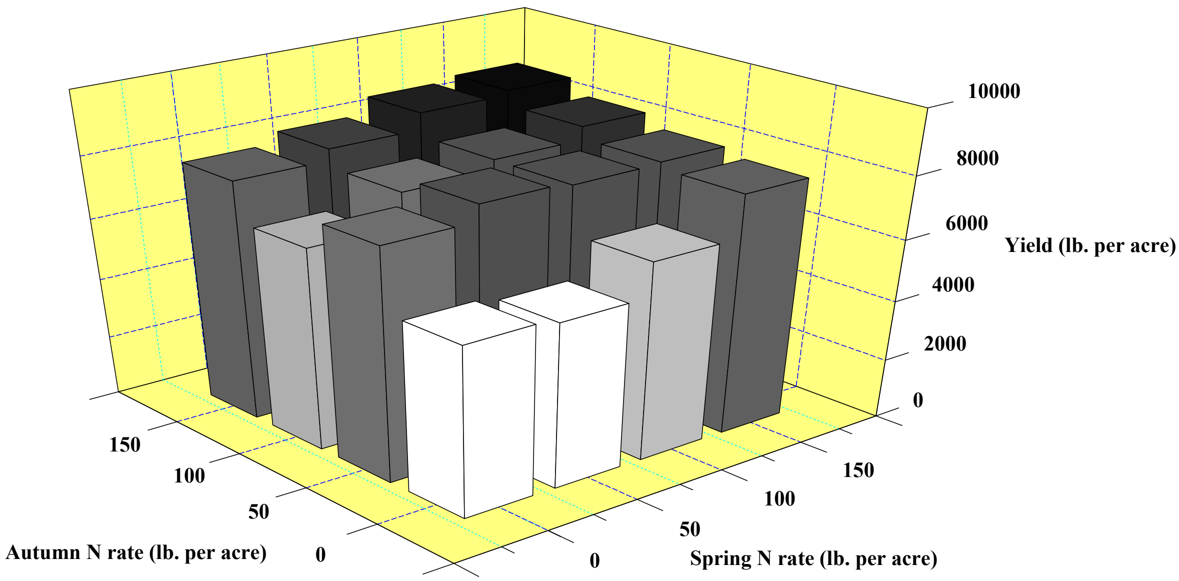
| Treatment | N in autumn | N in early spring |
|---|---|---|
| | --------- lb. N per acre --------- | |
| 1 | 0 | 0 |
| 2 | 0 | 50 |
| 3 | 0 | 100 |
| 4 | 0 | 150 |
| 5 | 50 | 0 |
| 6 | 50 | 50 |
| 7 | 50 | 100 |
| 8 | 50 | 150 |
| 9 | 100 | 0 |
| 10 | 100 | 50 |
| 11 | 100 | 100 |
| 12 | 100 | 150 |
| 13 | 150 | 0 |
| 14 | 150 | 50 |
| 15 | 150 | 100 |
| 16 | 150 | 150 |

- We established the annual ryegrass into a conventionally tilled seedbed at the Southwest Research and Education Center near Mt. Vernon, MO in late August of 2002, 2003 and 2004 (Fig. 1). The seeding rate was 30 lb. per acre of pure live seed. After seeding, the autumn fertilizer treatments were applied.

Fig. 1. Planting annual ryegrass at the Southwest Research and Education Center near Mt. Vernon, MO. The annual ryegrass was planted into a conventional seedbed in late August of 2002, 2003 and 2004. In 2002, the stand established well but dry weather conditions in autumn limited fall growth. Growth in the autumn of 2003and 2004 was excellent.

- This past year (2003-2004), two harvests were possible in autumn for all treatments, although autumn yields were greatest for plots receiving 50 or more lb. per acre of N at planting. When an additional 50 or more lb. per acre of N was applied in spring, earlier and more frequent harvests were possible. This suggests that plots not receiving any N in autumn use residual soil N for a while, but that this supply runs out in about 60 days.
- Season long (total) yields were in excess of 8,000 lb. per acre for the best treatments (Fig. 2). While the highest N rates provided the greatest yields, it appears that 50 lb. per acre of N in autumn followed by 50 lb. per acre in early spring provides an even distribution of forage yield and gives the best economic response.

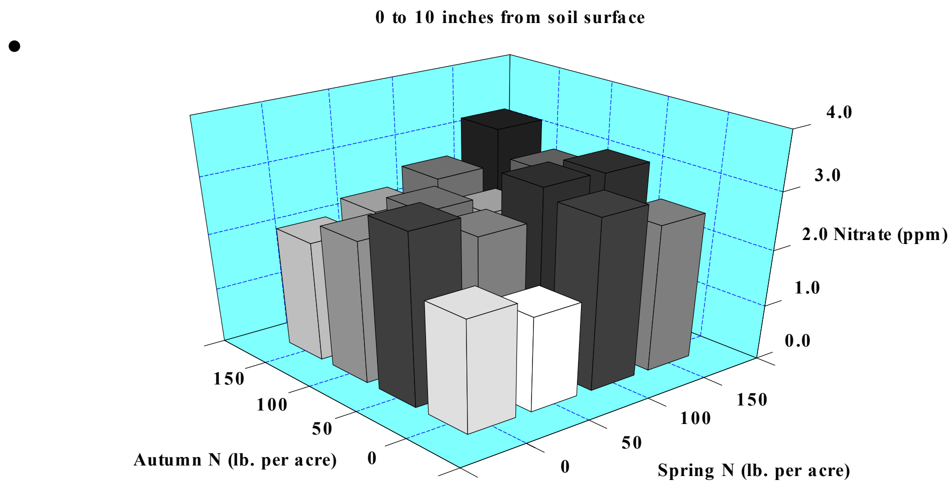
Fig. 2. Season-long (August 2003 to June 2004) annual ryegrass yields in response to fall and spring applied N at Mt. Vernon, MO.

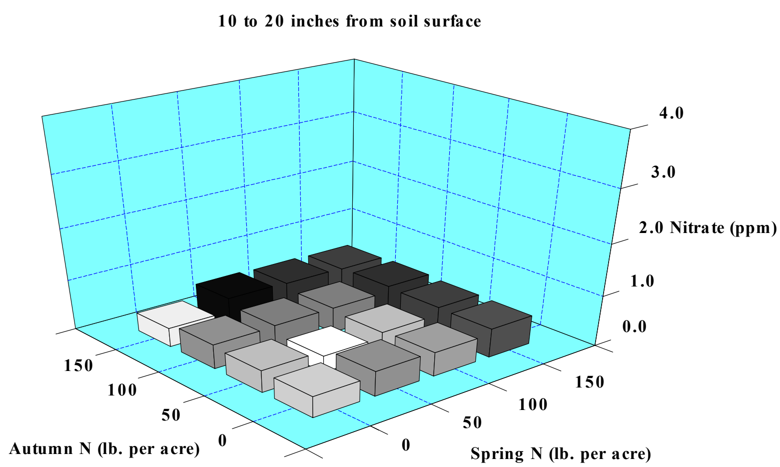


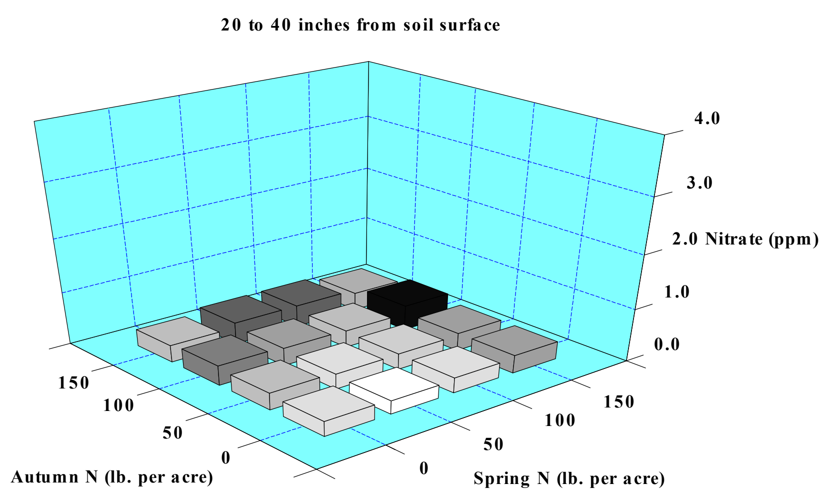

- Forage quality samples show that annual ryegrass is excellent forage. Samples for the last two years have showed that annual ryegrass averaged 24% crude protein and had acid detergent fiber values less than 22%. In short, few other forages can produce such excellent quality feed for winter and early spring grazing.

- Soil samples were taken to a 40-inch depth prior to applying fertilizer treatments each year and again after the annual ryegrass ended its spring growth in June. Samples were split into three depth classes (0-10, 10-20, and 20-40 inches) and then analyzed for $NH_4$ and $NO_3$ content. Initial results showed that plots had equal ($P>0.05$) levels of pre-experiment $NH_4$ and $NO_3$. Samples collected in June 2004 showed that soil nitrate levels, 0 to 10 inches from the soil surface, were 3 ppm when 150 lb. per acre of N was applied in both autumn and spring, while the all the other treatments had 3 ppm of nitrate or less (Fig. 3). At deeper depths, (10 to 20 and 20 to 40 inches from the surface) soil nitrate levels were less than 1 ppm for all treatments. This suggests that little N is lost due to leaching from annual ryegrass pastures at the rates of N we examined.

Fig. 3. Soil nitrate levels June of 2004 when fertilized with 0, 50, 100, 150 lb. per acre of N in autumn and 0, 50, 100, 150 lb. per acre of N in early spring.



More than 1,000 individuals had the opportunity to view this research project as part of various extension education programs and field days conducted at the Southwest Research and Education Center. As we develop more comprehensive data over the next year, we will be able to extend our results even further.

**Objectives left to finish:**

- Over the next year we will continue our research on N fertilization of annual ryegrass. Because annual ryegrass is planted in August and harvested through winter and early spring, we are only partway through the third year of data collection. As outlined in our original proposal, the tasks in the table below will be conducted over the next year. Note that no additional funding is requested.

| | |
|---|---|
| Harvest plots for forage yield and retain subsamples for forage quality analysis | Ongoing as forage growth dictates. Anticipate 5 to 7 harvests per year. |
| Apply N to plots receiving early spring fertilizer | 3/1/05 |
| Take five, 3 inch diameter cores from each plot & count the number of tillers | 4/15/05 |
| Take soil cores from each plot to determine residual soil N | 6/1/05 |
| Analyze samples taken to date for forage quality | 7/31/05 |
| Prepare final report to Missouri Fertilizer and Lime Council | 12/15/05 |
| Prepare a guidesheet on N fertilization of annual ryegrass | 12/15/05 |
| Work with publications office on articles for the popular press | 12/15/05 |

- In addition, we will be fully analyzing our field data next summer. We are most interested in refining N recommendations for annual ryegrass so that maximum economic productivity can be obtained by forage-livestock producers. In addition, we would like to understand more about the fate of N applied at relatively high rates to annual ryegrass. Our preliminary data as well as that from other regions suggests that annual ryegrass can capture nearly all of the N applied to the surface. This may make it an ideal crop for operations with large amounts of livestock manure.

- We will continue to integrate our findings into the curriculum of the Missouri Grazing Schools, grazing workshops statewide, and at the Southwest Research and Education Center Field day. These outreach efforts can be expected to reach more than 1,000 producers, agency staff, and agri-business personnel. Additionally, as more comprehensive data are collected, we will start work on a new guidesheet about annual ryegrass fertilization. In addition, we will prepare articles to be published in statewide and national magazines such as Missouri Ruralist, Graze, Stockman Grass Farmer and scientific journals.

# Potassium Management

# 2003

## Effect of Potassium Fertilization on Leafhopper Tolerance and Persistence of Alfalfa

C. Jerry Nelson, Rob Kallenbach and Wayne Bailey

Objectives:

1. Determine effect of K-fertilization on leafhopper tolerance.
2. Measure effect of glandular hairs on leafhopper tolerance.
3. Evaluate interaction of K-fertilization and glandular hairs on alfalfa persistence.

Background for Research:

Potato leafhopper is likely the most serious pest of alfalfa in Missouri, costing alfalfa producers more than $1 million per year for control treatments and losses of production and quality when not controlled. Alfalfa weevil, another major alfalfa pest, is more predictable, damage is limited largely to the first harvest, and the symptoms are clearly visible for determining if and how to manage the pest. In contrast, potato leafhoppers are small, infestations are less predictable, and scouting with a sweep net is needed to determine threshold levels for treatment. The typical visible symptoms of leaf yellowing and stunted growth appear after the damage is done and any treatment then will be late and ineffective. Thus, preventive measures such as selection of a glandular-haired variety, using good soil fertility practices (especially K) to maintain stand health, and using IPM methodologies for detection and early control of potato leafhopper can be effective and provide economic alternatives to routine scheduled sprays.

Our goal was to evaluate how glandular hairs on some new varieties and rates of K fertilization affect populations of potato leafhopper in alfalfa. The experiment is being conducted at the Forage Systems Research Center near Linneus in North Central Missouri. At the site the Lagonda silt loam soil slopes to an Armstrong silty clay loam. The site was selected in 2000 and the entire field was limed and P was applied according to soil test recommendations. Our first two attempts (fall, 2000 and spring, 2001) did not yield uniform stands that were acceptable for the project so they were tilled up. We established an excellent stand in fall, 2001. We also retested the soil fertility level in October, 2001, and topdressed the plot area with 400 lbs of 0-46-0 to increase seedling vigor and develop good ground cover to enhance survival over winter. Eight blocks (four replicates of two alfalfa varieties) of 2 acres each were planted. One variety (normal) has smooth stems and leaves (PLH susceptible) whereas the other variety (PLH resistant) has glandular hairs that deter infestation and feeding of potato leafhoppers (Figure 1). Sub-plots were 1) no insecticide (control), 2) insecticide applied when the leafhopper population reached economic threshold (IPM standard), and 3) insecticide applied to the regrowth 7 days and 21 days after harvests 1 and 2 (scheduled spray). Insect treatments were subdivided into K treatments of 0, 125, and 250 lbs/acre annually, half being applied after the first harvest and half being applied after the fourth harvest in mid-September. All plots receive P (75 lbs/acre) annually after the fourth harvest.

We had good alfalfa emergence, and the unusually warm weather during October and November of 2001 was favorable for development of the alfalfa seedlings and their ability to over winter. The seedlings entered winter with more than six leaves, a stage that allows plants to develop good winter hardiness and a root system that tolerates normal freezing and thawing. We had a good stand in spring 2002, and were able to initiate the experiment with the insect and K treatments beginning immediately after the first harvest. Year 1 of the project was 2002, Year 2 was 2003. We are now ready to go to Year 3 (2004).

**Changes in Soil Test for K**

Soil samples had been taken to 6 inches over the entire field by sub-sampling within four replicate sections in July, 1998 (Table 1). This was prior to lime and fertilizer application in anticipation of using the area for experimental use. The soil was fertilized with P and limed to soil test in 2000. After seeding in fall of 2001 we re-sampled the area and topdressed 400 lbs of P to further raise the level of 39 lbs/acre. It is apparent that the P fixation capacity of this soil is higher than for many soils as it took more P than expected to raise the soil-test P. The P test was adequate on samples collected in April of 2002 before the experimental treatments began (Table 1). The K levels were moderate and the pH of 6.7 was in the optimum range for alfalfa.

The K treatments were first applied (half the annual rate) after the first harvest in May of 2002; the remaining half rate of the K and the total annual P was applied after the fourth harvest in September. Soil in the plots was sampled to 6 inches again after the first harvest of 2003. At that time the P level averaged about 50 lb/acre and the K level of the control treatment (0 K) was significantly lower ($p<0.05$) than that at the 250 lb rate. Yields in 2002 and the first harvest of 2003 totaled about 6.0 tons/acre (Table 3), so a typical removal rate of 50 lbs K/ton of forage would exceed even the highest application rate of 250 lbs/acre. Thus, the K-test was decreasing, especially at the low fertilization rates (Table 1). This is desired for our research as our hypothesis is that plants at low K levels will be less resistant to the potato leafhopper.

We plan to take soil samples and test again after the first harvest in 2004. Our expectation is the soil tests for K will continue to decrease, especially at the lower rates as the productive stand uses more K annually than is applied. In addition, we propose to take some tissue samples for K analysis as we expect that tissue-K may be more important than soil-test K for conferring resistance to the potato leafhopper. The upper third of the canopy will be sampled midway in growths that constitute the second and third harvests as these are attacked most commonly.

**Leafhopper Populations**

Leafhoppers typically arrive in Missouri about May 5 in winds from the southwest and must lay eggs that hatch to develop a damaging population. The life cycle is such that leafhopper populations rarely reach economic levels prior to the first harvest (Figure 2). Generally, few leafhoppers are found during regrowth after the third harvest in Missouri, and this has also been the case in our research. We counted both the adults and the nymphs (immature, non-mobile stage), and in both years the adult component made up more than 80% of the total count. After the first harvest, the population of leafhoppers increased rapidly during early to mid-June in both years, but in 2002 the PLH-resistant variety in the no-spray treatment (control) had fewer than 30% as many leafhoppers as did the normal variety. In 2003 both varieties had nearly the same level as the infestation built rapidly in early June. The rapid increase was unexpected as the glandular-haired varieties usually show resistance in field studies, but the populations in the IPM and scheduled spray treatments also increased very rapidly, such that not even the scheduled spray treatment kept the population in check (compare treatments for 2003 in Figure 2). But, after climbing rapidly, leafhopper populations declined in the PLH-resistant variety suggesting some control while they continued to increase in the normal variety. Except for this period the scheduled spray treatment did an excellent job of leafhopper control between harvests in both years. Some oscillations occurred in the leafhopper populations, mainly due to weather events.

Leafhopper populations exceeded the IPM thresholds in both years (Figure 2). The leafhopper populations developed rapidly shortly after the first harvest of 2002 and reached the highest levels of the summer. In fact, the normal variety reached the economic threshold only 7 days after the first harvest in 2002. Yield of the second harvest was 0.67 tons/acre for the normal variety with no spray compared with 0.88 tons/acre for the PLH-resistant variety with no spray, showing the value of the glandular hairs. In the third harvest of 2002 the leafhopper population in the control treatment developed slower, did not reach the same level, and did not affect alfalfa yield (both treatments yielded 0.87 tons/acre).

In both years, except for the third growth of 2003 as the threshold was not reached, a single insecticide application in the IPM treatment controlled the leafhoppers until the next harvest date. Therefore, over the two years, the number of sprays was reduced from eight with the scheduled spray treatment to only three when based on scouting and IPM thresholds.

The K fertilization treatment did not affect leafhopper populations in 2002. On June 18, 2003, however, there were about 20% more adults in the high K treatment than the control, but the K treatments of 125 and 250 lb/acre had significantly fewer nymphs, the most damaging form (data not shown). On July 17, 2003 there were again significantly fewer nymphs on the 250 lb/acre K treatment than on the 0 and 125 lb/acre K treatments. These data are preliminary and we expect more definitive results in the future as differentials in K treatments broaden.

## Alfalfa Yields

Insect treatments did not affect yield in 2002 or 2003 except, as mentioned above, for the variety difference in the control treatment at the second harvest (Table 3). In 2003, the PLH-resistant variety had a higher yield in the third harvest than the control. In all cases, the yields of the two varieties were similar in the first and fourth harvests when potato leafhopper infestations were very low or absent. Thus, the glandular-haired character is effective, yet advantageous only when the insect pest is present, and when the populations are at or exceed the established thresholds. These resistance responses have caused Extension agents in some other states to increase the economic threshold populations for glandular-haired varieties by three times (or more) compared with the economic threshold for normal varieties.

Alfalfa yields were not affected by K fertilization rate in 2002 (Table 3), mainly because the treatments were initially applied after the first harvest and only half the K was applied. The differential in K did not have a major influence on yield during the lower yielding periods of summer even though that is the time when potato leafhopper damage is most likely. This is consistent with our earlier research that shows that K stimulates crown development in a gradual manner, especially over winter. The rest of the K was applied after the last (fourth) harvest.

In 2003 some effects of the K rates became apparent, mainly in the second harvest when populations of potato leafhopper increased very rapidly regardless of insecticide treatment. The cumulative total yield in 2003 for the K rates of 125 and 250 lbs/acre was nearly ($p<0.06$) significantly higher than the control. This suggests that treatments are beginning to separate, and will be of great interest next year (2004) as removal will continue to decrease the soil-test K.

### Changes in Plant Density

The alfalfa stands looked good for both varieties in spring, 2002, when plant density was counted after the first harvest (Table 2). The K and leafhopper treatments did not begin until after the first harvest so there was no effect on plant density due to K or insect control. We did note, however, that the plant density of the PLH-resistant variety was about 30% lower than the normal variety. The seed of the normal variety was coated (adding 30% in weight) so the pure live seed planted per unit of "seed" weight was also lower. One advertised advantage of coating is that germination and seedling survival are improved, so the same seeding rate should give a similar stand. That did not occur here, and the perceived value of the seed coating was not realized. This result should be tested further under Missouri conditions.

Plant density was determined again after the fourth harvest in 2002 and after the first and fourth harvests in 2003 (Table 2). The plant density for all treatments gradually decreased with time through 2002 and 2003. As the stands lost plants, the PLH-resistant variety continued to maintain its advantage of higher plant density, a factor we have noted before in many earlier studies that compare seeding rates. Similarly, the high-K treatment retained its initial advantage over the control (due to natural effects of field variation despite plot randomization) as the stand decreased through both years, again being consistent with previous studies. We do not expect reductions in yield due to low plant density until the stand has fewer than four plants/sq ft. This occurs because the plants still have sufficient capacity to produce and elongate additional stems from the crown to offset the loss of nearby plants and maintain a high number of stems/sq ft.

