2006 Missouri Fertilizer and Agricultural Lime Board Report

Finding Alternatives to Ammonium Nitrate as a Nitrogen Source for Tall Fescue Pastures

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

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

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

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

The **overall objective** is to develop research-based recommendations that help industry personnel and farmers determine the best alternative to ammonium nitrate fertilizer for spring and late-summer N applications to tall fescue pastures. Specifically, we are comparing ammonium nitrate to ammonium sulfate, urea, coated urea products, and mixtures of ammonium sulfate with urea and mixtures of ammonium sulfate with ESN polymer coated urea as a source of nitrogen for tall fescue.

Procedures:

Experiment 1 (Spring applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N on 17 and 18 March 2005 at the Forage Systems Research Center near Linneus, MO and the Southwest Research and Education Center near Mount Vernon, MO. In 2006, fertilizer was applied at the same rate and time of year but the Bradford Research and Extension Center in Columbia replaced the site at the Forage Systems Research Center. The sources of N are listed in Table 1 and include several urea based products already on the market, mixtures of some of these products, as well as untreated urea, ammonium sulfate, and ammonium nitrate as checks. The 75 lb/acre N rate was selected because it is a common fertilization rate for producers. Soil P and K levels are maintained at levels recommended by the University of Missouri Soil Testing Laboratory.

Experiment 2 (Late-summer applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-August 2005 and 2006 at the same locations (but different plot areas) as described above for Experiment 1. The same sources of N were used as in Experiment 1. Our focus for this experiment was on autumn growth for stockpiling or deferred grazing regimes.

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

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

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

Preliminary Results:

Experiment 1

Forage Yield. Our preliminary data for the first two years indicate that only the initial harvest responded to N applied in March. Nearly 80% of the annual dry matter was harvested at the first sampling date in May and few treatment differences were measured in the two subsequent harvests; thus yields are reported as annual totals for both years (Tables 2). We hypothesized that the "coated urea" products might have yielded greater the summer or autumn after application because of their slow N release activity. But this was not the case. Additionally, no one product was overwhelmingly consistent in producing high yields.

We noted that ammonium sulfate ranked in the top producing group at nearly all harvests and locations and its performance is perhaps the most surprising data from this experiment. Another somewhat surprising result was that ammonium nitrate, urea, and ammonium sulfate proved to be nearly equal N fertilizer sources for tall fescue in spring. We should note that in each year both locations received ample moisture within 5 days of the fertilizer application to get urea into the soil

solution. An extended dry period after application of these products may have resulted in more volatilization of urea and thus a comparative advantage for the "coated urea" products.

Thus far, our preliminary data show that a spring application of 75 lb/acre N increased yields by approximately 2250 lb/acre over the unfertilized control or about 30 lb of additional forage for each pound of N fertilizer applied. Ground moisture affected this relationship drastically as the range was 987 to over 4800 lb/acre.

Soil Analysis. One of the questions posed while designing this research was whether the array of products and mixtures of products would alter the soil sulfate and/or nitrate such that forage quality might be enhanced. Another question regarded the fate of nitrate in the soil from different sources of N. At this point, we have one year of data for two locations (Table 3). When ammonium sulfate was the only source of N applied, the concentration of sulfate in the soil solution was approximately two and three times greater, respectively, than those treatments that had mixtures with ammonium sulfate and those that contained no ammonium sulfate. Nearly all plots treated with ammonium sulfate showed a decline in soil sulfate concentration during the growing season. Soil sulfate concentrations from plots treated with only ammonium sulfate declined nearly 35%, those with ammonium sulfate mixed with another product declined nearly 25%, while there was virtually no decline in soil sulfate where no sulfate was applied. It is yet to be seen if sulfate levels in forage increased as a result of the greater plant available sulfur in the soil solution. We are monitoring soil pH and in the final report will describe how it is affected by yearly applications of ammonium sulfate.

Soil nitrate concentrations were rarely influenced by the source of N applied to the plots. However on 19 May 2006, treatments that included polymer coated urea showed 4.8 ppm nitrate, which was nearly 40% greater than treatments without polymer coated urea. It is interesting that this slow release activity of the polymer did not occur at the other location. The soil nitrate concentration averaged across locations and treatments was 2.9 ppm (data not shown).

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

Experiment 2

Forage Yield. For N applied in late-summer, many of the products yielded similarly and in most cases 10 or more of the products showed equal yields (Table 4). Consistently, urea, ammonium nitrate, and ammonium sulfate had comparable yields in three of four site-years. Tall fescue fertilized with urea yielded 35% less than that fertilized with ammonium nitrate during the dry autumn of 2005 in Mt. Vernon. Five days elapsed before any precipitation fell at the site and for 14 days only 0.20 inches of rain fell. This is a classic example of the risk associated with using urea as the N source for late-summer applications to pasture. Despite the promise in utilization of polymer coated urea to lessen this risk, it yielded less than most other treatments. The polymer coated urea has not shown much promise as a substitute for urea or ammonium nitrate for spring or late-summer N applications. We have yet to analyze the forage quality or soil fertility of samples collected in the autumn.

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

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

Table 2. Total annual forage yield of tall fescue fertilized with different nitrogen sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Nitrogen was applied 16 March ± 2 days in both years at 75 lb/acre for each fertilizer source. Values are the total of three harvests taken during the growing season.