As the stands thin with time, i.e., plants/sq ft decrease, the number of stems/plant that contributes to yield at a given harvest will increase. This is evident from the first harvest in 2002 when plant density was high for both varieties. Number of stems/plant was inversely related to plant density and averaged 2.4 stems/plant for the PLH-resistant variety and 2.9 stems/plant for the normal variety. As the stand thinned the stems/plant gradually increased. We expect the stems/plant to begin to show a K effect as the stand thins, especially as it approaches four plants/sq ft. The effect of the leafhopper treatments may also be accentuated at that time as the plants will be less vigorous and more stressed. A goal is to continue to follow the stand reduction for a longer time.
Similar to the May count in 2002, plant densities after the first and fourth harvests in 2003 did not differ due to the K or leafhopper treatments, but the PLH-resistant variety continued to have about 30% more plants/sq ft than the normal variety. We counted stems per plant allowing us to calculate stems/sq ft (data not shown). We calculated the weight (yield) per stem using yield data for the fourth harvest. Despite the 30% lower plant density, by mid-September the crowns of the normal variety had expanded to have only 8% fewer stems/sq ft, mainly because the lower plant density was offset by having 23% more stems/plant (Table 2). In other studies we found that alfalfa plants in stands with low densities tend to develop larger crowns and support more stems.

We expected little effect on plant density due to K fertilization or leafhopper control this early in the experiment as the young plants are vigorous and are thinning mainly due to plant competition for light. We expect stems/sq ft to remain stable for both varieties until plant density is reduced to about four plants per sq ft. Thereafter, the reduced ability of the crown to spread with low K will not offset the continued plant loss, resulting in a gradual yield decrease. Thus, as the stands thin, the ability of the crown to spread or compensate for plant loss will be compromised and detrimental effects from leafhoppers will be more evident.

**Objectives for Year 3 (2004):**

Our objectives are to continue the experiment as proposed. It is anticipated the K effect will be expressed even more dramatically if leafhopper populations are high, so we will monitor alfalfa weevil and especially potato leafhopper throughout the growing season. The control, IPM and scheduled spray treatment will be maintained. Forage yield will be measured. We will use the sod cutter to lift alfalfa plants from the soil for accurate counting after the first and fourth harvests. As before, stems/plant will be counted after the first and fourth cuttings to monitor development and spread of the crowns.

We will take soil samples again after the first harvest to continue to monitor the soil-test K levels and any other nutrient that may be changing. We will also take tissue samples from the upper third of the canopy about midway through the regrowth periods that contribute to harvests 2 and 3. Our expectation is that tissue-K level may decrease faster with time than will the soil test and yield response. The tissue-K is likely associated with leafhopper resistance. The University Soil Test lab has a new instrument for accurately measuring minerals in plant tissues. We will thus sample topgrowth from four replications, two sample dates, three K rates, two varieties, and three insect treatments. The total is 4X2X3X2X3= 144 total samples. Samples will be dried, ground and analyzed. With a processing and analytical cost of $15/sample, these analyses add $2160 to the Year 3 budget.

Other funds were used in 2001 to establish the stand. We knew we it would take 3 years (2002, 2003, and 2004) to get good base data on responses, but that the stands would last longer. So far the stands have begun to thin, but are still above threshold population for yield responses. The K will help sustain the stand by enhancing crown development. We hope to continue this integrated experiment beyond 2004 as is contributing to our understanding of how interactions of crop management strategies affect an important pest in an environmentally friendly way.

Figure 1. Electron micrographs of a leafhopper and of glandular hairs on an alfalfa leaf. The hairs are multi-cellular extensions of epidermal cells, and can be upright or flat. The upright hairs are the most effective in conferring resistance. The sticky exudates from the hair ends and the physical structure of the upright hairs are deterrents to egg laying and feeding by the leafhoppers. Some nymphs actually are entrapped by the sticky hairs.

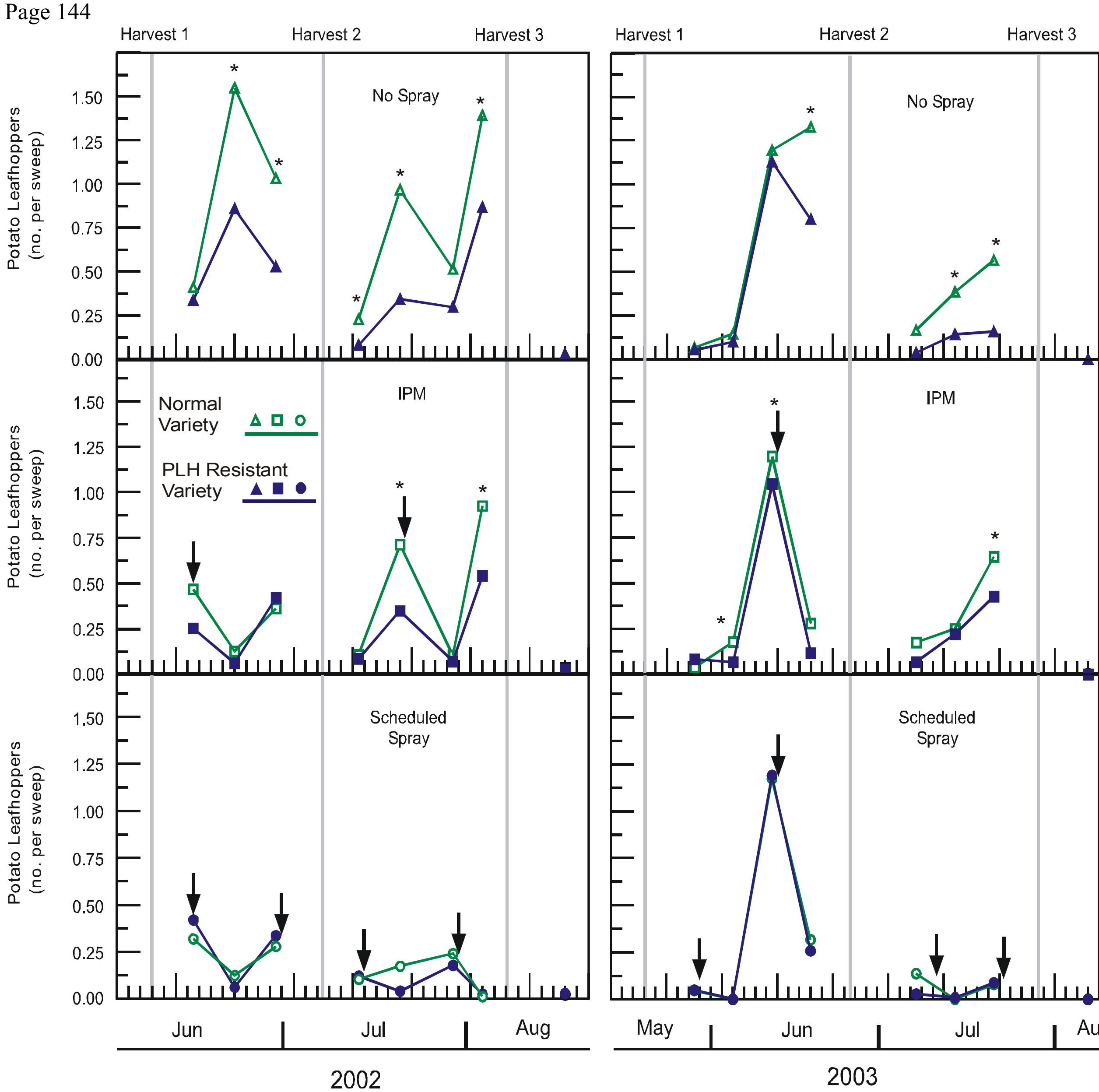



Figure 2. Top panel shows populations of potato leafhopper between harvest dates in the no-spray treatment (control). Each panel also indicates the relative control provided by the PLH-resistant variety compared with the normal variety. Middle panel shows the populations in the spray treatment based on IPM and population sampling with dates of sprays indicated by arrows. Note the excellent control after the spray. The lower panel shows the populations in the scheduled spray treatment with the arrows showing the dates of spray that were scheduled 7 and 21 days after the first and second harvests. Leafhoppers were not found previous to the first harvest and only a few were captured in the sweep net in the early regrowth of the fourth harvest. Asterisks (*) indicate the leafhopper populations are significantly different ($p<0.05$) between the two varieties on those sampling dates.

Table 1. Soil test results from samples taken at different times prior to and during the experimental period. Plots were established in fall, 2001.

| Sample Date | Sampled Area | Remarks | K | pH | P |
|---|---|---|---|---|---|
| | | | lb/a | | lb/a |
| July 14, 1998 | Field | Prepare for establishment | 192 | 6.0 | 22 |
| April 26, 2002 | Field | Before experiment started | 184 | 6.7 | 63 |
| May 28, 2003 | 0 – K plots | After first cutting, but | 142 | 6.4 | 45 |
| | 125 – K plots | before K treatments | 145 | 6.5 | 54 |
| | 250 – K plots | were applied in 2003 | 147 | 6.5 | 55 |

Table 2. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on plant density and stems/plant on several dates in 2002 and 2003.

| Summary of treatments | Plants on 6-02 | Plants on 9-02 | Plants on 5-03 | Plants on 9-03 | Stems/plt on 9-02 | Stems/plt on 5-03 | Stems/plt on 9-03 |
|---|---|---|---|---|---|---|---|
| | ----------------------no./sq. ft. ---------------- | | | | --------------------no. --------------- | | |
| Insect control | | | | | | | |
| No spray | 20.3 | 18.9 | 18.9 | 11.3 | 2.7 | 3.4 | 6.7 |
| IPM spray | 18.3 | 18.6 | 16.3 | 11.7 | 2.6 | 3.1 | 6.7 |
| Scheduled | 18.7 | 17.9 | 15.0 | 11.0 | 2.7 | 3.1 | 6.6 |
| | | | | | | | |
| Pr > F* | 0.56 | 0.66 | 0.64 | 0.59 | 0.28 | 0.55 | 0.88 |
| LSD (0.05)** | NS*** | NS | NS | NS | NS | NS | NS |
| | | | | | | | |
| <u>K treatment</u> | | | | | | | |
| 0 lbs/acre | 18.2 | 17.8 | 15.1 | 10.9 | 2.8 | 3.2 | 6.8 |
| 125 lbs/acre | 18.5 | 18.4 | 14.5 | 10.8 | 2.7 | 3.3 | 6.8 |
| 250 lbs/acre | 20.7 | 19.1 | 16.7 | 12.3 | 2.5 | 3.1 | 6.4 |
| | | | | | | | |
| Pr > F | 0.18 | 0.58 | 0.10 | 0.02 | 0.12 | 0.49 | 0.46 |
| LSD (0.05) | NS | NS | NS | 1.1 | NS | NS | NS |
| | | | | | | | |
| Variety | | | | | | | |
| PLH resistant | 22.3 | 21.0 | 17.7 | 12.6 | 2.4 | 3.0 | 6.0 |
| Normal | 15.9 | 15.9 | 13.1 | 10.0 | 2.9 | 3.4 | 7.4 |
| | | | | | | | |
| Pr > F | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| LSD (0.05) | 2.3 | 1.8 | 1.4 | 0.9 | 0.2 | 0.3 | 0.6 |

* Probability values of 0.05 or lower indicate the treatment means are significantly different
** LSD indicates the difference among means that is needed to be statistically different
*** NS = not significant

Table 3. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on yield of alfalfa at each of four harvests in 2002 and 2003. Harvest dates and total annual yields are also shown.

| Summary of treatments | 2002 | | | | | 2003 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H-1 6-10 | H-2 7-08 | H-3 8-09 | H-4 9-10 | Total Yield | H-1 5-19 | H-2 6-25 | H-3 7-29 | H-4 9-11 | Total Yield |
| | ---------------------------------------- | | | | --tons / acre-- | ---------------------------------------- | | | | |
| Insect treatment | | | | | | | | | | |
| No spray | 2.52 | 0.77 | 0.87 | 0.96 | 5.12 | 1.92 | 1.81 | 0.42 | 0.36 | 4.51 |
| IPM spray | 2.46 | 0.84 | 0.84 | 0.93 | 5.07 | 1.89 | 1.74 | 0.41 | 0.36 | 4.40 |
| Scheduled spray | 2.67 | 0.79 | 0.87 | 0.92 | 5.24 | 1.95 | 1.81 | 0.45 | 0.34 | 4.55 |
| Pr>F* | 0.65 | 0.29 | 0.22 | 0.45 | 0.81 | 0.35 | 0.23 | 0.47 | 0.51 | 0.36 |
| LSD (0.05)** | NS*** | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| K treatment | | | | | | | | | | |
| 0 lbs/acre | 2.55 | 0.80 | 0.91 | 0.91 | 5.17 | 1.89 | 1.69 | 0.44 | 0.33 | 4.35 |
| 125 lbs/acre | 2.61 | 0.80 | 0.85 | 0.95 | 5.21 | 1.92 | 1.82 | 0.45 | 0.38 | 4.57 |
| 250 lbs/acre | 2.49 | 0.80 | 0.82 | 0.95 | 5.05 | 1.94 | 1.86 | 0.40 | 0.35 | 4.55 |
| Pr>F | 0.56 | 0.99 | 0.19 | 0.64 | 0.72 | 0.28 | 0.01 | 0.47 | 0.19 | 0.06 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | 0.08 | NS | NS | NS |
| Variety | | | | | | | | | | |
| PLH resistant | 2.61 | 0.83 | 0.86 | 0.95 | 5.25 | 1.91 | 1.77 | 0.45 | 0.37 | 4.50 |
| Normal | 2.49 | 0.77 | 0.86 | 0.93 | 5.04 | 1.93 | 1.81 | 0.41 | 0.33 | 4.48 |
| Pr>F | 0.07 | 0.01 | 0.77 | 0.55 | 0.07 | 0.57 | 0.12 | 0.04 | 0.01 | 0.70 |
| LSD (0.05) | NS | 0.05 | NS | NS | NS | NS | NS | 0.04 | 0.02 | NS |

* Probability values of 0.05 or lower indicate the means are significantly different
** LSD indicates the difference among treatment means that is needed to be statistically different
** NS = not significant

# Cotton Response to Midseason Potassium Applications and Bronze Wilt

**Third Year (2003) Progress Report**
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## Objectives

(1) Determine effects of foliar midseason potassium (K) applications on lint yields of modern cotton varieties.
(2) Determine effects of midseason potassium applications on incidence and severity of bronze wilt in cotton.

## Introduction

Cotton is an important crop in Southeast Missouri and the relatively short growing season encourages producers to plant cotton varieties that mature quickly. These varieties achieve maximum yields by setting relatively greater number of bolls in a shorter time. This increased boll load per day requires that nutrients be available to the plant in greater rates per day. Potassium is an essential nutrient for cotton production because it is involved in maintaining plant water status, cell turgor pressure, and controlling the opening and closing of stomata. The opening of the stomata controls the availability of $CO_2$ and potassium has an indirect control over photosynthetic activity. Potassium is also involved in cellulose synthesis. Eighty-five percent of K movement in the soil is by diffusion. Since diffusion is a relatively slow process, K fertilization is required to maintain high levels of exchangeable K. Rapid plant growth and uptake may deplete K around the root surfaces. During peak flowering a cotton crop may require 3 to 4 lbs. of K per day and this may be larger than Southeast Missouri soils are capable of supplying.

Cotton bronze wilt was first observed in Missouri, Louisiana, and Mississippi in late July to early August of 1995. No cases were reported in Missouri during 1996, but it did develop in 1998-2000. Leaves, stems, and petioles of affected plants turn red and the plants grow poorly and may produce no bolls. This discoloration is also characteristic of potassium deficiency. Yield losses have been up to 80% in some fields. Research has shown that some cotton varieties are more susceptible to bronze wilt than other varieties. However, no one has been able to identify a pathogen that causes bronze wilt. Field observations at the Delta Center have shown that bronze wilt is sometimes induced by water stress and subsides after irrigation. This suggests that the problem may not be a disease but a gene that is turned on and off by the environment. Because potassium is important in plant water relations, we hypothesize that foliar K applications may help reduce bronze wilt in cotton.

## Methods and Materials

A cotton study was conducted on a field at the University of Missouri-Delta Center Lee Farm (36$^{o}$N, 89$^{o}$W) in Pemiscot County, Missouri in 2001, 2003, and 2003. The eight varieties of cotton were planted on a Tiptonville silt-loam series soil(Typic Argiudoll, fine-silty, mixed, thermic) in early May of each year. Soil samples of the study area were collected from the 0 to 15-cm depth before planting. The soil test recommendation for K for this area was for a maintenance fertilization of 28 $kgha^{-1}$ of $K_2O$. Forty-seven $kgha^{-1}$ of KCl was applied in early April each year to plots scheduled for pre-plant K. The nitrogen recommendation was 112 $kgha^{-1}$ N. Urea-Ammonium nitrate 32% liquid fertilizer was applied at a rate of 28 $kgha^{-1}$ at planting and the remainder (84 $kgha^{-1}$) was applied at first-square (mid-June). Other than potassium fertilization the standard practices for cultivating dry land cotton in Southeast Missouri were employed.

The experimental design was a split plot with potassium treatment as main plot cotton variety as the sub-plot. The main plot K treatments are listed in Table 1. Mid-season foliar K applications were made using a Schwiess 4 row self-propelled high clearance sprayer at full bloom and full bloom + 10 days. The cotton varieties were STV 373, DP 1218BR, FM 958, FM 819, DP 436RR, PSC 355, STV 474, and BXN 47.

Plant height was measured twice during the growing season, following the second foliar K application and at cutout. A boll count was conducted prior to harvest, in early October of each year. Cotton petiole samples were collected twice during each growing season at the same time as plant height was measured. These samples represent the petiole of the fourth fully expanded leaf counted from the top. These samples were collected following each potassium application. The petioles were dried, ground, digested using $H_2SO_4$ and $H_2O_2$, and analyzed by atomic absorption for K content.

In late October of each year the two middle rows of each strip were mechanically harvested and the seed cotton weighed and recorded. The seed cotton was ginned using a 20-saw Continental gin stand preceded by an inclined cleaner and feeder extractor. The gin stand was followed by one stage of lint cleaning. Lint samples from each plot were sent to the International Textile Research Center for fiber quality analysis using a high volume instrument.

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.

Project Accomplishments 2001

Data collected during 2001 is presented as tables 2-11. Plant growth measurements were significantly effected by K treatment and cotton variety. Levels of potassium were significantly effected both K treatment and variety for the 7-13 sampling date but neither factor produced significant differences for the 8-3 sampling date. Cotton yield and lint quality parameters were significantly effected by cotton variety and not K treatment. Bronze Wilt was not encountered in any plot during 2001.

This data was presented to cotton producers and researchers in poster form at the 2002 Belt-Wide Cotton Conferences. This conference is being held in Atlanta GA and is attended by over 1,500 participants.

Project Accomplishments 2002

Data collected during 2001and 2002 is presented as Tables 2-11. In 2002 plant growth measurements were significantly effected by K treatment and cotton variety. There was also a K by variety interaction. Levels of potassium were significantly effected both K treatment and variety for the first sampling date. For the second sampling date levels of tissue K were affected by K treatment but not by variety. Cotton yield and lint quality parameters were significantly affected by cotton variety and K treatment. There was also a variety by treatment interaction for yield and fiber properties in 2002. Yields were erratic among the K treatments. The fiber property micronaire was affected by K treatment generally increasing as applied K increased. This indicates a delay in maturity with increasing K rates. Trash content was increased with increasing K rate. As with micronaire a significant difference was observed with the application of pre-plant K. Average trash contents were generally equivalent for all foliar K treatments that received the same preplant K. Trash content was significantly greater for treatments receiving 25 lbs/acre pre-plant K. This also indicates a delay in maturity with increasing K rates. Fiber strength was generally decreased by increasing K rates. Bronze Wilt was not encountered in any plot during 2002.

This data was presented to cotton producers and researchers as an oral presentation at the 2003 Belt-Wide Cotton Conferences. This conference is being held in Memphis, TN and is attended by over 1,500 participants.

Project Accomplishments 2003

Data collected during 2001, 2002, and 2003 is presented as Tables 2-11. In 2003 plant growth measurements were significantly effected by K treatment and cotton variety. In 2003 there was no K by variety interaction. Levels of potassium were significantly effected both K treatment and variety for the first sampling date. For the second sampling date levels of tissue K were affected by K treatment but not by variety. Cotton yield and the lint quality parameters of micronaire, length, and strength were significantly affected by cotton variety and K treatment. Yields were erratic among the K treatments. The fiber property micronaire was affected by K treatment generally increasing as applied K increased. This indicates a delay in maturity with increasing K rates. Fiber length was generally increased by increasing K rates. Fiber strength was generally decreased by increasing K rates. Bronze Wilt was not encountered in any plot during 2003.

The authors speculate that differences in the response of yield and fiber quality to foliar K applications for the three years can be attributed to differences in weather conditions during the boll-filling period following cut out. Bolls produced early in the season have the benefit of the soil applied K only. Weather during the early and mid season was similar all three years. The increasing levels of petiole K indicate that foliar treatments were effective at supplying K to the cotton plants. In 2001 dry cool weather was not favorable for filling out late season bolls with quality fiber. The cotton plants were unable to use the available K to produce fiber. Hot weather combined with abundant rain in fall of 2002 allowed the cotton plants to take advantage of available K. The late season bolls were to be filled with longer, higher micronaire fibers. Both 2001 and 2002 were not typical fall weather years. 2003 was much more typical in terms of fall weather. The results for yield and fiber quality response to foliar K fertilization for 2003 would be more typical.

This data was presented to agronomy researchers at the American Society of Agronomy Annual meeting held in Denver, CO. Over 3,000 participants attended this meeting. This data was also presented to cotton producers and researchers as an oral presentation at the 2004 Belt-Wide Cotton Conferences. This conference is being held in Memphis, TN and is attended by over 3,300 participants. Currently a manuscript is being prepared for submission to Agronomy Journal or Journal of Cotton Science.

Table 1. Potassium treatments and application dates for 2002.

| Treatment # | Pre-plant K<br>April 23, 2001 | Peak bloom K<br>August 1, 2002 | Peak bloom +10 K<br>August 13, 2002 |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 5 | 0 |
| 3 | 0 | 5 | 5 |
| 4 | 25 | 0 | 0 |
| 5 | 25 | 5 | 0 |
| 6 | 25 | 5 | 5 |

Table 2. Average plant growth parameters as affected by K treatments averaged across all varieties.

| Treatment # | Plant Height (peak bloom) | | | | Plant Height (cut out) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| 1 | 20.2 | 24.5 | 26.6 | 23.8 | 30.4 | 33.6 | 38.9 | 34.3 |
| 2 | 19.8 | 24.4 | 25.7 | 23.3 | 28.8 | 33.8 | 38.5 | 33.7 |
| 3 | 20.6 | 24.5 | 26.7 | 23.9 | 29.1 | 34.3 | 36.9 | 33.4 |
| 4 | 20.6 | 25.1 | 27.2 | 24.3 | 30.1 | 34.3 | 39.3 | 34.6 |
| 5 | 22.0 | 25.1 | 26.8 | 24.6 | 31.1 | 34.2 | 39.2 | 34.8 |
| 6 | 21.7 | 25.1 | 26.8 | 24.5 | 29.8 | 32.3 | 37.5 | 33.2 |
| LSD=0.05 | 1.2 | NS | | | 1.5 | 1.1 | | |

Table 3. Average plant growth parameters as affected by varieties averaged across all K treatments.

| Variety | Plant height (peak bloom) | | | | Plant height (cut out) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| STV 373 | 21.0 | 26.0 | 25.4 | 24.1 | 30.9 | 34.3 | 39.5 | 34.9 |
| DP 1218BR | 22.0 | 26.8 | 27.8 | 25.5 | 31.5 | 35.3 | 39.0 | 35.3 |
| FM 958 | 19.2 | 22.1 | 24.6 | 22.0 | 27.2 | 32.0 | 35.4 | 31.5 |
| FM 819 | 21.0 | 24.1 | 24.3 | 23.1 | 29.6 | 31.5 | 35.1 | 32.0 |
| DP 436RR | 19.6 | 22.9 | 26.1 | 22.9 | 26.9 | 31.6 | 35.9 | 31.5 |
| PSC 355 | 20.4 | 26.2 | 27.8 | 24.8 | 29.1 | 35.4 | 39.4 | 34.6 |
| STV 474 | 21.0 | 24.8 | 28.6 | 24.8 | 31.6 | 34.9 | 40.0 | 35.5 |
| BXN 47 | 22.2 | 25.3 | 28.5 | 25.3 | 32.5 | 35.0 | 42.8 | 36.8 |
| LSD=0.05 | 1.3 | 1.1 | | | 1.7 | 1.3 | | |

Table 4. Average petiole K % as affected by K treatments averaged across all varieties.

| Treatment # | Petiole K% (peak bloom) | | | | Petiole K% (peak bloom + 10 days) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| 1 | 4.94 | 5.51 | 3.42 | 4.62 | 4.89 | 1.50 | 4.61 | 3.67 |
| 2 | 4.79 | 5.50 | 3.35 | 4.55 | 4.97 | 1.81 | 4.68 | 3.82 |
| 3 | 4.79 | 5.80 | 3.46 | 4.68 | 5.41 | 2.07 | 4.84 | 4.12 |
| 4 | 5.04 | 7.76 | 3.62 | 5.47 | 6.01 | 2.05 | 4.94 | 4.33 |
| 5 | 5.23 | 5.45 | 3.77 | 4.82 | 5.19 | 2.30 | 5.15 | 4.21 |
| 6 | 5.23 | 6.23 | 3.61 | 5.02 | 4.99 | 2.35 | 5.04 | 4.13 |
| LSD=0.05 | 0.44 | 0.56 | | | NS | 0.24 | | |

Table 5. Average petiole K % as affected by varieties averaged across all K treatments.

| Variety | Petiole K% (peak bloom) | | | | Petiole K% (peak bloom + 10 days) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| STV 373 | 5.38 | 6.21 | 3.57 | 5.05 | 5.46 | 2.30 | 4.90 | 4.22 |
| DP 1218BR | 4.57 | 5.31 | 3.41 | 4.43 | 4.70 | 1.86 | 4.60 | 3.72 |
| FM 958 | 4.73 | 5.66 | 3.61 | 4.67 | 5.37 | 1.91 | 4.76 | 4.01 |
| FM 819 | 5.81 | 5.61 | 3.73 | 5.05 | 5.08 | 2.03 | 5.08 | 4.06 |
| DP 436RR | 4.56 | 5.59 | 3.41 | 4.52 | 6.15 | 1.88 | 4.67 | 4.23 |
| PSC 355 | 4.24 | 5.34 | 3.33 | 4.30 | 4.32 | 1.93 | 4.75 | 3.67 |
| STV 474 | 5.52 | 6.07 | 3.54 | 5.04 | 5.64 | 2.12 | 5.14 | 4.30 |
| BXN 47 | 4.16 | 5.87 | 3.73 | 4.59 | 5.27 | 2.10 | 5.11 | 4.16 |
| LSD=0.05 | 0.51 | 0.65 | | | NS | 0.28 | | |

Table 6. Average cotton lint yield parameters as affected by K treatments averaged across all varieties.

| Treatment # | Boll # | | | | Seed Cotton Weight | | | | Lint Yields lbs/acre | | | | Gin turnout | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| 1 | 7.52 | 8.85 | 6.63 | 7.67 | 11.40 | 12.28 | 11.31 | 11.66 | 1018 | 1005 | 975 | 999 | .40 | .37 | .39 | .39 |
| 2 | 8.39 | 9.40 | 6.52 | 8.10 | 10.99 | 12.40 | 11.08 | 11.49 | 982 | 1015 | 948 | 982 | .40 | .37 | .39 | .39 |
| 3 | 7.99 | 9.10 | 6.18 | 7.76 | 11.15 | 12.66 | 11.78 | 11.86 | 1006 | 1044 | 1012 | 1021 | .41 | .37 | .38 | .39 |
| 4 | 8.84 | 9.05 | 6.56 | 8.15 | 11.34 | 12.62 | 11.72 | 11.89 | 1022 | 1034 | 1011 | 1022 | .40 | .37 | .39 | .39 |
| 5 | 7.72 | 8.85 | 7.13 | 7.90 | 11.70 | 12.22 | 11.85 | 11.92 | 1043 | 1009 | 1048 | 1033 | .40 | .37 | .39 | .39 |
| 6 | 8.69 | 8.54 | 6.81 | 8.01 | 11.43 | 12.17 | 11.84 | 11.81 | 1023 | 996 | 1018 | 1012 | .40 | .37 | .39 | .39 |
| LSD=0.05 | NS | NS | | | NS | 0.51 | | | NS | 43 | | | NS | NS | | |

Table 7. Average cotton lint yield parameters as affected by varieties averaged across all K treatments.

| Variety | Boll # | | | | Seed Cotton Weight | | | | Lint Yields lbs/acre | | | | Gin turnout | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave | 2001 | 2002 | 2003 | ave |
| STV 373 | 9.38 | 9.20 | 6.98 | 8.52 | 10.72 | 11.95 | 8.60 | 10.42 | 977 | 996 | 744 | 906 | .41 | .38 | .38 | .39 |
| DP 1218BR | 7.93 | 9.35 | 6.77 | 8.02 | 11.61 | 11.67 | 13.16 | 12.15 | 1070 | 968 | 1154 | 1064 | .41 | .37 | .39 | .39 |
| FM 958 | 7.02 | 7.95 | 5.73 | 6.90 | 11.41 | 13.42 | 11.27 | 12.03 | 1015 | 1015 | 987 | 1006 | .40 | .37 | .39 | .39 |
| FM 819 | 6.60 | 8.50 | 6.09 | 7.06 | 11.16 | 11.28 | 11.54 | 11.33 | 990 | 990 | 1017 | 999 | .40 | .37 | .40 | .39 |
| DP 436RR | 7.76 | 8.75 | 6.70 | 7.74 | 11.52 | 12.73 | 12.94 | 12.40 | 976 | 975 | 1029 | 993 | .38 | .34 | .36 | .36 |
| PSC 355 | 8.66 | 8.25 | 7.07 | 7.99 | 11.64 | 13.24 | 12.61 | 12.50 | 1010 | 1074 | 1052 | 1045 | .39 | .36 | .37 | .37 |
| STV 474 | 9.38 | 9.55 | 6.58 | 8.50 | 11.62 | 13.11 | 12.50 | 12.41 | 1083 | 1109 | 1148 | 1113 | .42 | .38 | .40 | .40 |
| BXN 47 | 8.82 | 10.56 | 7.18 | 8.85 | 11.00 | 11.58 | 10.14 | 10.91 | 1005 | 969 | 886 | 953 | .41 | .37 | .39 | .39 |
| LSD=0.05 | 1.33 | 1.16 | | | 0.64 | 0.61 | | | 64 | 49 | | | 0.01 | 0.01 | | |

Table 8a. Average fiber quality parameters as affected by K treatments averaged across all varieties.

| Treatment # | Micronaire | | | Length | | | Strength | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average |
| 1 | 4.78 | 4.46 | 4.62 | 1.143 | 1.139 | 1.141 | 31.39 | 32.23 | 31.81 |
| 2 | 4.79 | 4.49 | 4.64 | 1.145 | 1.138 | 1.142 | 31.62 | 31.86 | 3.174 |
| 3 | 4.82 | 4.46 | 4.64 | 1.142 | 1.143 | 1.143 | 31.39 | 32.19 | 31.79 |
| 4 | 4.81 | 4.56 | 4.68 | 1.140 | 1.141 | 1.140 | 31.42 | 31.88 | 31.6 |
| 5 | 4.82 | 4.57 | 4.64 | 1.148 | 1.144 | 1.146 | 31.33 | 31.53 | 31.43 |
| 6 | 4.79 | 4.61 | 4.70 | 1.145 | 1.129 | 1.136 | 31.50 | 31.98 | 31.74 |
| LSD=0.05 | NS | 0.07 | | NS | 0.008 | | NS | 0.54 | |

Table 9a. Average fiber quality parameters as affected by varieties averaged across all K treatments.

| Variety | Micronaire | | | Length | | | Strength | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average |
| STV 373 | 4.61 | 4.22 | 4.42 | 1.146 | 1.162 | 11.54 | 29.76 | 30.41 | 30.09 |
| DP 1218BR | 5.12 | 4.69 | 4.91 | 1.100 | 1.101 | 11.00 | 29.70 | 29.68 | 29.19 |
| FM 958 | 4.77 | 4.53 | 4.65 | 1.161 | 1.162 | 11.61 | 33.91 | 34.94 | 34.43 |
| FM 819 | 4.54 | 4.31 | 4.42 | 1.179 | 1.177 | 11.78 | 34.24 | 34.75 | 34.59 |
| DP 436RR | 4.80 | 4.52 | 4.66 | 1.157 | 1.146 | 11.51 | 30.31 | 30.60 | 30.46 |
| PSC 355 | 4.99 | 4.94 | 4.96 | 1.137 | 1.121 | 11.29 | 32.28 | 32.62 | 32.45 |
| STV 474 | 4.85 | 4.56 | 4.70 | 1.130 | 1.112 | 11.22 | 30.48 | 30.94 | 30.71 |
| BXN 47 | 4.73 | 4.38 | 4.55 | 1.141 | 1.135 | 11.38 | 30.85 | 31.21 | 31.03 |
| LSD=0.05 | 0.07 | 0.08 | | 0.009 | 0.009 | | 0.38 | 0.62 | |

Table 8b. Average fiber quality parameters as affected by K treatments averaged across all varieties.

| Treatment # | Elongation | | | Uniformity | | | Trash | | | +b | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average |
| 1 | 5.73 | 5.11 | 5.42 | 84.03 | 83.08 | 83.55 | 2.2 | 2.4 | 2.3 | 8.31 | 8.65 | 8.48 |
| 2 | 5.72 | 5.13 | 5.43 | 83.87 | 82.79 | 83.33 | 2.1 | 2.4 | 2.3 | 8.28 | 8.84 | 8.57 |
| 3 | 5.82 | 5.15 | 5.48 | 83.85 | 82.84 | 83.34 | 1.9 | 2.7 | 2.3 | 8.21 | 8.77 | 8.49 |
| 4 | 5.74 | 5.06 | 5.40 | 83.87 | 83.09 | 83.48 | 2.2 | 2.6 | 2.4 | 8.22 | 8.77 | 8.49 |
| 5 | 5.76 | 5.12 | 5.44 | 84.20 | 82.97 | 83.58 | 2.3 | 2.5 | 2.4 | 8.24 | 8.86 | 8.55 |
| 6 | 5.74 | 5.31 | 5.53 | 83.98 | 83.23 | 83.61 | 2.2 | 2.9 | 2.6 | 8.22 | 8.77 | 8.49 |
| LSD=0.05 | NS | 0.13 | | NS | 0.22 | | NS | 0.2 | | NS | 0.16 | |

Table 9b. Average fiber quality parameters as affected by varieties averaged across all K treatments.

| Variety | Elongation | | | Uniformity | | | Trash | | | +b | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average | 2001 | 2002 | 2-year Average |
| STV 373 | 5.70 | 4.98 | 5.32 | 83.48 | 82.64 | 83.04 | 2.2 | 2.4 | 2.3 | 8.57 | 8.98 | 8.78 |
| DP 1218BR | 6.15 | 5.54 | 5.85 | 83.90 | 82.65 | 83.28 | 1.5 | 2.1 | 1.8 | 8.50 | 9.13 | 8.82 |
| FM 958 | 4.40 | 3.76 | 4.08 | 83.93 | 83.04 | 83.49 | 2.0 | 2.5 | 2.3 | 7.89 | 8.25 | 8.07 |
| FM 819 | 4.59 | 4.24 | 4.42 | 84.26 | 83.20 | 83.73 | 2.6 | 3.2 | 2.9 | 7.31 | 8.04 | 7.68 |
| DP 436RR | 6.35 | 5.68 | 6.02 | 84.27 | 82.98 | 83.63 | 1.7 | 2.3 | 2.0 | 7.94 | 8.65 | 8.30 |
| PSC 355 | 6.90 | 6.30 | 6.60 | 84.70 | 83.53 | 83.46 | 2.8 | 2.9 | 2.9 | 8.36 | 8.92 | 8.64 |
| STV 474 | 6.07 | 5.46 | 5.76 | 83.63 | 82.92 | 83.28 | 2.3 | 2.4 | 2.4 | 8.67 | 9.21 | 8.94 |
| BXN 47 | 5.86 | 5.19 | 5.53 | 83.56 | 82.95 | 83.26 | 2.0 | 2.7 | 2.4 | 8.72 | 9.15 | 8.93 |
| LSD=0.05 | 0.14 | 0.17 | | 0.36 | 0.26 | | 0.4 | 0.3 | | 0.14 | 0.18 | |

Table 10. Average incidence and severity of Bronze Wilt as affected by K treatments averaged across all varieties.

| Treatment # | Bronze Wilt rating 7-19-2002 | Bronze Wilt rating 7-27-2002 | Bronze Wilt rating 8-3-2002 | Bronze Wilt rating 8-17-2002 |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 |
| LSD=0.05 | NS | NS | NS | NS |

Table 11. Average incidence and severity of Bronze Wilt as affected by K treatments averaged across all K treatments.

| Variety | Bronze Wilt rating 7-19-2002 | Bronze Wilt rating 7-27-2002 | Bronze Wilt rating 8-3-2002 | Bronze Wilt rating 8-17-2002 |
|---|---|---|---|---|
| STV 373 | 0 | 0 | 0 | 0 |
| DP 1218BR | 0 | 0 | 0 | 0 |
| FM 958 | 0 | 0 | 0 | 0 |
| FM 819 | 0 | 0 | 0 | 0 |
| DP 436RR | 0 | 0 | 0 | 0 |
| PSC 355 | 0 | 0 | 0 | 0 |
| STV 474 | 0 | 0 | 0 | 0 |
| BXN 47 | 0 | 0 | 0 | 0 |
| LSD=0.05 | NS | NS | NS | NS |

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

**First Year (2003) Progress report**

David Dunn and Gene Stevens
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## 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 lbK/a), and excessive (200 lbK/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.

Two additional studies were conducted on these reference plots. In one study a Cardy meter was used to determine plant K status. Cardy meter determinations for K were collected three times during the growing season. The results were then compared to traditional plant analysis values. In the second study basal stalk breaking strength was determined and compared to plant tissue K levels. Following harvest 12-inch long basal stalk samples were collected from each plot. These samples were evaluated for breaking strength by progressively adding weights to a cup suspended by a string from the stalk. The weight at which each stalk failed was recorded. These stalks were then dried, ground, and analyzed for K concentration

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 2003:

Data collected during 2003 is presented in Tables 1, 2, and 3 and Figures 1and 2. In 2003 grain yields were significantly increased by both levels of K fertilization (Table 1). Grain yields for the 50 and 200 lbsK/a treatments were statistically equivalent. This indicted that the University of Missouri's revised soil test recommendations for K on rice appear to be appropriate. Flag leaf K levels were greater than lower leaf levels (Table 2). This difference was greater at 10% heading than at internode elongation. Table 3. shows the relationship between tissue K levels and rice grain yields. The best correlation between yields and tissue K levels were found at the first tiller growth stage Tissue K levels of lower leaves were better correlated with yield than flag leaves. Cardy meter determinations were found to compare well with traditional lab tissue analysis (Figure 1). Rice stalk breaking strength was correlated to lower stalk tissue K levels (Figure 2).

This data was presented to 175 rice producers at the 2003 Rice Farm Field Day held 8-27-03 in Qulin, MO and 900 interested parties at the Delta Center Field Day held 9-2-03 in Portageville MO. Results were also presented to 55 crops researchers at the Southern Plant Nutrition Conference held 10-6,7-03 in Olive Branch, MS and to 2,400 crops researchers at the American Society of Agronomy Annual meeting in Denver, CO held 11-3,4,5,6-2003(Appendix 1). Additionally two abstracts for presentations at the 2004 Rice Technical Working Group Conference held in New Orleans, LA have been accepted (Appendix 2 and 3).

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

| Treatment | Yield (bu/a) | Moisture % | Milling Head%/Whole% |
|---|---|---|---|
| O lbs K/a | 95a | 14a | 57a/65a |
| 50 lbs K/a | 112b | 13.5a | 57a/66a |
| 200 lbsK/a | 117b | 13.3a | 56a/66a |

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

| Growth Stage | Plant Part | Tissue K % | | |
|---|---|---|---|---|
| | | 0 lbs K/a | 50 lbs K/a | 200 lbs K/a |
| First tiller | Whole | 2.93 | 3.15 | 3.43 |
| | | | | |
| Internode elongation | Whole | 2.17 | 2.24 | 2.42 |
| Internode elongation | Flag leaf | 1.78 | 2.08 | 2.25 |
| Internode elongation | Lowest leaf | 1.49 | 1.80 | 1.94 |
| Internode elongation | Stem | 2.40 | 2.92 | 3.25 |
| | | | | |
| 10% Heading | Whole | 1.36 | 1.39 | 1.44 |
| 10% Heading | Flag leaf | 1.43 | 1.85 | 1.93 |
| 10% Heading | Lowest leaf | 1.26 | 1.43 | 1.44 |
| 10% Heading | Stem | 0.88 | 1.57 | 1.64 |
| 10% Heading | Head | 0.95 | 1.11 | 0.69 |

Table 3. Correlation of plant tissue K levels with grain yields, 2003.

| Growth Stage | Plant Part | $R^2$ value | Equation |
|---|---|---|---|
| First tiller | Whole | 0.54 | y = 0.03x-0.30 |
| | | | |
| Internode elongation | Whole | 0.37 | y = 0.02x-0.18 |
| Internode elongation | Flag leaf | 0.23 | y = 0.17x+0.24 |
| Internode elongation | Lowest leaf | 0.39 | y = 0.15x-0.22 |
| Internode elongation | Stem | 0.30 | y = 0.036x-1.03 |
| | | | |
| 10% Heading | Whole | 0.32 | y = 0.01x+0.18 |
| 10% Heading | Flag leaf | 0.07 | y = 0.007x+0.75 |
| 10% Heading | Lowest leaf | 0.39 | y = 0.015x-0.22 |
| 10% Heading | Stem | 0.41 | y = 0.03x-0.30 |
| 10% Heading | Head | .003 | y = -0.001x+0.80 |

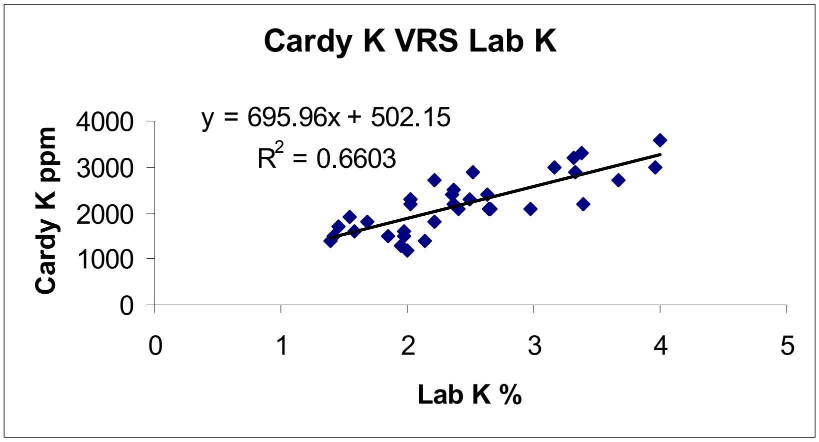



Figure 1. Relationship between Cardy meter K determinations and traditional Lab tissue analysis for rice plants at midseason, 2003.

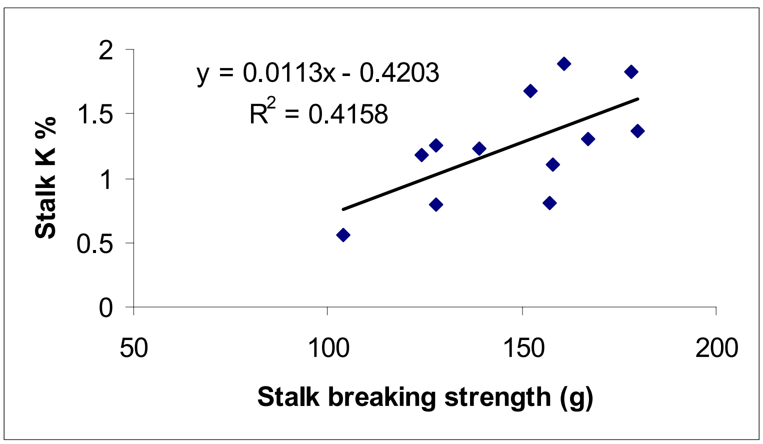



Figure 2. Relationship between rice stalk breaking strength and tissue K levels, 2003.

Appendix 1. Abstract of poster presented at 2003 American Society of Angonomy Annual meeting, Denver CO, 11-6-2003.

Potassium Nutrition of Rice

David J. Dunn and William E. Stevens

Proper potassium (K) nutrition is critical for maximizing rice grain yields. K is mobile within the rice plant. If the developing rice plant is unable to obtain sufficient K from the soil, older leaves are scavenged for the K needed by younger leaves. Profitable rice production hinges on accurate and relevant information about plant-soil interactions. The objective of this study is to correlate rice tissue K levels with grain yields. Reference plots for potassium fertilization were established at the Missouri Rice Research Farm at Qulin, MO. The plots received one of three levels of K fertilization, deficient (0 kg/ha), adequate (56 kg/ha), and excessive (224 kg/ha). 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 divided into plant components i.e. upper leaf, lower leaf, stalk, and whole plant. These tissue samples were dried, ground, digested and analyzed for K%. Each plot was mechanically harvested for yield. Correlations were then made between yield and plant tissue K levels. Potassium fertilization significantly increased rice grain yields (0 kg/ha K = 95 kg/ha grain, 65 kg/ha K = 119 kg/ha grain, and 224 kg/ha K = 140 kg/ha grain). The K content of older leaves was a better indicator of yield limiting K status than younger leaves.

Appendix 2. Abstract of oral presentation to be given at Rice Technical Working Group meeting, New Orleans, LA, 3-1-2003

# Potassium and Rice Production: Missouri Update

Dunn, D.J, Stevens, W.E. and Beighley, D

Proper potassium (K) nutrition is critical for maximizing rice grain yields. Incidences of K deficiency in rice have been increasing in Missouri. A 170 kg-ha$^{-1}$ rice crop removes over 11 kg $K_2O$ ha$^{-1}$ each year. K is very mobile within the rice plant. Older leaves are scavenged for the K needed by younger leaves. 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. The objective of this study was correlate rice tissue K levels with grain yields.

Reference plots for potassium fertilization were established at the Missouri Rice Research Farm at Qulin, MO in 2002 and 2003. These plots received one of three levels of K fertilization, deficient (0 kg $K_20$ ha$^{-1}$), adequate (56 kg $K_20$ ha$^{-1}$), and excessive (224 kg $K_20$ ha$^{-1}$). Soil testing at this site indicated that a K fertilization rate of 56 kg $K_20$ ha$^{-1}$ K was required for optimum rice production. Plant tissue samples were collected from each plot three times during the growing season, first tiller, internode-elongation, and 10% heading. These samples were divided into plant components i.e. flag leaf, lower leaf, stem, and whole plant. These tissue samples were dried, ground, digested using $H_2SO_4$-$H_2O_2$ and analyzed for K% by atomic absorption. Each plot was mechanically harvested for yield. 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)

Flag leaves were found to have greater tissue levels than lower leaves for each K fertilization level. This difference was greater at 10% heading than at internode- elongation. The tissue K levels of lower leaves were better correlated to yield than flag leaves. The two-year average $r^2$ value between K level and yield at 10% heading for lower leaves was 0.42 vrs 0.07 for flag leaves. Potassium fertilization significantly increased rice grain yields (0 kg/ha K = 4536 kg/ha grain, 56 kg/ha K = 5494 kg/ha grain, and 224 kg/ha K = 6098 kg/ha grain).

Appendix 3. Abstract of poster to be presented at the Rice Technical Working Group meeting, New Orleans, LA, 3-1-2003.

## Using a Cardy Meter to Determine Rice Potassium Status at Mid-season

Dunn, D.J., Stevens, W.E., Kenty, M and Beighley, D.

The increased cost of rice production paired with low commodity prices necessitates more efficient nutrient management for the crop. The ability to monitor nutrient levels throughout the growing season is critical. This allows detected deficiencies to be corrected on a timely basis and improves the possibility of achieving optimal yields. Plant tissue analysis is available to the producer from university and independent labs. A common problem of traditional lab analysis is the time lag between sample collection and results returned to the crop advisor. Sampling and conducting the tissue analysis the same day can eliminate this time lag.

One method of same day analyses is the Cardy portable electrode-based ion meters (Horiba, Ltd., Kyoto, Japan). The Cardy K ion meter offer crop advisors the ability to quickly evaluate crop K levels. Cardy meters have been widely used in vegetable production with $NO_3$-N and K thresholds established for several crops.

This study evaluates the Cardy meter as a tool for determining in-season rice plant K status. Plots with one of three levels of K fertilization were established. Three times during the growing season tissue samples were collected from each plot. These times were internode-elongation (IE), IE + 7 days, and IE + 14 days. These tissue samples were then analyzed for K content by two different methods. Approximately 30 cm of row from each plot was collected. The above ground portion of this sample was separated from the roots using a garden pruning shear. The remaining portion of the lower stem was washed of soil and algae using tap water. The basal 10 cm of the plants were separated from the leaves and retained for analysis. These stems sections were dried with paper towels. Half the stems were then placed oriented up and the other half oriented down. Five cm from each sample was cut into one cm pieces. These pieces were frozen over night and sap was extracted using a sap press. The extracted sap was then analyzed for K content using the Cardy meter. The remaining five cm of sample was dried and ground, digested using $H_2SO_4$ and $H_2O_2$. The results of these two analyses were then compared.

It was difficult to extract sap from the rice stems. At growth stages before IE there was not enough stem tissue available to extract the sap. As the sampling occurred after establishment of a permanent flood several problems were encountered. Algae were some times present on the basal stem. Washing with tap water was necessary to remove the algae. Drying of the stems with paper towels was then necessary to remove the tap water. If the water was not removed before sap extraction the Cardy meter determinations were quite variable. Freezing the stems overnight served to rupture the cell walls within the stems and allow more sap to be extracted.

The Cardy meter determinations were well correlated to traditional lab K analysis, with an $r^2$ value of 0.66.

# 2004

## Effect of Potassium Fertilization on Leafhopper Tolerance and Persistence of Alfalfa

C. Jerry Nelson, Rob Kallenbach and Wayne Bailey

Objectives:

1. Determine effect of K-fertilization on leafhopper tolerance.
2. Measure effect of glandular hairs on leafhopper tolerance.
3. Evaluate interaction of K-fertilization and glandular hairs on alfalfa persistence.

Background for Research:

Potato leafhopper is likely the most serious pest of alfalfa in Missouri, costing alfalfa producers more than $1 million per year due to costs for control treatments and losses of production and quality when not controlled. Alfalfa weevil, another major alfalfa pest, is more predictable, with damage limited largely to the first harvest, and with clearly visible symptoms. In contrast, potato leafhoppers are small (Fig. 1), infestations are less predictable, and scouting with a sweep net is needed to determine threshold levels for treatment. The typical symptoms of leaf yellowing and stunted growth appear after the damage is done and insecticide treatments after visible symptoms appear are ineffective. Thus, preventive measures, such as selection of a glandular-haired variety, using good soil fertility practices (especially K) to maintain stand health, and using IPM methodologies for detection and early control of potato leafhopper can be effective and provide economic alternatives to routine scheduled sprays.

Our goal has been to evaluate effects of glandular hairs on new alfalfa varieties and rates of K fertilization on populations of potato leafhopper and stand persistence. The experiment is being conducted at the Forage Systems Research Center near Linneus in North Central Missouri. Soil is Lagonda silt loam that slopes to an Armstrong silty clay loam. The site was selected in 2000 based on 1998 soil tests. Lime and P were applied according to soil-test recommendations. Our first two seeding attempts (fall, 2000 and spring, 2001) did not give stands that were uniform enough for the project, so the area was tilled and reseeded in fall, 2001. That stand was excellent. We retested the soil in October, 2001, and topdressed the plot area with 400 lbs of 0-46-0 to increase seedling vigor and develop good ground cover to enhance survival over winter.

Eight blocks (four replicates of two alfalfa varieties) of 2 acres each were established. One variety (normal) has smooth stems and leaves (PLH susceptible) whereas the other variety (PLH resistant) has glandular hairs that deter infestation and feeding by potato leafhoppers (Figure 1). Sub-plots were 1) no insecticide (control), 2) insecticide applied when the leafhopper population reached economic threshold (IPM standard), and 3) insecticide applied to the regrowth 7 days and 21 days after harvests 1 and 2 (scheduled spray). Insect treatments were subdivided into K treatments of 0, 125, and 250 lbs/acre annually, half applied after the harvest 1 and half applied after harvest 4 in mid-September. After the experiment began, all plots received annual applications of P (75 lbs/acre) after harvest 4. We initiated the experiment with the insect and K treatments beginning after harvest 1 in 2002. Data were collected in 2002, 2003 and 2004.

### Changes in Soil Test for K

Soil K levels were moderate when the experiment began, and the pH of 6.7 was in the optimum range for alfalfa. Soil test K has gradually decreased in the 0-K treatment (Table 1) and to a lesser extent in the 125-K treatment. The 250-K treatment is maintaining the soil test value with yields of about 5.5 tons/acre annually (Table 2), which would be consistent with a removal rate of about 50 lbs K/ton of forage. Thus, the K-tests are decreasing, especially at the low application rates (Table 1). This is desired for our research as our hypothesis is that plants at low-K levels will be less resistant to the potato leafhopper.

We plan to take samples for soil tests again after harvest 1 in 2005. Our expectation is the soil tests for K will continue to decrease, especially at the lower fertilization rates as the productive stand uses more K annually than is applied. In addition, we propose to take some tissue samples for K analysis during times when leafhoppers are in the stand. Our hypothesis is that tissue-K may be more important than soil-test K for conferring resistance to the potato leafhopper. The upper third of the canopy will be sampled midway in growths that constitute harvest 2 and harvest 3 because these growths are commonly attacked.

**Leafhopper Populations**

Leafhoppers typically arrive in Missouri about May 5 in winds from the southwest and lay eggs that develop into a damaging population of nymphs. The life cycle in Missouri is such that leafhopper populations rarely reach economic levels prior to harvest 1 (Figure 2). Generally, few leafhoppers are found during regrowth after harvest 3, and this has also been the case in our research. We counted both the adults and the nymphs (immature, non-mobile stage), and in all three years the adult component was much greater than the nymph component.

After harvest 1, the population of leafhoppers increased rapidly during early to mid-June each year. In 2002, the PLH-resistant variety in the no-spray treatment (control) had 30% fewer leafhoppers than did the normal variety. However, 2003 both varieties had nearly the same potato leafhopper populations as the infestation built rapidly in early June. The very rapid increase in 2003 was unexpected, especially for the glandular-haired variety, and even the scheduled spray treatment did not keep the population in check (compare treatments for 2003 in Figure 2). After increasing rapidly, leafhopper populations declined in the PLH-resistant variety suggesting some control while they continued to increase in the normal variety. Except for this period, the scheduled spray treatment did an excellent job of control between harvests in all years. Some oscillations occurred in the leafhopper populations, mainly due to weather events.

Leafhopper populations exceeded the IPM thresholds in 2002 and 2003, but not in 2004 (Figure 2). In 2002, the normal variety reached the economic threshold only 7 days after harvest 1. Yield of harvest 2 was 0.67 tons/acre for the normal variety with no spray compared with 0.88 tons/acre for the PLH-resistant variety with no spray, showing the value of the glandular hairs. In harvest 3 of 2002 the leafhopper population in the control treatment developed slower, did not reach the same level, and did not affect alfalfa yield (both treatments yielded 0.87 tons/acre).

In 2002 and 2003, except for the harvest 3 of 2003 when the economic threshold was not reached, a single insecticide application in the IPM treatment controlled the leafhoppers until the next harvest date. In 2004, with the unique weather patterns, the leafhopper populations did not reach economic threshold in any harvest. Even so, the populations in the PLH resistant variety were about 55-75% those in the normal variety, again showing the resistance even at low populations. Therefore, over the 3-year period, the scheduled spray treatment required 12 sprays whereas only three were needed when treatment was based on scouting and IPM thresholds.

The K fertilization treatment did not affect leafhopper populations in 2002. On June 18, 2003, however, there were about 20% more adults in the high K treatment than the control, but the K treatments of 125 and 250 lb/acre had significantly fewer nymphs, the most damaging form (data not shown). On July 17, 2003 there were again significantly fewer nymphs on the 250 lb/acre K treatment than on the 0 and 125 lb/acre K treatments. The trend was not as consistent in 2004 with the lower populations of both adults and nymphs. In 2004, however, we noted that the proportion of nymphs was highest (27-37% of total leafhoppers) one week after harvest 1 or harvest 2, after which the proportion decreased to less than 5% at 2 week before increasing again to 7-11% at 3 weeks and to about 25% at 4 weeks. The change was consistent for each regrowth and was largely due to oscillations in the adult population as the nymph populations were relatively stable. These data are preliminary and we expect more definitive results in the future as differentials in K treatments broaden.

### Alfalfa Yields

Insect treatments did not affect yield in 2002, 2003, or 2004 except for the variety difference in the control treatment at harvest 2 of 2002, harvest 3 of 2003, and harvest 4 of 2004 (Table 3). In all years, the yields of the two varieties were similar in harvest 1 as potato leafhopper infestations were very low or absent. Thus, the glandular-haired character is always effective, but advantageous only when insect populations are at or exceed the established thresholds. These resistance responses have caused Extension agents in some other states to increase the economic threshold populations for glandular-haired varieties by three times (or more) compared with that for normal varieties. Our data can not be used to verify those suggestions.

Alfalfa yields were not affected by K fertilization rate in 2002 (Table 3), mainly because the treatments were initially applied after harvest 1, and only half the K was applied. The differential in K did not have a major influence on yield during the lower yielding periods of summer, 2002, even though that is the time when potato leafhopper damage is most likely. The rest of the K was applied after harvest 4.

Effects of K rates on yield became apparent in 2003, mainly in harvest 2 when populations of potato leafhopper increased rapidly regardless of insecticide treatment. Total yields in 2003 for K rates of 125 and 250 lbs/acre were higher than the control ($p<0.06$). In 2004, the trend continued with the 125 and 250 lb K-treatments yielding more than the 0-K control, with total annual yield being about 0.65 tons/acre higher. This suggests that the K treatments are beginning to separate, high K removal will continue to decrease the soil-test K and may affect the tissue-K level and the leafhopper tolerance of the plants.

### Changes in Plant Density

Stands of both varieties were good in early June, 2002, when plant density was counted after harvest 1 (Table 2). The K and leafhopper treatments had not begun so there was no effect on plant density due to K or insect control. We did note, however, that plant density of the PLH-resistant variety was about 30% higher than the normal variety. The seed of the normal variety was coated (adding 30% in weight) so the pure live seed planted per unit of “seed” weight was also lower. One advertised advantage of coating is that germination and seedling survival are improved, so the same seeding rate, based on seed weight, should have given a similar stand. That did not occur here, and the perceived value of the seed coating was not realized. This result should be tested further under Missouri conditions.

Plant density was determined again after harvest 4 in 2002 and after harvests 1 and 4 in 2003 and

2004 (Table 2). The plant density for all treatments gradually decreased with time, but the change was not affected by the insect management strategy. As the stands lost plants, the PLH-resistant variety continued to maintain its advantage of higher plant density over the normal variety, and the high-K treatment retained its initial advantage over the control (due to natural effects of field variation despite plot randomization). This is consistent with earlier seeding rate studies. Based on earlier studies we do not expect reductions in forage yield due to low plant density until the stand has fewer than four plants/sq ft. Yield is maintained because the remaining plants with high K have sufficient capacity to produce and elongate additional stems from the crown to offset the loss of nearby plants and to maintain a high number of stems/sq ft.

As the stands thin with time, i.e., plants/sq ft decrease, the number of stems/plant that contributes to yield at a given harvest will increase. This is evident from the first harvest in 2002 when plant density was high for both varieties, and number of stems/plant was inversely related to plant density, averaging 2.4 stems/plant for the PLH-resistant variety and 2.9 stems/plant for the normal variety. As the stands thinned the stems/plant gradually increased. We expect the stems/plant to show a K effect as stands thin, especially as it approaches four plants/sq ft. The effect of the leafhopper treatments may be accentuated at that time as the plants will be less vigorous and more stressed. A goal is to continue to follow the stand reduction for a longer time.

Similar to the May count in 2002, despite the continued thinning of the stand plant densities after harvests 1 and 4 in 2003 and again in 2004 did not differ due to the K or leafhopper treatments. But the PLH-resistant variety, which began with about 30% more plants/sq ft than the normal variety, thinned at a faster rate such that densities were similar for the varieties in 2004. This was expected as plant competition is stronger with more plants. We counted stems/plant allowing us to calculate stems/sq ft (data not shown). Despite the 30% lower plant density, by mid-September the crowns of the normal variety had expanded to have only 8% fewer stems/sq ft, mainly because the lower plant density was offset by having 23% more stems/plant (Table 2). In other studies we found that alfalfa plants in stands with low densities tend to develop larger crowns and support more stems. We calculated the weight (yield) per stem using yield data for the harvest just prior to the plant and stem counts. The yield enhancement that was showing up in 2004 due to maintaining a high K soil test was due almost exclusively to greater weight per stem. This response may be due to more rapid regrowth allowing the canopy to capture more of the radiation early in the regrowth period.

We expected little effect on plant density due to K fertilization or leafhopper control this early in the experiment because the young plants are vigorous and are thinning mainly due to plant competition for light. This is also indicated by the rapid loss of plants during the summer period, when plant to plant competition for light, minerals and water is strong. We expect stems/sq ft to remain stable for both varieties until plant density is reduced to about four plants per sq ft. Thereafter, the reduced ability of the crown to spread with low K will not completely offset the continued plant loss, resulting in a gradual yield decrease. Thus, as stands thin, the ability of the crown to spread or compensate for plant loss will be compromised by low K and the detrimental effects from leafhoppers will be more evident.

<u>Objectives for Year 4 (2005):</u>

The 3-years of funding for this project expired at the end of 2004, but we have requested an extension. The objectives are to continue the experiment, but add some more to the data collection as the stands thin. It is anticipated the

K effect will be expressed even more dramatically if leafhopper populations are high, so we will continue to monitor alfalfa weevil and especially potato leafhopper throughout the growing season to get more years of data for evaluating year-to-year effects. The control, IPM and scheduled spray treatments will be maintained. Forage yield will be measured. We will use the sod cutter to lift alfalfa plants from the soil for accurate counting after harvests 1 and 4. As before, stems/plant will also be counted.

We will take soil samples each year after harvest 1 to continue to monitor the soil-test K levels and any other nutrients that may be changing. We will also take tissue samples from the upper third of the canopy about midway through the regrowth periods that contribute to harvests 2 and 3. Our expectation is that tissue-K at low-K application rates may decrease faster with time than will the soil test and yield response. The tissue-K is likely more closely associated with leafhopper resistance than is soil-K. The University Soil Test lab has a new instrument for accurately measuring minerals in plant tissues.

Other funds were used in 2001 to establish the stand. We knew we it would take 3 years (2002, 2003, and 2004) to get good base data on responses, but that the stands would likely last longer. So far the stands have begun to thin, but are still above threshold population of 3-4 plants/sq ft for yield responses. The K will help sustain the stand by enhancing crown development. We hope to continue this integrated experiment beyond 2004 as it is contributing to our knowledge of the insect and how interactions of crop management strategies affect an important pest in an environmentally friendly way.

**Summary of Findings to Date**

1. Potato leafhoppers apparently migrate to Missouri too late to build populations that cause a yield loss prior to harvest 1 that occurs in mid-to late May. Similarly, the populations are low or non-existent after harvest 3 (about August 5) in a 4-cut system. Thus, major concerns are with the growths following harvests 1 and 2.

2. The leafhopper populations on the alfalfa variety with glandular hairs were consistently 25 to 45% lower than for the control cultivar. The effects were similar for the adult and the nymph forms of the leafhopper.

3. In our Missouri studies, the leafhopper population consisted mainly of adults, which contrasts other states where the main stage is nymphs. We have no explanation for this observation, but adults are generally regarded as being less damaging than nymphs to alfalfa plants.

4. During the first 3 years of the experiment, the rate of K fertilization has not altered the leafhopper populations in either variety.

5. Alfalfa yields did not respond to K fertilizer until the soil-test K had decreased to 133 lbs/acre. The primary component affected by K was weight or yield per stem. This is similar to our earlier research, in which a transition occurred when the stand thinned to fewer than 4 plants/sq.ft. With the thinner stand, high K rates stimulated crown activity so when a plant died the adjacent plants developed more stems/plant to maintain the threshold number of stems/sq ft. Maintaining the high number of stems/sq ft helps minimize weed invasion and associated competition that further weakens thin stands when K is low.

6. In this study the PLH resistant variety began with more plants/sq ft because, without coating, the effective seeding rate was higher. But the plant density decreased for both varieties, especially the PLH resistant one due to more plant-to-plant competition. Plant density of the varieties decreased at different

rates (due to competition) and after 3 production years both varieties had similar densities. We expect the two will remain similar as they continue to thin until they reach a density of about 4 plants/sq ft, after which the variety in which crown development responds best to K may thin slower, very likely the PLH-resistant one as leafhoppers will cause less stress to those plants allowing them to spread the crown.

7. It is important to dig roots of alfalfa for counting as often 2, 3, and sometimes 4 plants will coexist as one (see 2003 report). The way the “clump” thins is important to understand, i.e., do all plants in a clump die at the same time? Or, do stronger plants persist until only one is left? Unfortunately, the current experiment is not designed to give that answer.

8. In this study, like others, the plant density gradually declines as the stand ages. In our case, a similar number of plants disappeared during summer as during winter, i.e., between May and September and between September and May, respectively. Summer death is likely due to stresses of diseases, insects and severe competition among plants. Winter death is likely due to diseases, winter kill, and some plant heaving, but the latter two were minimized by taking harvest 4 before September 15, allowing a tall stubble to be maintained over winter to help moderate soil temperature changes. Effects of leafhopper control and K fertilization will become more evident as the stand thins.

Figure 1. Electron micrographs of a potato leafhopper (left) and of glandular hairs on an alfalfa leaf (right). The hairs are multi-cellular extensions of epidermal cells, and can be upright or flat. The upright hairs are the more effective than flat hairs in conferring resistance. The sticky exudates from the hair ends and the physical structure of the upright hairs are deterrents to egg laying and feeding by the leafhoppers. Some nymphs can actually be entrapped by the sticky hairs.

Table 1. Soil test results from samples taken at different times prior to and during the experimental period. Plots were established in fall, 2001. Samples were taken to 6 inches.

| Sampling Date | Sampled Area | Remarks | K | pH | P |
|---|---|---|---|---|---|
| | | | lb/a | | lb/a |
| July 14, 1998 | Field | Prepare for establishment | 192 | 6.0 | 22 |
| April 26, 2002 | Field | Before insect and K started | 184 | 6.7 | 63 |
| May 28, 2003 | 0 – K plots | K treatments in 2003 and and 2004 were applied after harvest 1 | 142 | 6.4 | 45 |
| | 125 – K plots | | 145 | 6.5 | 54 |
| | 250 – K plots | | 147 | 6.5 | 55 |
| June 7, 2004 | 0 – K plots | | 108 | 6.4 | 65 |
| | 125 – K plots | | 133 | 6.5 | 74 |
| | 250 – K plots | | 154 | 6.3 | 67 |

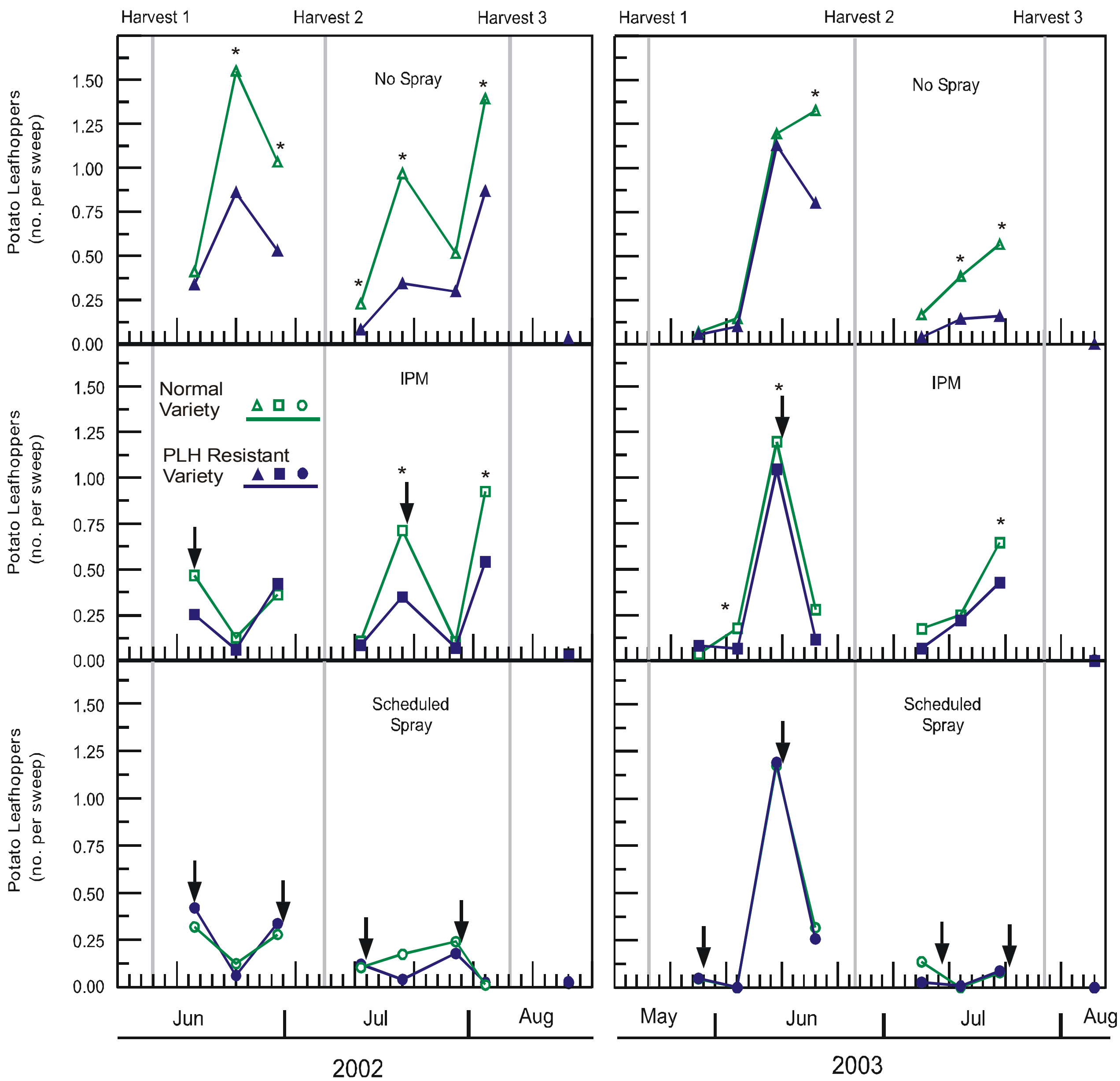



Figure 2. Top panel shows populations of potato leafhopper between harvest dates in the no-spray treatment (control). Note the relative control provided by the PLH-resistant variety compared with the normal variety. Middle panel shows the populations in the spray treatment based on IPM, with dates of needed sprays indicated by arrows. Note the excellent control after the spray. The lower panel shows the populations in the scheduled spray treatment with the arrows showing spray dates scheduled 7 and 21 days after harvests 1 and 2. Leafhoppers were not found previous to harvest 1 and only a few were detected after harvest 3. Asterisks (*) indicate dates when populations are significantly different ($p<0.05$) between varieties.

Leafhopper populations are not shown for 2004 because they did not reach threshold levels during any growth period. Similar to other years very few leafhoppers were detected in 2004 prior to harvest 1 and after harvest 3.

Table 2. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on plant density and stems/plant on several dates in 2002, 2003 and 2004.

| Summary of | Plant Density | | | | | | Stems/plant | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| treatments | 6-02 | 9-02 | 5-03 | 9-03 | 5-04 | 9-04 | 9-02 | 5-03 | 9-03 | 5-04 | 9-04 |
| | ----------------------no./sq. ft. ------------------------------ | | | | | | -------------------------------no. ---------------------- | | | | |
| Insect control | | | | | | | | | | | |
| No spray | 20.3 | 18.9 | 18.9 | 11.3 | 10.2 | 9.8 | 2.7 | 3.4 | 6.7 | 4.1 | 3.8 |
| IPM spray | 18.3 | 18.6 | 16.3 | 11.7 | 11.8 | 10.6 | 2.6 | 3.1 | 6.7 | 3.7 | 3.7 |
| Scheduled | 18.7 | 17.9 | 15.0 | 11.0 | 11.7 | 10.2 | 2.7 | 3.1 | 6.6 | 3.7 | 3.8 |
| Pr > F* | 0.56 | 0.66 | 0.64 | 0.59 | 0.22 | 0.35 | 0.28 | 0.55 | 0.88 | 0.27 | 0.60 |
| LSD (0.05)** | NS*** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| <u>K treatment</u> | | | | | | | | | | | |
| 0 lbs/acre | 18.2 | 17.8 | 15.1 | 10.9 | 11.0 | 10.0 | 2.8 | 3.2 | 6.8 | 4.0 | 3.8 |
| 125 lbs/acre | 18.5 | 18.4 | 14.5 | 10.8 | 11.0 | 10.1 | 2.7 | 3.3 | 6.8 | 3.8 | 3.8 |
| 250 lbs/acre | 20.7 | 19.1 | 16.7 | 12.3 | 11.7 | 10.5 | 2.5 | 3.1 | 6.4 | 3.7 | 3.7 |
| Pr > F | 0.18 | 0.58 | 0.10 | 0.02 | 0.81 | 0.60 | 0.12 | 0.49 | 0.46 | 0.66 | 0.73 |
| LSD (0.05) | NS | NS | NS | 1.1 | NS | NS | NS | NS | NS | NS | NS |
| Variety | | | | | | | | | | | |
| PLH resistant | 22.3 | 21.0 | 17.7 | 12.6 | 11.8 | 10.2 | 2.4 | 3.0 | 6.0 | 3.7 | 3.6 |
| Normal | 15.9 | 15.9 | 13.1 | 10.0 | 10.7 | 10.2 | 2.9 | 3.4 | 7.4 | 4.0 | 3.9 |
| Pr > F | 0.01 | 0.01 | 0.01 | 0.01 | 0.09 | 0.93 | 0.01 | 0.01 | 0.01 | 0.16 | 0.05 |
| LSD (0.05) | 2.3 | 1.8 | 1.4 | 0.9 | NS | NS | 0.2 | 0.3 | 0.6 | NS | 0.3 |

* Probability values of 0.05 or lower indicate the treatment means are significantly different

** LSD indicates the difference among means that is needed to be statistically different

*** NS = not significant

Table 3. Effects of potato leafhopper control treatments, potassium fertilization rates, and varieties (PLH-resistant vs. normal) on yield of alfalfa at each of four harvests in 2002, 2003 and 2004. Harvest dates and total annual yields are also shown

| | 2002 | | | | | 2003 | | | | | 2004 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Summary of treatments | H-1 6-10 | H-2 7-08 | H-3 8-09 | H-4 9-10 | Total Yield | H-1 5-19 | H-2 6-25 | H-3 7-29 | H-4 9-11 | Total Yield | H-1 5-17 | H-2 6-22 | H-3 7-26 | H-4 9-16 | Total Yield |
| | | | | | | ------tons / acre-- | | | | | | | | | |
| Insect treatment | | | | | | | | | | | | | | | |
| No spray | 2.52 | 0.77 | 0.87 | 0.96 | 5.12 | 1.92 | 1.81 | 0.42 | 0.36 | 4.51 | 2.53 | 1.63 | 1.49 | 1.02 | 6.67 |
| IPM spray | 2.46 | 0.84 | 0.84 | 0.93 | 5.07 | 1.89 | 1.74 | 0.41 | 0.36 | 4.40 | 2.48 | 1.55 | 1.45 | 0.98 | 6.46 |
| Scheduled spray | 2.67 | 0.79 | 0.87 | 0.92 | 5.24 | 1.95 | 1.81 | 0.45 | 0.34 | 4.55 | 2.50 | 1.52 | 1.45 | 1.08 | 6.56 |
| Pr>F* | 0.65 | 0.29 | 0.22 | 0.45 | 0.81 | 0.35 | 0.23 | 0.47 | 0.51 | 0.36 | 0.84 | 0.06 | 0.59 | 0.09 | 0.40 |
| LSD (0.05)** | NS*** | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| K treatment | | | | | | | | | | | | | | | |
| 0 lbs/acre | 2.55 | 0.80 | 0.91 | 0.91 | 5.17 | 1.89 | 1.69 | 0.44 | 0.33 | 4.35 | 2.39 | 1.58 | 1.26 | 0.90 | 6.13 |
| 125 lbs/acre | 2.61 | 0.80 | 0.85 | 0.95 | 5.21 | 1.92 | 1.82 | 0.45 | 0.38 | 4.57 | 2.56 | 1.57 | 1.57 | 1.09 | 6.79 |
| 250 lbs/acre | 2.49 | 0.80 | 0.82 | 0.95 | 5.05 | 1.94 | 1.86 | 0.40 | 0.35 | 4.55 | 2.57 | 1.55 | 1.56 | 1.09 | 6.77 |
| Pr>F | 0.56 | 0.99 | 0.19 | 0.64 | 0.72 | 0.28 | 0.01 | 0.47 | 0.19 | 0.06 | 0.01 | 0.68 | 0.01 | 0.01 | 0.01 |
| LSD (0.05) | NS | NS | NS | NS | NS | NS | 0.08 | NS | NS | NS | 0.08 | NS | 0.09 | 0.05 | 0.24 |
| Variety | | | | | | | | | | | | | | | |
| PLH resistant | 2.61 | 0.83 | 0.86 | 0.95 | 5.25 | 1.91 | 1.77 | 0.45 | 0.37 | 4.50 | 2.53 | 1.57 | 1.45 | 1.06 | 6.61 |
| Normal | 2.49 | 0.77 | 0.86 | 0.93 | 5.04 | 1.93 | 1.81 | 0.41 | 0.33 | 4.48 | 2.48 | 1.56 | 1.48 | 0.99 | 6.51 |
| Pr>F | 0.07 | 0.01 | 0.77 | 0.55 | 0.07 | 0.57 | 0.12 | 0.04 | 0.01 | 0.70 | 0.09 | 0.73 | 0.32 | 0.01 | 0.12 |
| LSD (0.05) | NS | 0.05 | NS | NS | NS | NS | NS | 0.04 | 0.02 | NS | NS | NS | NS | 0.04 | NS |

* Probability values of 0.05 or lower indicate the means are significantly different

** LSD indicates the difference among treatment means that is needed to be statistically different

** NS = not significant

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

**Second Year (2004) Progress 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 2004. In this study 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), all were applied pre-plant. At boot stage the 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 2004:**

Data collected during 2004 is presented in Tables 1, 2, 3, and Figure 1. In 2003 grain yields were significantly increased by both levels of K fertilization (Table 1). 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 appear to be 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).
Figure 1 shows the effect of K fertilization at boot stage on rice yields at varying pre-flood soil test K

levels. Rice grain yields were increased by late season potassium in plots that tested low in K at pre-flood. However yields were not increased to the levels of plots that received adequate pre-plant K fertilization. Plots that tested high in K at pre-flood did not respond to K fertilizers applied at boot. These results show the importance of proper K nutrition at early stages of rice growth.

This data was presented to 175 rice producers at the 2003 Rice Farm Field Day held 8-24-04 in Qulin, MO and 900 interested parties at the Delta Center Field Day held 9-2-04 in Portageville MO. Results were also presented to 55 crops researchers at the Southern Plant Nutrition Conference held 10-7,6-03 in Olive Branch, MS. Additionally oral and poster presentations were made at the 2004 Rice Technical Working Group Conference held in New Orleans, LA before an audience of 250 rice researchers and consultants (Appendix 1 and 2). Data from this project was used in Certified Crop Advisor Continuing Education presented to 50 persons at the Delta Center 12-9-2004. 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 (in press).

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

| Treatment | Yield (bu/a) | Moisture % | Milling Head%/Whole% |
|---|---|---|---|
| O lbs K/a | 168a | 14.3a | 58a/65a |
| 50 lbs K/a | 190b | 14.6a | 57a/66a |
| 200 lbsK/a | 192b | 15.0a | 56a/65a |

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

| Growth Stage | Plant Part | Tissue K % | | |
|---|---|---|---|---|
| | | 0 lbs K/a | 50 lbs K/a | 200 lbs K/a |
| First tiller | Whole | 2.53 | 2.99 | 2.62 |
| | | | | |
| Internode elongation | Whole | 2.19 | 2.27 | 2.82 |
| Internode elongation | Flag leaf | 1.85 | 2.34 | 2.37 |
| Internode elongation | Lowest leaf | 1.62 | 1.99 | 2.24 |
| Internode elongation | Stem | 2.77 | 2.88 | 3.20 |
| | | | | |
| 10% Heading | Whole | 1.50 | 1.71 | 1.74 |
| 10% Heading | Flag leaf | 1.60 | 1.56 | 1.73 |
| 10% Heading | Lowest leaf | 1.45 | 1.39 | 1.37 |
| 10% Heading | Stem | 1.47 | 1.28 | 1.49 |
| 10% Heading | Head | 0.92 | 0.91 | 0.86 |

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

| 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)… | | |
| First tiller | 131 | 154 | 220 | 3.5 | 4.5 | 5.7 |
| Inter-node elongation | 1770 | 2070 | 1853 | 33.1 | 44.7 | 52.8 |
| 100% heading | 6734 | 7055 | 7660 | 101 | 120 | 131 |

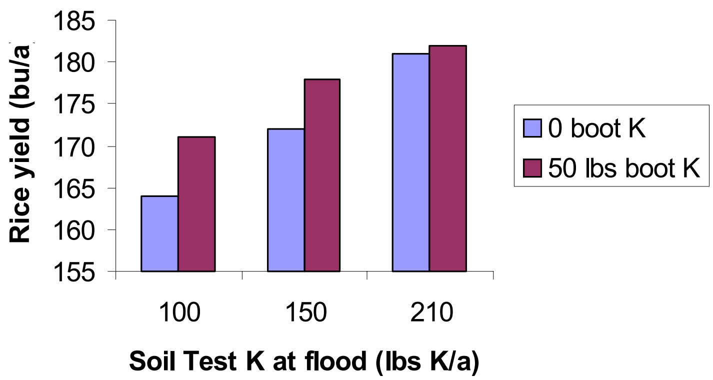



Figure 1. Rice response to K fertilization at boot growth stage for varying pre-flood soil test K levels, 2004

Appendix 1. Abstract of oral presentation given at the Rice Technical Working Group meeting, New Orleans, LA, 3-1-2003

Potassium and Rice Production: Missouri Update

Dunn, D.J, Stevens, W.E. and Beighley, D

Proper potassium (K) nutrition is critical for maximizing rice grain yields. Incidences of K deficiency in rice have been increasing in Missouri. A 170 kg-$ha^{-1}$ rice crop removes over 11 kg $K_2O$ $ha^{-1}$ each year. K is very mobile within the rice plant. Older leaves are scavenged for the K needed by younger leaves. 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. The objective of this study was correlate rice tissue K levels with grain yields.

Reference plots for potassium fertilization were established at the Missouri Rice Research Farm at Qulin, MO in 2002 and 2003. These plots received one of three levels of K fertilization, deficient (0 kg $K_20$ $ha^{-1}$), adequate (56 kg $K_20$ $ha^{-1}$), and excessive (224 kg $K_20$ $ha^{-1}$). Soil testing at this site indicated that a K fertilization rate of 56 kg $K_20$ $ha^{-1}$ K was required for optimum rice production. Plant tissue samples were collected from each plot three times during the growing season, first tiller, internode-elongation, and 10% heading. These samples were divided into plant components i.e. flag leaf, lower leaf, stem, and whole plant.

These tissue samples were dried, ground, digested using $H_2SO_4$-$H_2O_2$ and analyzed for K% by atomic absorption. Each plot was mechanically harvested for yield. 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)

Flag leaves were found to have greater tissue levels than lower leaves for each K fertilization level. This difference was greater at 10% heading than at internode- elongation. The tissue K levels of lower leaves were better correlated to yield than flag leaves. The two-year average $r^2$ value between K level and yield at 10% heading for lower leaves was 0.42 vrs 0.07 for flag leaves. Potassium fertilization significantly increased rice grain yields (0 kg/ha K = 4536 kg/ha grain, 56 kg/ha K = 5494 kg/ha grain, and 224 kg/ha K = 6098 kg/ha grain).

Appendix 2. Abstract of poster presented at the Rice Technical Working Group meeting, New Orleans, LA, 3-1-2003.

## Using a Cardy Meter to Determine Rice Potassium Status at Mid-season

Dunn, D.J., Stevens, W.E., Kenty, M and Beighley, D.

The increased cost of rice production paired with low commodity prices necessitates more efficient nutrient management for the crop. The ability to monitor nutrient levels throughout the growing season is critical. This allows detected deficiencies to be corrected on a timely basis and improves the possibility of achieving optimal yields. Plant tissue analysis is available to the producer from university and independent labs. A common problem of traditional lab analysis is the time lag between sample collection and results returned to the crop advisor. Sampling and conducting the tissue analysis the same day can eliminate this time lag.

One method of same day analyses is the Cardy portable electrode-based ion meters (Horiba, Ltd., Kyoto, Japan). The Cardy K ion meter offer crop advisors the ability to quickly evaluate crop K levels. Cardy meters have been widely used in vegetable production with $NO_3$-N and K thresholds established for several crops.

This study evaluates the Cardy meter as a tool for determining in-season rice plant K status. Plots with one of three levels of K fertilization were established. Three times during the growing season tissue samples were collected from each plot. These times were internode-elongation (IE), IE + 7 days, and IE + 14 days. These tissue samples were then analyzed for K content by two different methods. Approximately 30 cm of row from each plot was collected. The above ground portion of this sample was separated from the roots using a garden pruning shear. The remaining portion of the lower stem was washed of soil and algae using tap water. The basal 10 cm of the plants were separated from the leaves and retained for analysis. These stems sections were dried with paper towels. Half the stems were then placed oriented up and the other half oriented down. Five cm from each sample was cut into one cm pieces. These pieces were frozen over night and sap was extracted using a sap press. The extracted sap was then analyzed for K content using the Cardy meter. The remaining five cm of sample was dried and ground, digested using $H_2SO_4$ and $H_2O_2$. The results of these two analyses were then compared.

It was difficult to extract sap from the rice stems. At growth stages before IE there was not enough stem tissue available to extract the sap. As the sampling occurred after establishment of a permanent flood several problems were encountered. Algae were some times present on the basal stem. Washing with tap water was necessary to remove the algae. Drying of the stems with paper towels was then necessary to remove the tap water. If the water was not removed before sap extraction the Cardy meter determinations were quite variable. Freezing the stems overnight served to rupture the cell walls within the stems and allow more sap to be extracted.

The Cardy meter determinations were well correlated to traditional lab K analysis, with an $r^2$ value of 0.66.

# 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, David Dunn

Accomplishments for First Year:

Research was initiated in 2004 to evaluate the effects of foliar-applied K fertilizer sources and rates of application on glyphosate-resistant soybean response and weed control. Three two-year field trials were established at the MU Greenley Center at Novelty in Northeast Missouri and at the MU Delta Center at Portageville in Southeast Missouri on soils with initial low or high soil test K and with a diverse, high population of weeds. Roundup-Ready® soybeans were no-till planted and treatments 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-based herbicide (i.e. Roundup WeatherMAX® at 22 oz/acre tank mixture) on plots with weeds. All treatments were applied at a standard postemergence timing for weed control at a 15 gallons/acre carrier volume.

Evaluations of foliar salt injury were conducted at 3, 7, 14 and 28 days after K treatments were applied at the Greenley Center and 22 days after K treatments were applied at the Delta Center. A low soil testing K site was also added at the Delta Center Lee Rice Farm on irrigated land which was previously grown to rice and this site was not evaluated for leaf injury. Weed control from the combined glyphosate/K fertilizer applications was also evaluated after application of the treatments. Soil samples to a depth of 6 inches were taken for analysis of soil test K in the plow layer after treatment applications and leaf samples were collected at initial bloom to determine crop K status in treated and non-treated plants. Grain yields were also determined.

Rainfall during the 2004 cropping year was above average across Missouri and foliar K deficiency symptoms were only visually observed in the irrigated Rice Farm site in Southeast Missouri, possibly due to the compacted nature of the soil at this site. Crop K deficiency is often associated with drought and compacted soil conditions. Foliar leaf injury due to all rates of the K fertilizer treatments were ≤ 10% which is a common commercial standard for acceptable injury due to herbicide application (Tables 1 & 2). In general, weed control at both the Novelty and Portageville were above 90% and decreased with increasing rates of the K fertilizer source mixed with glyphosate. At the Portageville site, weed control of individual weed species were recorded including palmer amaranth, ivyleaf and entireleaf morning glory, and large crabgrass

Table 1. Soybean injury 3 days after treatment (DAT), total dry weight reduction 28 DAT, and grain yield at Novelty in 2004. Soybean grain yield at a low soil test K site on the Rice Farm near Portageville in 2004.

| K-source | Rate | Novelty (high soil test K) | | | | | | Rice Farm (low soil test K) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Injury 3 DAT | | Dry Wt. Reduction | | Yield | | Yield | |
| | | Weed-free | Glyphosate | Weed-free | Glyphosate | Weed-free | Glyphosate | Weed-free | Glyphosate |
| | lb $K_2O$/a | % | | % | | bu/A | | bu/A | |
| Weed-free | | 0 | | 0 | | 70 | | 59 | |
| Untreated | | 0 | | 100 | | 10 | | 48 | |
| DAS | | | 1 | | 99 | | 70 | | 56 |
| 0-0-62 | 2.4 | 0 | 2 | 100 | 99 | 70 | 67 | 63 | 54 |
| | 9.6 | 1 | 5 | 100 | 97 | 68 | 68 | 60 | 53 |
| | 19.2 | 9 | 6 | 100 | 97 | 69 | 64 | 51 | 59 |
| 5-0-20-13 | 2.4 | 1 | 2 | 100 | 98 | 68 | 66 | 56 | 55 |
| | 9.6 | 5 | 8 | 100 | 94 | 70 | 67 | 56 | 50 |
| | 19.2 | 5 | 5 | 100 | 95 | 65 | 67 | 56 | 58 |
| 3-18-18 | 2.4 | 1 | 0 | 100 | 99 | 67 | 67 | 53 | 57 |
| | 9.6 | 1 | 3 | 100 | 97 | 70 | 67 | 55 | 66 |
| | 19.2 | 4 | 2 | 100 | 94 | 67 | 69 | 56 | 61 |
| 0-0-25-17 | 2.4 | 2 | 2 | 100 | 99 | 69 | 65 | 61 | 49 |
| | 9.6 | 4 | 6 | 100 | 96 | 68 | 65 | 51 | 61 |
| | 19.2 | 4 | 6 | 100 | 90 | 67 | 66 | 56 | 53 |
| LSD (p=0.05) | | 2 | | 7 | | 5 | | NS | |

[a]Abbreviations: DAS, diammonium sulfate; DAT, days after treatment; and LSD, least significant difference.
[b]K-sources: 0-0-62, potassium chloride (Kalium); 5-0-20-13, Trisert K+ (Tessenderlo Kerley); 3-18-18, potassium phosphate, (NA-CHURS/ALPINE); and 0-0-25-17, potassium thiosulfate (Tessenderlo Kerley).

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.

| | | Injury 22 DAT | | Palmer amaranth control | | Ivyleaf and entireleaf morningglory control | | Large crabgrass control | | Yield | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| K-source | Rate | Weed-free[c] | Glyphosate | Weed-free | Glyphosate | Weed-free | Glyphosate | Weed-free | Glyphosate | Weed-free | Glyphosate |
| | | % | | % | | % | | % | | bu/A | |
| Weed-free | | 0 | | 100 | | 100 | | 100 | | 45 | |
| Untreated | | 0 | | 0 | | 0 | | 0 | | 25 | |
| DAS | | | 0 | | 88 | | 71 | | 88 | | 47 |
| 0-0-62 | 2.4 | 5 | 6 | 86 | 95 | 88 | 90 | 75 | 94 | 45 | 49 |
| | 9.6 | 5 | 5 | 88 | 95 | 88 | 93 | 78 | 93 | 43 | 53 |
| | 19.2 | 5 | 10 | 88 | 95 | 90 | 93 | 84 | 94 | 45 | 46 |
| 5-0-20-13 | 2.4 | 4 | 5 | 86 | 93 | 88 | 89 | 79 | 93 | 39 | 43 |
| | 9.6 | 3 | 10 | 81 | 95 | 84 | 91 | 79 | 94 | 48 | 41 |
| | 19.2 | 5 | 0 | 86 | 95 | 90 | 93 | 76 | 93 | 46 | 46 |
| 3-18-18 | 2.4 | 5 | 10 | 86 | 95 | 84 | 94 | 78 | 95 | 51 | 49 |
| | 9.6 | 0 | 4 | 85 | 94 | 86 | 91 | 86 | 95 | 48 | 47 |
| | 19.2 | 4 | 3 | 89 | 95 | 88 | 91 | 79 | 90 | 42 | 48 |
| 0-0-25-17 | 2.4 | 3 | 5 | 79 | 95 | 88 | 91 | 78 | 94 | 45 | 53 |
| | 9.6 | 0 | 3 | 83 | 94 | 81 | 91 | 69 | 93 | 49 | 52 |
| | 19.2 | 3 | 0 | 81 | 94 | 86 | 90 | 79 | 88 | 46 | 52 |
| LSD (p=0.05) | | 8 | | 7 | | 6 | | 8 | | 11 | |

[a]Abbreviations: DAS, diammonium sulfate; DAT, days after treatment; and LSD, least significant difference.
[b]K-sources: 0-0-62, potassium chloride (Kalium); 5-0-20-13, Trisert K+ (Tessenderlo Kerley); 3-18-18, potassium phosphate, (NA-CHURS/ALPINE); and 0-0-25-17, potassium thiosulfate (Tessenderlo Kerley).
[C]Weed-free was maintained by hand weeding which was generally not as effective as glyphosate application in 2004.

(Table 2). For these species, weed control was significantly higher when the K fertilizer sources were mixed with glyphosate than compared to when the recommended additive diammonium sulfate (DAS) was mixed in with the glyphosate. A similar weed control response to K fertilizer sources compared to DAS was not observed at the Novelty site (Table 1).

No significant increases in grain yields over the weed-free control were observed at any of the locations due to application of the different sources and rates of foliar K (Tables 1 & 2). However, significant differences in yields were observed among the K fertilizer treatments at the Novelty and Portageville sites in plots maintained weed-free or with weeds when glyphosate was applied. The low soil test K Rice Farm site had no significant differences in grain yield among the K fertilizer treatments probably due to higher experimental variability at this site.

One graduate student (M.S. student) is receiving his training working on this project for his thesis research in soil science. The research results were presented to growers and agricultural professionals at the 2004 Greenley Center Field Day. In addition, Motavalli et al. (2004) gave an invited presentation at the 2004 North Central Extension-Industry Soil Fertility Conference on their research on foliar K fertilization.

References:

Motavalli, P.P., K.A. Nelson, W.E. Stevens, and S. Phurahong. 2004. Foliar application of K on soybeans. pp. 56-64. Proceedings of the North Central Extension-Industry Soil Fertility Conference, Nov. 17-18, 2004, Ames, IA. Vol. 20. Potash & Phosphate Institute, Brookings, SD.

Objectives for Year 2:

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

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 (e.g. Roundup WeatherMAX®).
3. Evaluate the cost-effectiveness of applying K fertilization with glyphosate-based herbicides for no-till glyphosate-resistant soybean production.

**The field studies at Novelty and Portageville will be repeated for a second year to evaluate the effects of foliar-applied K fertilizer sources and rates of application on glyphosate-resistant soybean response and weed control under different climatic conditions. In addition, the M.S. student will undertake a greenhouse study to examine soybean response to foliar K sources under different soil moisture conditions and to evaluate different methods to quickly assess plant K deficiency, including use of the chlorophyll meter and Cardy K meter. The cost-effectiveness of the foliar K treatments will be determined using the results from the field studies at the end of the second year of research to provide a more comprehensive picture of whether this fertilization strategy is economical under a range of soil and climatic conditions.**

# Multiple Nutrient Studies

# 2003

## Increasing Phosphorus and Magnesium Concentrations in Stockpiled Tall Fescue

Missouri Fertilizer and Lime Council
First Year Report (First four months of research)
Dale G. Blevins
Professor of Agronomy, University of Missouri

**Objective:** To determine if high rates of phosphorus fertilization on both low P and adequate P soils will result in leaf P and Mg concentrations in stockpiled tall fescue that meet the nutrient requirements for grazing beef cows in winter and early spring.

**Problem:** This new project was based on results of our current study that is near completion, where stockpiled tall fescue on a low P soil treated with 12.5 or 25 lbs P/acre had leaf P and Mg concentrations during winter and early spring that dropped below levels recommended for the diets of beef cows. Therefore diets of beef cows grazing stockpiled tall fescue may need to be supplemented with grain, alfalfa hay or mineral blocks to provide P and Mg in the diet. Another approach is to determine if higher levels of soil or fertilizer P will bust the P and Mg levels in the leaves of tall fescue entering winter, such that the leaf levels will remain above the levels recommended for beef cow diets during winter and early spring.

**Procedures:** Two tall fescue areas were selected at the University of Missouri Southwest Research Center near Mt. Vernon and soil from these areas were sampled and tested for phosphorus and other macronutrient elements. These two sites, one with low soil P (<10 lbs/acre) and one with around 25 lbs P/acre, were selected based on their proximity and their similarity of tall fescue stands. The plot areas were mowed and the forage removed during the third week in August 2003. Plots were measured at 10' x 25' with 5' alleys, and at each site plots were treated with 0, 50, 100 or 200 lbs P/acre. Each treatment was replicated six times. Tall fescue samples were collected in mid-October and mid-November, and will be sampled from mid-December (if snow will allow), mid-January, mid-February, mid-March, and through mid-April. During the third weeks in May and August, hay will be harvested, hay yield will be calculated and sub-samples will be collected for nutrient analyses. At each sampling date, two different types of samples have been harvested from each plot. One sample consists of 20 of the most recently collared leaves, and the second type of sample was four grab samples combined within each plot. In the previous study, 20 of the most recently collared leaves were harvested, and this type of sampling was maintained for comparison, and the grab samples was added to reflect the harvest of a grazing cow. The Oct and Nov samples were dried, ground in a coffee grinder, and digested in nitric acid in a microwave digestion system (CEM Corp.). This sampling and digestion procedure will be used during the remainder of the sampling season. Digested samples will be filtered, diluted and K will be determined by flame ionization, Mg and Ca by atomic absorption, and P by colorimetric analysis. Data will be analyzed by SAS and graphs will be prepared by plotting leaf macronutrient concentrations versus month of the year and phosphate treatments.

**Results** (Since October 2003)

Phosphorus treatments of these plots have been spectacular, prompting calls from several people who have visited the site. Consequently, I have invited people from International Minerals, the Phosphate Potash Institute, Fluid Fertilizer Institute and MFA to visit the plots, and this is before we have actually provided any nutrient data. The excitement caused by these plots was based on the growth that has been observed. Surprisingly, the tall fescue has shown a growth response to the 200 lbs P/acre application rate than is beyond that of the 100 lbs P/acre treatment! Because of the dramatic increase in growth observed with the highest phosphorus treatments, we measured leaf lengths in plants growing in these plots. Lengths of 10 of the most recently collared leaves were measured in plots of each P treatment. Leaves of tall fescue plants from plots treated with 200 lbs P/acre were also twice as long as those of tall fescue plants growing in untreated plots (Fig. 1). The leaves from the 200 lbs P/acre treatment were longer than those from the 100 lbs P/acre plots. It is interesting that with the zero P treatment, the tall fescue leaves were longer in plots with the higher P level, and this is logical. The dramatic differences in leaf lengths in October 2003 are seen in the picture shown in Figure 2. Leaf growth of the tall fescue has certainly responded to high phosphorus treatments, now we will see if the high phosphorus rates maintain high concentrations of phosphorus and magnesium during winter stockpiling.

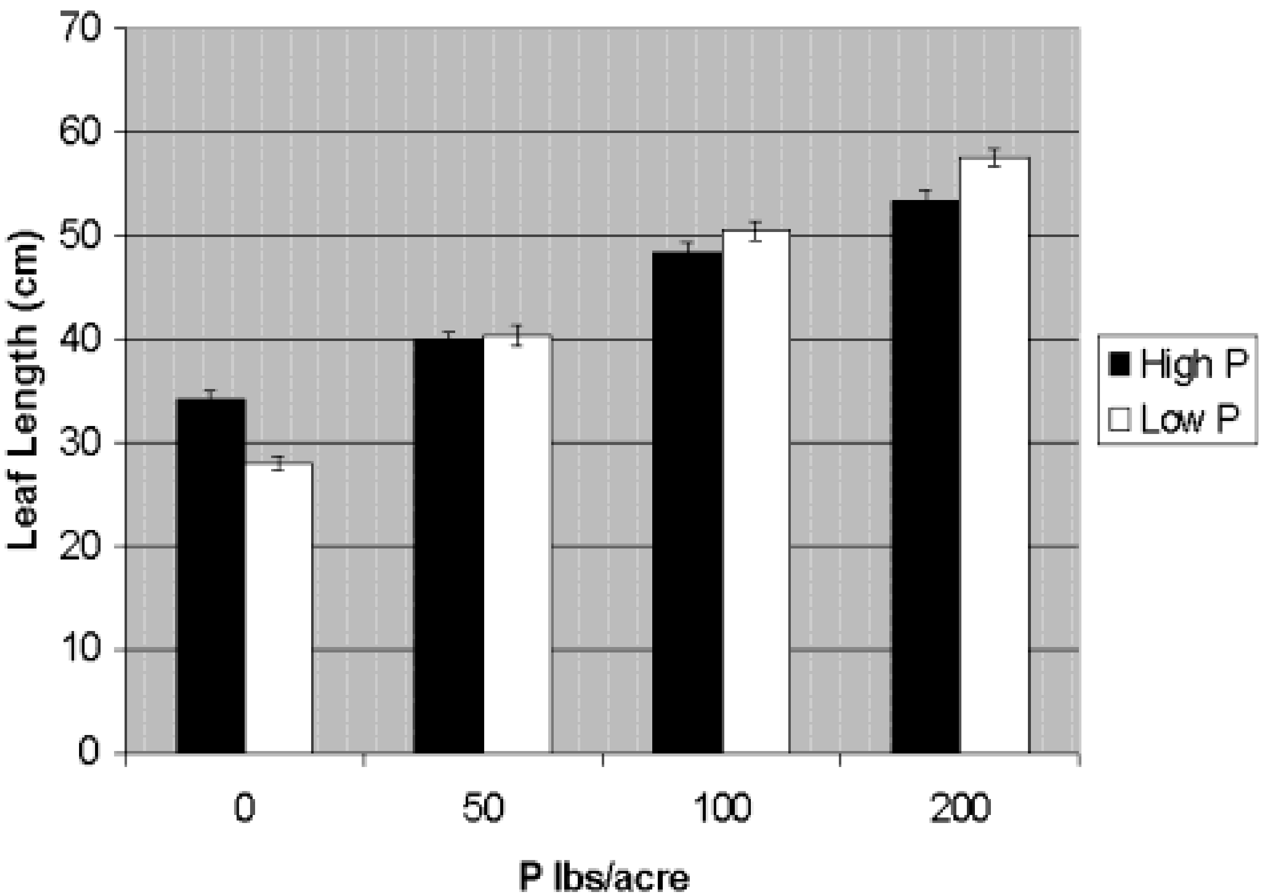



**Figure 1.** Leaf length of tall fescue in November after application of different phosphorus levels the third week in August 2003 (Southwest Center, Mt. Vernon, MO).

Figure 2. The plot on the right was treated with 200 lbs P/acre and the plot on the left was untreated tall fescue. During the fall of 2003, high phosphorus treatments produced tremendous growth of tall fescue leaves.

# 2004

## Increasing Phosphorus and Magnesium Concentrations in Stockpiled Tall Fescue
**Second Year Report (one year and five months into project)**

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

**2. Objective:** To determine if high rates of phosphorus (P) fertilization on both low P and adequate P soils will result in leaf P and magnesium (Mg) concentrations in stockpiled tall fescue that meet the nutrient requirements for grazing, lactating beef cows in winter and early spring.

**3. Review of procedures:** Established tall fescue pastures were selected in summer, 2003 based on Bray I P soil test values. The HP used in this report stands for the higher soil P site (Bray I P = 19 lbs /acre) and LP stands for the lower soil P site (Bray I P = 7 lbs/acre). The phosphorus treatments used in this study included 0, 50, 100 and 200 lbs P/area. Treatments were applied the third week of August 2003. Twenty of the most recently collared leaves and grab samples were harvested each month beginning in October and ending in April. Dried samples were ground, digested in nitric acid and analyzed for P, Mg, calcium (Ca) and potassium (K).

**4. Results:** When grab sample data were compared to results from the 20 most recently collared leaves, they were identical. In this report, only results from the 20 most recently collared leaves are presented.

The first fall (2003) of this study produced amazing tall fescue leaf growth response to P fertilization. Leaf growth was tremendous, and the increasing response even to the high P fertilization rate of 200 lbs P/acre was surprising (Fig. 1). The improved growth of the tall fescue leaves at 100 and 200 lbs P/acre was easily visible when looking at the plots in the fall of 2003. It is possible that the Creldon soil at this site with its high aluminum, manganese and iron may be influenced by high levels P, since the P would be "remediating" the toxic effects of the high levels of the metals. Therefore, the high P treatments may be doing more here that just providing P for uptake by tall fescue roots.

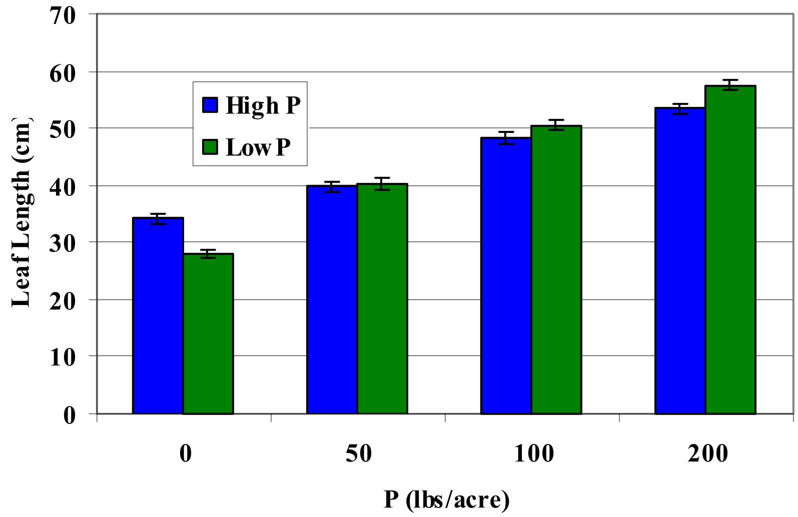



Figure 1. Leaf length (most recently collared leaf) of tall fescue in fall 2003 following phosphorus treatments of high soil P and low soil P plots.

Tall fescue leaf P concentrations were more responsive to P fertilization treatments on the LP plots than on the HP plots (Fig. 2). In both cases, leaf P concentrations decreased with all treatments from October to February. In February, leaf P concentrations dropped below the 0.2% level required for grazing, lactating beef cows. For all treatments, leaf P levels in March were greater than those in February. One of the major objectives of this research was achieved, in that the 100 or 200 lbs P/acre treatments produced leaf P concentrations above the 0.2% target levels during winter. The drop in leaf P concentrations between October and February may be a result of nutrient mobilization from leaves to rhizomes during late fall and winter as a storage mechanism.

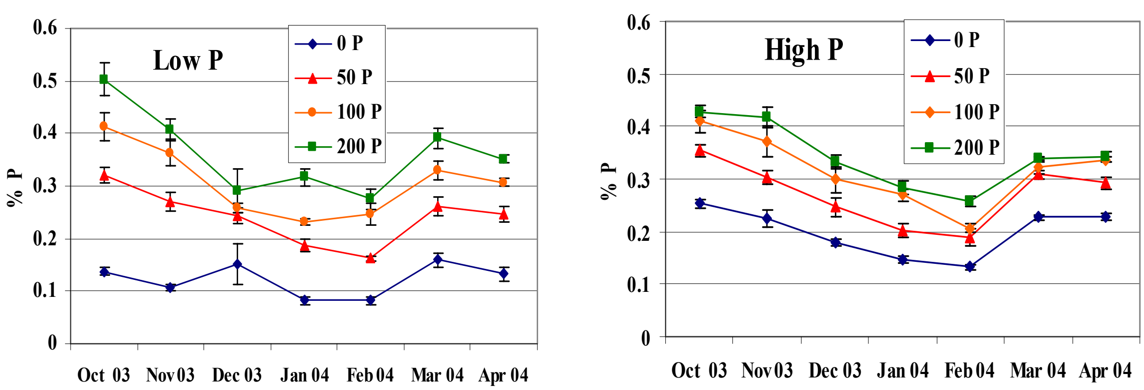



Figure 2. Phosphorus concentrations of stockpiled tall fescue leaves from plots treated with 0, 50, 100, or 200 lbs P/acre.

Magnesium concentrations of the stockpiled tall fescue leaves were higher with the P fertilization treatments compared to the control treatment (Fig. 3). Leaves from the low soil P plots were slightly more responsive to P treatments that those from the high P soil plots. Again, as with leaf

P, leaf Mg concentrations decreased during fall and early winter until February, and in February and March Mg levels in leaves of most treatments had dropped below the 0.2% level required for the diets for grazing, lactating beef cows. In the case of leaf Mg concentrations, high rates of P fertilization improved the situation, but leaf levels were lower than required for grazing, lactating beef cows with all treatments. Based on the first year of results, this low leaf Mg problem with stockpiled tall fescue will require additional approaches for improvement.

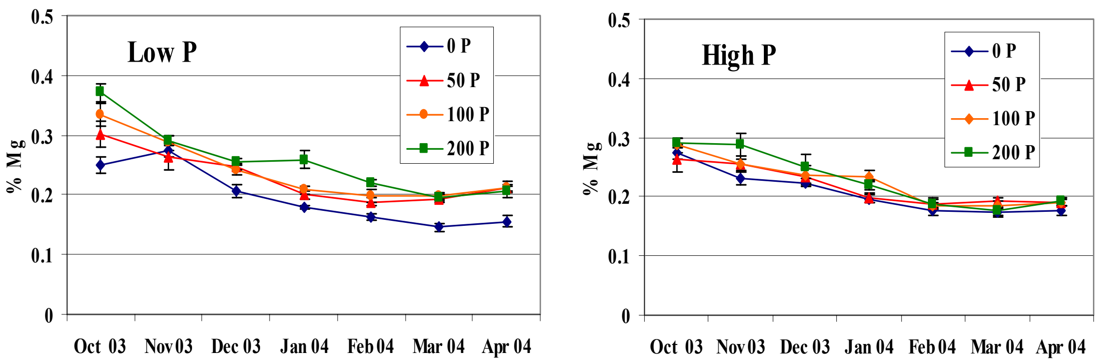



Figure 3. Magnesium concentrations of stockpiled tall fescue leaves from plots treated with 0, 50, 100, or 200 lbs P/acre.

Leaf Ca level was much lower in this study than in our previous studies conducted in this same general area. Checking the soil test results (Table 1) indicated that this current set of plots had much lower Ca levels than plots used in our previous studies. The soil test information indicated that this particular area had not been limed in quite a while. The highest P fertilization rate (200 lbs P/acre) produced leaf Ca concentrations that were much higher than control levels at most sampling dates (Fig. 4). Also, leaf Ca concentration appeared to decline between November and February, in contrast to no change found in our previous study. The low leaf Ca concentrations in this study were lower than the 0.3% required in diets of grazing, lactating beef cows, and this information may be extremely important in looking at the likelihood of forage causing grass tetany. We have focused our efforts on leaf Mg concentrations in the past, but leaf Ca concentration is also an important factor, and in this area of SW Missouri, perhaps a more important factor?

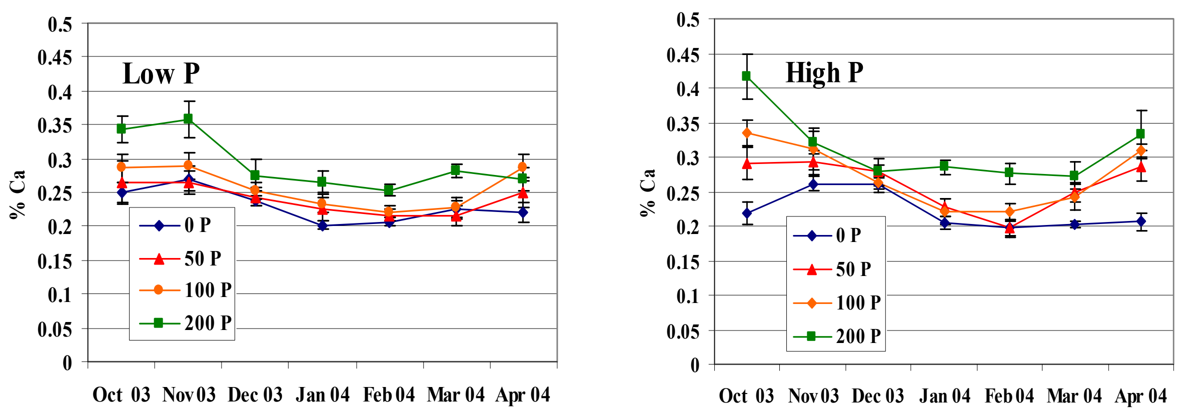



Figure 4. Calcium concentrations of stockpiled tall fescue leaves from plots treated with 0, 50, 100, or 200 lbs P/acre.

Potassium concentrations of the stockpiled tall fescue leaves declined from October to February with all P treatments (Fig. 5). Interestingly, the response of leaf K concentration to P fertilization was greater on the higher soil P site. The leaf K concentrations increased during March and April, but there was no consistent P fertilization effect during this time. Again, as for the other macronutrient elements, the decline in leaf K concentration during the fall and early winter may indicate K mobilization from leaves to underground storage sites. This is an hypothesis that we are currently testing
.

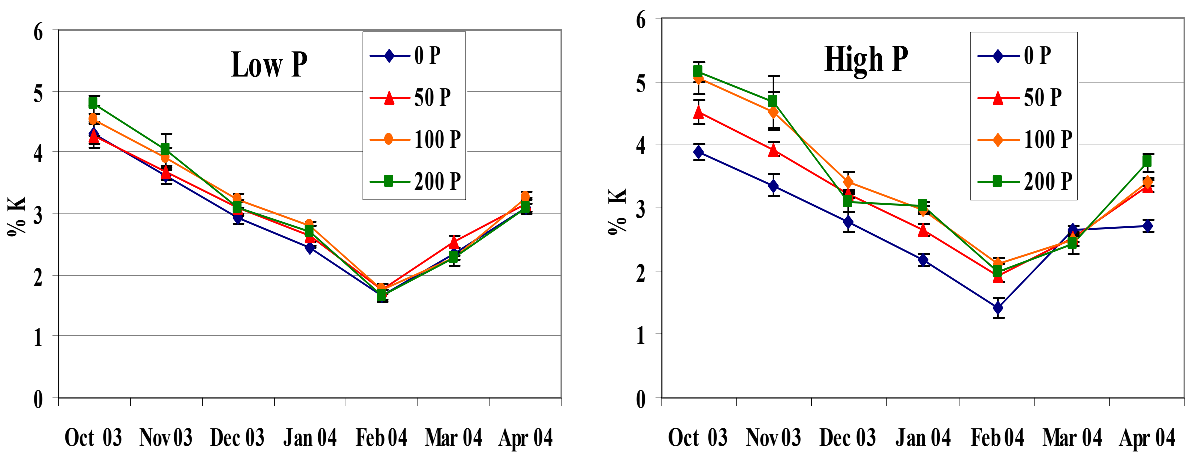



Figure 5. Potassium concentrations of stockpiled tall fescue leaves from plots treated with 0, 50, 100, or 200 lbs P/acre.

Soil samples taken in August, at the end of the first year of study, indicated that much of the P added as fertilizer was "fixed" or "sorbed" by the aluminum, iron and manganese in this Creldon soil (Table 1).

Table 1. Soil test results one year following phosphorus fertilization treatments of the high and low P plots.

| | **P (lbs/Ac)** | **pHs** | **% O.M.** | **Bray I P (lbs/Ac)** | **Bray II P (lbs/Ac)** | **Ca (lbs/Ac)** | **Mg (lbs/Ac)** | **K (lbs/Ac)** |
|---|---|---|---|---|---|---|---|---|
| **HP** | **0** | 5.42 | 3.13 | 16 | 57 | 1679 | 258 | 338 |
| | **50** | 5.33 | 3.05 | 40 | 121 | 1820 | 255 | 286 |
| | **100** | 5.27 | 3.28 | 72 | 203 | 1597 | 252 | 265 |
| | **200** | 4.93 | 3.17 | 121 | 324 | 1645 | 250 | 255 |
| **LP** | **0** | 5.55 | 2.87 | 7 | 22 | 1743 | 259 | 330 |
| | **50** | 5.28 | 3.00 | 16 | 42 | 1810 | 245 | 292 |
| | **100** | 5.33 | 2.97 | 23 | 61 | 1932 | 257 | 297 |
| | **200** | 5.23 | 2.92 | 68 | 175 | 1857 | 264 | 277 |

**5. Summary** - The high rates of P fertilization used in this study helped tall fescue maintain leaf P concentrations during winter that exceeded the requirements for grazing, lactating beef cows. However, leaf Mg and Ca levels dropped below those required for the cows during late winter, and other methods of improving levels of these important cations in forage are required.

# Miscellaneous Tests

# 2003

## Soil-specific Phosphorus Rates

John Lory, Peter Scharf and Peter Motavalli
Collaborator: Newell Kitchen

**Report Overview:**
Preliminary results indicate:
- The amount of phosphorus (P) needed to raise soil test P differs among Missouri soils. Incorporating soil specific P recommendations into our recommendation system has the potential to improve the accuracy of P recommendations.
- A linear function should be used to predict the amount of P needed to raise soil test P when soil test P is above 10 lbs/acre. Our current system recommends diminishing amounts of P as soil test P increases.

**Project Objectives:**
Develop and incorporate soil-specific phosphorus (P) recommendations into the Missouri soil test recommendation system.
- Evaluate the Missouri P buildup algorithm by testing the effect of added P on soil test P for 20 soils selected from the five major soil regions of Missouri.
- Correlate differences among the 20 soils in the amount of P needed to reach an optimum soil test P level with soil characteristics currently available or easily obtained by Missouri soil testing laboratories.
- Evaluate the effect of initial soil test P level on rate of P reaction with the soil and the change in soil test P after P addition.

**Importance of research area:**
Missouri has soils with a wide range of mineralogical and chemical properties. The Ozark soil region has ancient soils dominated by kaolinitic clays and that have high aluminum and iron oxide contents, traits associated with high P buffering capacity. The other four soil regions all have younger soils but with a diversity of parent material ranging from loess to sediments. It is likely that P buffer capacities range widely among Missouri soils although there is little data to quantify these differences.

U.S. soils required as little as 5 to as much as much as 11 lbs/acre of phosphate to raise soil test P one unit. Missouri P recommendations assume that all soils have the same buffer capacity; there is no mechanism to predict which soils are likely to require more or less P to raise soil test. It is likely that the current recommendation system recommends too little P on some soils and too much on others for building P levels.

Missouri phosphorus recommendations also assume that it takes more P to raise soil test P at low soil test P levels than high soil test levels. A literature review of 20 field studies indicated relationship between added P and the increase in soil test P is predominantly a linear relationship except in very low testing soils. This project is will determine if Missouri should convert to a linear algorithm as suggested by the literature review of soils in other states and countries.

We will also attempt to identify soil characteristics that can be used to predict differences in the amount of added P needed to raise soil test P among Missouri soils. This approach has been used in Vermont where “available aluminum” is used with soil test P to predict the amount of phosphate fertilizer needed to reach a target soil test level (Jokela et al., 1999). North Carolina research considers clay percentage as a predictor of P needed to raise soil test P (Cox et al., 1981).

**Methods and materials:**

***Laboratory study***

- Soils were identified and collected from each of the 5 major soil regions of the state with the aid of local Natural Resource Conservation Service and University Extension personnel in Fall of 2000 (Table 1).

**Table 1**. Selected characteristics of 21 Missouri soils used in the project.

| Region of state | County | Soil type | Initial soil test P[1] | Sand | Clay |
|---|---|---|---|---|---|
| | | | lb/acre | % | % |
| Bootheel | Mississippi | Commerce silty clay loam | 64 | 38.1 | 19.5 |
| Bootheel | New Madrid | Sharkey clay | 29 | 40.4 | 38.0 |
| Bootheel | Stoddard | Lilbourn fine sandy loam | 59 | 50.9 | 12.2 |
| Bootheel | Stoddard | Loring silt loam | 15 | 9.4 | 10.3 |
| Clay pan | Boone | Mexico silt loam, eroded | 38 | 25.4 | 27.7 |
| Clay pan | Knox | Putnam silt loam | 41 | 7.8 | 16.6 |
| Clay pan | Monroe | Putnam silt loam | 13 | 13.2 | 15.1 |
| Clay pan | Monroe[2] | Mexico silt loam | 17 | 31.8 | 17.9 |
| Loess/Drift | Gentry | Grundy Silt Loam | 54 | 3.1 | 18.6 |
| Loess/Drift | Lafayette | Higginsville silt loam, eroded-Combo | 80 | 38.0 | 18.2 |
| Loess/Drift | Linn | Loganda silt loam | 33 | 11.7 | 24.7 |
| Loess/Drift | Ray | Sharpsburg silt loam-9% slope, eroded | 26 | 33.7 | 28.6 |
| Osage plain | Vernon | Barco loam | 27 | 48.4 | 23.9 |
| Osage plain | Vernon | Osage silty clay | 14 | 33.7 | 16.0 |
| Osage plain | Vernon | Barden silt Loam | 27 | 40.5 | 16.1 |
| Osage plain | Vernon | Barden silt Loam | 54 | 37.5 | 24.9 |
| Ozarks | Christian | Clarksville very cherty silt loam | 21 | 10.7 | 17.5 |
| Ozarks | Laclede | Viraton silt loam | 11 | 16.3 | 17.5 |
| Ozarks | Lawrence | Creldon silt loam | 10 | 10.4 | 20.8 |
| Ozarks | Polk | Goss gravelly silt loam | 37 | 22.7 | 12.9 |
| River bottom | Saline | Haynie silt loam | 47 | 22.4 | 29.4 |
| | | | | | |

[1] Bray-I P.

[2] Not included in preliminary analysis due to analytic problems.

- Soils were analyzed for soil test P, potassium, calcium, magnesium; percent organic matter; pH, and percent water holding capacity. Soils will be analyzed for phosphorus sorption capacity, Mehlich-III soil test P, aluminum (Al) and iron (Fe) concentration in Mehlich-III and Bray-I extracts, oxalate extractable Al, and oxalate extractable Fe.
- Five P treatments (3 replicates) were added to 150 g of soil as diammonium phosphate. The treatments were 0, 0.01, 0.03, 0.05, and 0.08 mg P/g soil. An additional 2 P treatments (0.4 and 1 mg P/g soil) were added to 3 soils (the ones included in both the field and greenhouse experiments).
- A single manure treatment was included on all soils. Poultry litter was added at the rate of 0.05 mg P/g soil. The 7 P treatments were duplicated with manure on the 3 soils included in both the laboratory and field experiments.
- Treated soils were adjusted to field capacity based on water holding capacity determined for the soil. Soils were incubated in the dark at 20 $^{o}$C in covered plastic cups with an air exchange hole. There were a total of 450 incubation cups.
- Cups were mixed by shaking and then had water content corrected for moisture loss based on sample weight approximately every 10 days during the first month. Water additions were extended to closer to 20 days during the next 60-day period because water loss was so slow.
- All cups were sampled 32 and 90 days after P addition. Samples are dried at 30 $^{o}$C to constant weight. The cups will be sampled 1 more time after 3 complete wet-dry cycles where the cups are dried to constant weight (30 $^{o}$C) and then rewetted to field capacity.
- All samples will be analyzed for Bray-I P. Linear and nonlinear regression will be used to model the effect of added P and soil type on soil test P. Linear regression will be used to correlate soil properties with differences among soils in their response to added P.

Field study

- Three field locations were located at University of Missouri South farm, Forage Systems Research Center and Southwest Research Center (Table 2). Soils from these locations were also included in the laboratory experiment (Table 1).

**Table 2**. Location of field experiments.

| Region of state | County | Soil type |
|---|---|---|
| | | |
| Clay pan | Boone | Mexico silt loam, eroded |
| Loess/Drift | Linn | Loganda silt loam |
| Ozarks | Lawrence | Creldon silt loam |
| | | |

- Seven fertilizer treatments and 1 manure treatment (3 replicates) were surface-applied to established fescue in October 2001. Plots were 6 ft. X 6 ft. A 40-foot buffer area was established downslope between plots. Plots will be clipped periodically with all forage returned to the plots.
- Plots were sampled 30 days after P application. Plots will be sampled 90 (weather permitting), 180 and 365 days after P application. Samples will be dried at 30 $^{o}$C and analyzed for Bray-I P.
- Linear regression will be used to compare the response of soil test P to added P in the laboratory and field experiments.

**Preliminary results - Laboratory study:**
Added P increased Bray-I P in all cases but both the P treatment and the soil type affected the degree of that response based on samples taken 90 days after

P addition (Table 3). This result supports our hypothesis that the fertilizer P requirements to raise soil test P vary among Missouri soils.

Table 3. Analysis of Variance for the effect of P additions on soil test P 90 days after addition for 20 Missouri soils.

| Source of variation | df | Pr. >F |
|---|---|---|
| Soil | 19 | 0.0001 |
| P treatment | 4 | 0.0001 |
| Soil X P treatment interaction | 76 | 0.0001 |

The two soils in Fig. 1 represent the 2 responses typically seen among the 20 soils analyzed. Response to added P typically was linear below 80 lb/acre Bray-I soil test P but differed among soils. In this example the steeper slope of the Sharpsburg soil indicated that it required less P to raise soil test P than for the Lagonda soil. The Sharpsburg soil required 4.4 lbs $P_2O_5$/acre to raise soil test P 1 lb/acre compared to 7.7 for the Lagonda soil.

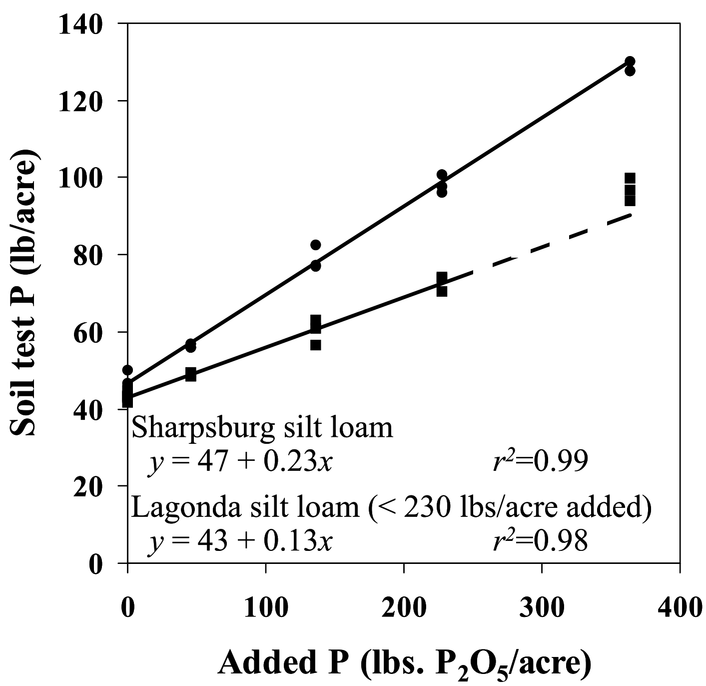



**Figure 1**. The effect of added P on soil test P on two Missouri soils. Soil test P was measured as Bray-I P.

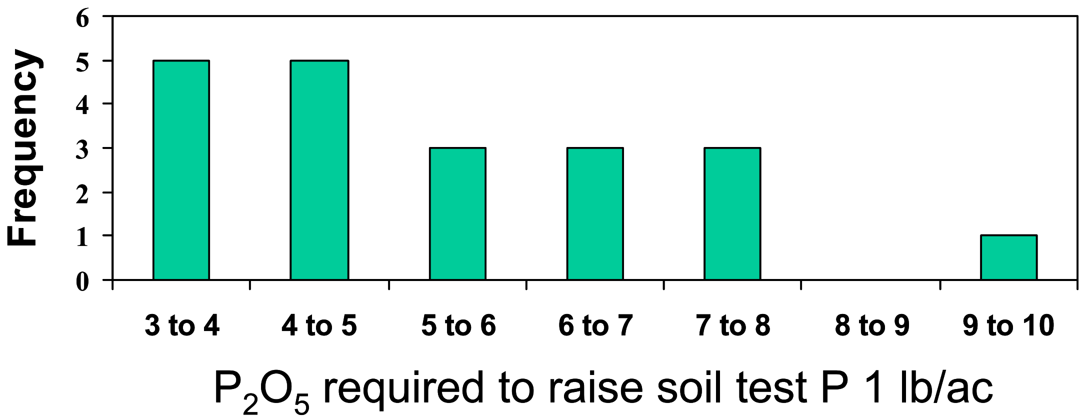



**Figure 2**. Frequency distribution of slope coefficients predicting increase in soil test P with added P for 20 Missouri soils. Slopes are reported as the quantity of $P_2O_5$ needed to raise soil test P 1 pound per acre. Slopes represent the linear response of soil test P 90 days after addition of 0 to 230 lbs/acre $P_2O_5$.

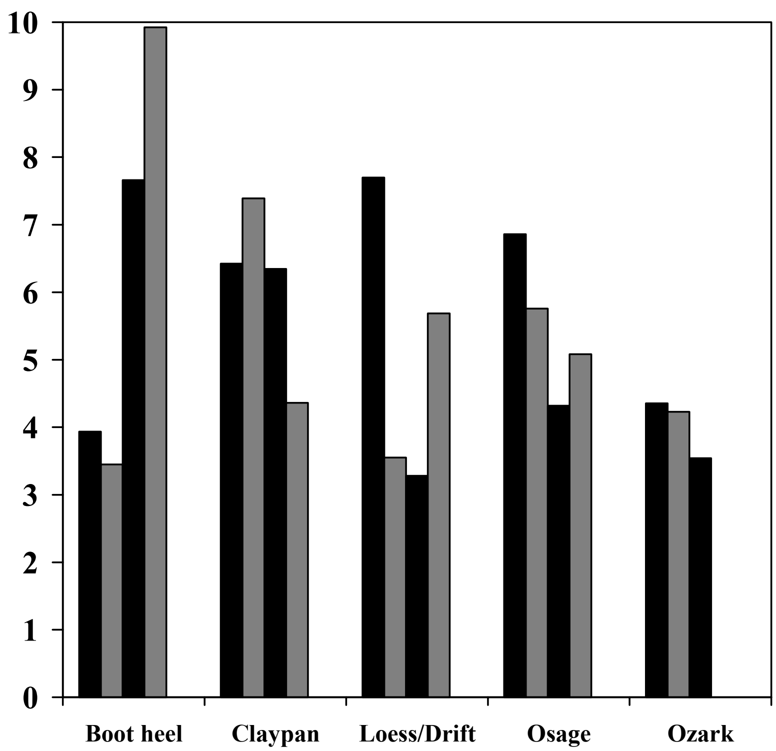



**Figure 3**. Slope coefficients predicting increase in soil test P with added P for 19 Missouri soils categorized by region of the state. Slopes are reported as the quantity of $P_2O_5$ required to raise soil test P 1 lb/ac. Slopes represent the linear response of soil test P 90 days after addition of 0 to 230 lbs/acre $P_2O_5$.

The amounts of $P_2O_5$ needed were relatively evenly distributed across the range of soils (Fig. 2). The variable P needs among soils confirms our hypothesis that soil specific P recommendations have the potential to increase the accuracy of P recommendations.

Our next objective will be to identify soil characteristics that can be used to predict the effect of soil type on the amount of P needed to raise soil test P. A preliminary review of the data indicates that regional trends were not a strong predictor of differences among soils (Fig. 3). Two trends were evident. Claypan soils typically had consistently high P additions to raise soil test P (greater than 4.3 lbs) and Ozark soil typically did not need as much P (all less than 4.5). In all other regions the amount of P needed was variable.

In year 2 of the grant we will complete analysis of the soils and use regression methods to determine what easily obtainable factors can be used to predict the effect of soil type on the amount of P needed to raise soil test P. Our objective is to develop a system that would allow us to recommend more fertilizer P on soils that require more P to raise soil test.

For 19 of the 20 Missouri soils there was linear increase in soil test P with additions of up to 227 lbs $P_2O_5$/acre (0.05 mg P/g soil). Initial soil test levels ranged from 13 to 83 lb $P_2O_5$/acre for all but one soil. Our current soil test system recommends less P to raise soil test P on higher testing soils. This approach was not supported by the our results which suggest that the same amount of fertilizer P is required to raise soil test P 1 unit at all soil test levels within the agronomic responsive range above 10 lbs soil test P/acre.

Our current system recommends 18 lb $P_2O_5$ per acre to raise soil test P 1 lb per acre at a soil test of 10 lbs/acre whereas it recommends 8 lbs $P_2O_5$ per acre at a soil test of 40 lbs/acre. Preliminary results from the laboratory predicted many soils require less P than our system currently recommends. The amount of $P_2O_5$ needed to raise soil test P 1 lb/acre ranged from 3.3 to 9.9 lbs lbs $P_2O_5$/acre among the 20 Missouri soils, depending on soil type. This preliminary result needs to be confirmed in the later sampling of the laboratory study and in the field experiment.

For 11 of the 20 soils there were indications that the highest P application rate (365 lbs $P_2O_5$/acre, 0.08 mg P/g soil) resulted in a greater than predicted increase in soil test P (e.g. Lagonda soil, Fig. 2). This non-linear effect was typically associated with the highest rate of added P and the resulting soil test level was always above 80 lb/acre soil test P (well above soil test P required for optimum agronomic response).

There are 2 possible mechanisms contributing to this effect. First, it may take longer for the higher rate of added P to equilibrate with the soil. Second, the higher rate may exceed the capacity of the soil to fix the added P as efficiently resulting in more remaining in an available pool. We will sample these soils one more time and also determine percent P fixation of the initial soils in an effort to determine which of these mechanisms is operating.

**Project status:**
This project was originally funded in the 2000 Agricultural Fertilizer and Lime projects. Notification of funding in 2000 was delayed. By the time we were notified we were unable to initiate the experiment until fall 2000 because of other commitments. During 2001 we have completed most of the anticipated milestones associated with year one of the project.

Table 4 outlines key milestones and the dates work was initiated and completed to meet the milestone.

Table 4. Key milestones for the soil specific P study.

| **Milestone** | **Initiated** | **Completed** |
|---|---|---|
| **Locate and characterize soils** | | |
| Select 20 soils from 5 soil regions | Fall 2000 | Spring 2001 |
| Identify and collect soils with help of local NRCS and UOE | Fall 2000 | Spring 2001 |
| Characterize soils | | |
| - initial MO soil tests | Spring 2001 | Spring 2001 |
| - soil physical properties | Spring 2001 | Spring 2001 |
| - P saturation | | |
| + Mehlich III P, AL, and Fe | 2/2002 | |
| + Oxalate extractable Al and Fe | 2/2002 | |
| Identify 3 field sites | Spring 2001 | Spring 2001 |
| - initial soil tests for uniformity | Spring 2001 | Summer 2001 |
| **Laboratory study** | | |
| Planning and setup | May 2001 | July 2001 |
| Implementation | | |
| - Initiate fertilizer and manure treatments | - | July 2001 |
| - 30-day sampling | - | August 2001 |
| - 90-day sampling | - | Oct. 2001 |
| - final sampling | | |
| Soil analysis for Bray-I P | | |
| - 30-day sampling | | |
| - 90-day sampling | Nov. 2001 | Dec. 2001 |
| - final sampling | | |
| Data analysis | Nov. 2001 | |
| **Field study** | | |
| Planning and setup | Sept. 2001 | Oct. 2001 |
| - Initiate fertilizer and manure treatments | | Oct. 2001 |
| - 30-day sampling | | Nov. 2001 |
| - 90-day sampling | | |
| - final sampling | | |
| Soil analysis for Bray-I P | | |
| - 30-day sampling | | |
| - 90-day sampling | | |
| - final sampling | | |
| Data analysis | Nov. 2001 | |
| | | |
| **Final Report** | | |

# 2004

## 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 1
In 2004, 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. Corn, soybean, and rice plots were harvested with a combine. Fescue hay was harvested with a mower with a bagging attachment. Grab samples were dried, and weighed to adjust each plot yields to a dry matter basis.

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.

**Objectives for year two**
We will follow the profitability and soil nutrient levels of these treatments over time. In 2005, 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 2005.

Table 1. Effect of fertilizer build-up programs on first-year corn and soybean yields on a non-irrigated Tiptonville silt loam soil at University of Missouri-Marsh Farm, Portageville, Missouri.

| Planted crop | Buildup program† | Recommended $P_2O_5$ | $K_2O$ | Fert cost‡ | Yield | Gross-Fert |
|---|---|---|---|---|---|---|
| Soybean | | ---lb/acre--- | | per acre | bu/acre | per acre |
| | Untreated check | 0 | 0 | 0 | 40.2 | $219 |
| | 1-year | 0 | 156 | $27 | 42.6 | $206 |
| | 4-year | 0 | 87 | $15 | 42.7 | $218 |
| | 8-year | 0 | 76 | $13 | 40.0 | $205 |
| Corn § | N only check | 0 | 0 | $52 | 123.5 | $190 |
| | 1-year | 0 | 183 | $83 | 138.2 | $188 |
| | 4-year | 0 | 85 | $67 | 127.7 | $183 |
| | 8-year | 0 | 68 | $64 | 127.4 | $186 |

† Initial soil test levels varied between plots. Averages were 92 lb Bray1-P/a and 230 lb am acetate K/a.

‡ Cost calculations include N on corn. 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 $1.96 bu corn.

§ Birds reduced plant densities in some corn plots.

Table 2. 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.

| Planted Crop | Buildup program † Soil crop target | Recommended $P_2O_5$ | $K_2O$ | Fert cost‡ | Yield | Gross-Fert |
|---|---|---|---|---|---|---|
| Rice | | ---lb/acre--- | | per acre | bu/acre | per acre |
| | N only check | 0 | 0 | $45 | 134.7 | $391 |
| | 1-year/rice target | 41 | 5 | $58 | 138.4 | $390 |
| | 4-year/rice target | 41 | 5 | $58 | 136.4 | $384 |
| | 8-year/rice target | 41 | 5 | $58 | 132.3 | $371 |
| | 1-year/soybean target | 110 | 79 | $91 | 153.9 | $408 |
| | 4-year/soybean target | 58 | 39 | $69 | 154.7 | $432 |
| | 8-year/soybean target | 50 | 32 | $65 | 149.9 | $421 |
| Soybean | Untreated check | 0 | 0 | $0 | 39.9 | $218 |
| | 1-year/rice target | 96 | 82 | $43 | 52.6 | $244 |
| | 4-year/rice target | 52 | 69 | $27 | 53.3 | $264 |
| | 8-year/rice target | 45 | 67 | $25 | 50.8 | $252 |
| | 1-year/soybean target | 183 | 326 | $110 | 58.3 | $208 |
| | 4-year/soybean target | 74 | 130 | $44 | 51.2 | $235 |
| | 8-year/soybean target | 56 | 97 | $33 | 51.3 | $247 |

† Initial soil test levels varied between plots. Average levels in the soybean field were 29 lb P/a, 165 lb K/a, and 9.2 CEC. Soil test levels in the rice pan were 37 lb P/a, 249 lb K/a, and 10.4 CEC. Current MU recommended target soil P buildup for rice is 35 lb Bray1-P/a and P target for soybeans is 45 lb P/a. Target ammonium acetate extractable K buildup for rice is 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.

Table 3. Effect of fertilizer build-up programs on average first-year fescue hay yields from an non-renovated pasture on a Tonti-Hogcreek complex (2% slope) near West Plains, Missouri.

| Trt No. | Buildup program† | Sulfur | Recommended ‡ $P_2O_5$ | $K_2O$ | Fert cost§ | Total hay | Gross-PKS |
|---|---|---|---|---|---|---|---|
| | | 1b/acre | ---lb/acre--- | | per acre | ton/acre | per acre |
| 1 | Untreated check | 0 | 0 | 0 | $0 | 1.52 | $46 |
| 2 | N only | 0 | 0 | 0 | $20 | 2.09 | $33 |
| 3 | 1-year | 9 | 405 | 155 | $167 | 2.99 | -$88 |
| 4 | 3-year | 9 | 115 | 90 | $69 | 2.81 | $5 |
| 5 | 8-year | 9 | 65 | 80 | $52 | 2.63 | $17 |
| 6 | 8-year | 0 | 65 | 80 | $44 | 2.33 | $16 |
| 7 | 8-year | 12 | 65 | 80 | $44 | 2.67 | $25 |
| 8 | 8-year | 24 | 65 | 80 | $45 | 2.62 | $22 |

† 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.

Table 4. Dry matter yields from three cuttings of fescue hay in fertilizer buildup experiment at West Plains, Missouri.

| Trt No. | Buildup program | Sulfur | Recommended $P_2O_5$ | $K_2O$ | Harvest Date May 13 | July 9 | Nov 16 |
|---|---|---|---|---|---|---|---|
| | | 1b/acre | ---lb/acre--- | | -------ton/acre ----- | | |
| 1 | Untreated check | 0 | 0 | 0 | 0.44 | 0.56 | 0.51 |
| 2 | N only | 0 | 0 | 0 | 0.84 | 0.66 | 0.60 |
| 3 | 1-year | 9 | 405 | 155 | 1.40 | 0.82 | 0.76 |
| 4 | 3-year | 9 | 115 | 90 | 1.31 | 0.77 | 0.73 |
| 5 | 8-year | 9 | 65 | 80 | 1.16 | 0.73 | 0.75 |
| 6 | 8-year | 0 | 65 | 80 | 1.00 | 0.68 | 0.64 |
| 7 | 8-year | 12 | 65 | 80 | 1.17 | 0.82 | 0.69 |
| 8 | 8-year | 24 | 65 | 80 | 1.18 | 0.73 | 0.71 |

# Using high boron levels to control weevils and leafhoppers in alfalfa

Dale G. Blevins and Wayne Bailey

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

4. Alfalfa establishment: A site was selected at the University of Missouri South Farm. 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 during 2005. Soils samples were collected from this site and analyzed at the University of Missouri Soil Testing Laboratory. 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 varieties for this study, Pioneer 54V46 (weevil susceptible) and Pioneer 54H91 (weevil resistant). Seeds from both varieties 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 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. The plot map is listed as Table 2 and shows the size of plots, the randomization and replication of the 0, 2.5, 5.0, 10.0 lbs/acre boron treatments.

The alfalfa emerged quickly, the stand was excellent, and the plants showed good fall growth (Figs. 1&2). Applications of boron treatments are underway, however timing of the applications was delayed by the heavy rains this fall, which resulted in water standing on the plots (Fig. 3).

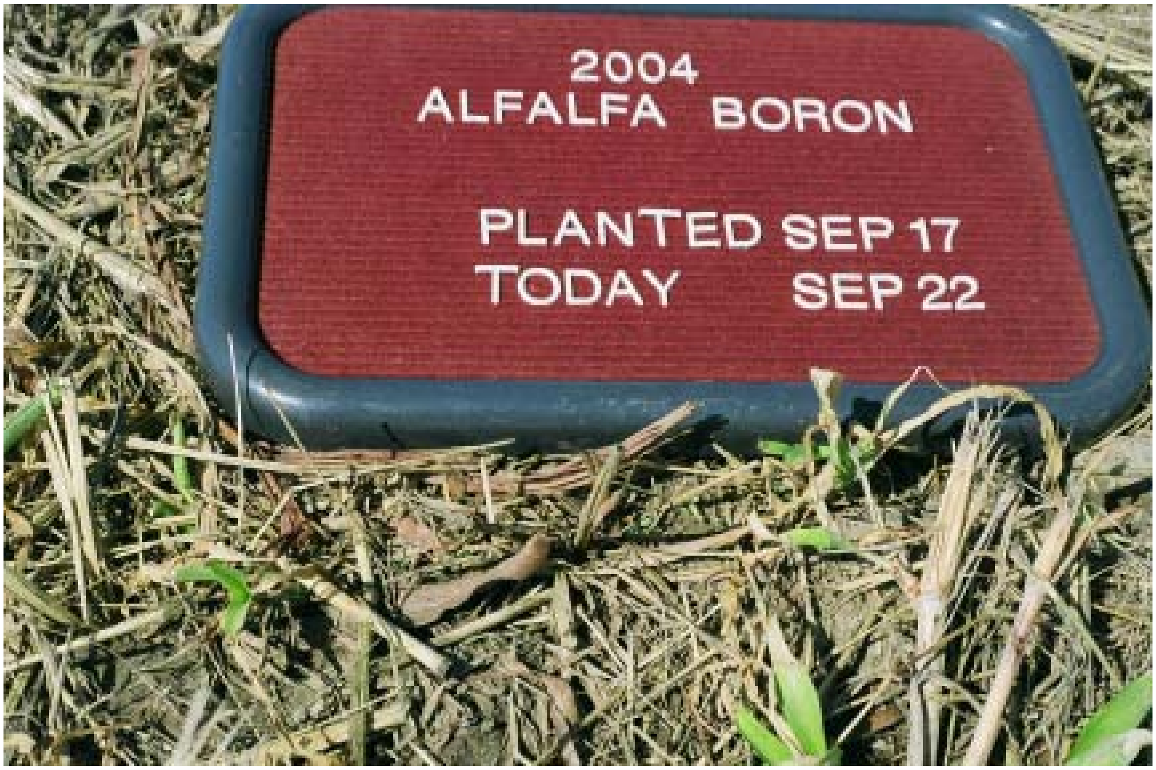


Figure 1. Alfalfa emergence on September 22, 2004 at South Farm.

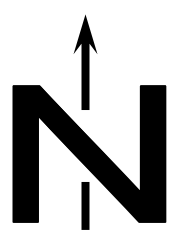

Figure 2. Alfalfa growth 10 days after planting.

Figure 3. Alfalfa rows with water standing in November 2004.

# Alfalfa - Boron Study

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 112 | 111 | 110 | 109 | 108 | 107 | 106 | 105 | 104 | 103 | 102 | 101 |
| 5 | 11 | 2 | 7 | 12 | 3 | 8 | 4 | 9 | 10 | 6 | 1 |
| 212 | 211 | 210 | 209 | 208 | 207 | 206 | 205 | 204 | 203 | 202 | 201 |
| 12 | 3 | 9 | 5 | 10 | 1 | 8 | 6 | 11 | 7 | 4 | 2 |
| 312 | 311 | 310 | 309 | 308 | 307 | 306 | 305 | 304 | 303 | 302 | 301 |
| 10 | 3 | 8 | 11 | 5 | 6 | 7 | 2 | 4 | 9 | 1 | 12 |
| 412 | 411 | 410 | 409 | 408 | 407 | 406 | 405 | 404 | 403 | 402 | 401 |
| 9 | 6 | 5 | 1 | 2 | 3 | 12 | 8 | 4 | 7 | 10 | 11 |

Gravel Road




**Seed Varieties:**
1-6: Pioneer 54V46
7-12: Pioneer 54H91

**Boron Treatments:**
1 & 7: 0 lbs B
2 & 8: 2.5 lbs B
3 & 9: 5.0 lbs B
4 & 10: 10.0 lbs B
5 & 11: 20.0 lbs B
6 & 12: Insecticide Control

**Plot Dimmensions:**
30’ x 14’

**Alley Widths:**
North/South Alleys 7’
East/West Alleys 14’

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