Fertilizer Source	Total Annual Forage Yield		
	Mt. Vernon 2005	Mt. Vernon 2006	Columbia 2006
	---------- lb/acre ----------		
Ammonium nitrate	**10232**	6178*	5679*
Urea	**9784**	**5736**	**5078**
Ammonium sulfate	10793*	**5697**	**5431**
Urea treated with Agrotain	**10518**	**6010**	**5069**
ESN polymer coated Urea	8983	4223	3947
Nurea	**10105**	**5359**	**5267**
Nurea with 10% polymer N	9376	**5590**	4772
Ammonium Sulfate (10S)/Urea	**9987**	**5755**	**4887**
Ammonium Sulfate (20S)/Urea	**9649**	**5871**	**5296**
Ammonium Sulfate (40S)/Urea	**9931**	**5748**	4370
Ammonium Sulfate (10S)/ESN	8856	4431	4246
Ammonium Sulfate (20S)/ESN	8513	4740	4213
Ammonium Sulfate (40S)/ESN	9492	**5767**	**4870**
Equal N from Urea, Ammonium sulfate and ESN	**9613**	**5250**	**5034**
Unfertilized Control	5943	3444	2658
LSD (0.05)	1228	828	845

* Highest numerical yield within a column.
Bolded values within a column do not differ from the highest numerical yield.

Table 3. Soil sulfate concentrations at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Nitrogen was applied 16 March ± 2 days at 75 lb/acre for each fertilizer source. Soil samples were collected to a six-inch depth on the dates reported below.

Fertilizer Source	Columbia			Mt. Vernon		
	6/1/06	8/23/06	10/19/06	5/19/06	7/27/06	10/11/06
	---------- sulfate ppm ----------					
Ammonium nitrate	6.1	6.5	6.2	4.5	4.8	4.0
Urea	5.9	6.2	5.4	4.8	5.1	5.3
Ammonium sulfate	19.1	10.8	12.4	12.0	8.2	9.2
Urea treated with Agrotain	6.1	6.7	4.6	5.1	4.9	4.8
ESN polymer coated Urea	6.2	6.4	5.0	5.2	5.1	4.3
Nurea	5.8	6.2	5.4	4.9	4.8	4.2
Nurea with 10% polymer N	5.7	6.1	6.3	4.7	4.8	4.8
Ammonium Sulfate (10S)/Urea	7.2	7.8	7.6	5.9	5.8	3.9
Ammonium Sulfate (20S)/Urea	8.8	7.2	6.1	7.0	5.5	5.6
Ammonium Sulfate (40S)/Urea	11.7	8.3	7.6	7.7	6.4	5.5
Ammonium Sulfate (10S)/ESN	7.4	6.5	6.2	5.8	5.7	4.6
Ammonium Sulfate (20S)/ESN	8.6	6.5	5.4	6.9	5.3	5.3
Ammonium Sulfate (40S)/ESN	11.8	8.0	6.9	7.7	6.1	6.1
Equal N from Urea, Ammonium sulfate and ESN	9.6	7.7	6.9	6.3	5.8	5.5
Unfertilized Control	6.6	6.6	5.8	5.4	5.3	5.2
LSD (0.05)	1.8	1.4	2.3	1.4	0.9	2.1

Table 4. Yield of autumn accumulated tall fescue fertilized with different nitrogen sources at the Southwest Research and Education Center near Mount Vernon, MO, the Forage Systems Research Center near Linneus, MO, and the Bradford Research and Extension Center near Columbia, MO. Nitrogen was applied August 17 ± 1 day in both years at 75 lb/acre for each fertilizer source. Forage was allowed to grow until harvested on the date reported below.

Fertilizer Source	Autumn accumulated yield			
	Mt. Vernon 12/2/2005	Linneus 12/13/2005	Mt. Vernon 11/29/2006	Columbia 11/28/2006
	----------lb/acre----------			
Ammonium nitrate	1932*	**1853**	**1918**	**2700**
Urea	1245	**1879**	**2201**	**2865**
Ammonium sulfate	**1579**	2174*	**2245**	**2787**
Urea treated with Agrotain	**1523**	**1820**	**1880**	**2696**
ESN polymer coated Urea	1249	**1795**	1549	2117
Nurea	**1437**	1655	**2188**	**2738**
Nurea with 10% polymer N	988	1681	**2176**	**2725**
Ammonium Sulfate (10S)/Urea	**1696**	**1929**	**2282**	**2539**
Ammonium Sulfate (20S)/Urea	1259	**1904**	**2137**	2877*
Ammonium Sulfate (40S)/Urea	**1903**	**1872**	2327*	**2763**
Ammonium Sulfate (10S)/ESN	**1856**	1717	1664	**2378**
Ammonium Sulfate (20S)/ESN	**1741**	1638	**2079**	2243
Ammonium Sulfate (40S)/ESN	**1761**	**2008**	**1882**	**2547**
Equal N from Urea, Ammonium sulfate and ESN	**1822**	**1953**	**2312**	**2819**
Unfertilized Control	492	881	834	1721
LSD (0.05)	522	430	616	586

* Highest numerical yield within a column.
Bolded values within a column do not differ from the highest numerical yield.

Timetable for proposed research: These studies began in March 2005 and are scheduled to end in December 2007 (three years of study). The table below gives a brief summary of the project's activities. (* indicates a task to be done on an annual basis throughout the three-year study)

Take soil core samples for initial soil nitrogen determinations for spring application.	3/15/2005*
Apply N fertilizer sources at the rate of 75 lb/acre to appropriate plots for spring application experiment.	3/15/2005*
Harvest plots for forage yield and retain subsamples for forage quality analysis from spring fertilized plots. Take soil cores from each plot to determine residual soil N and sulfate after each harvest.	5/20/2005 and 7/15/2005, and 10/5/2005*
Take soil core samples for initial soil nitrogen determinations for late-summer N application.	8/15/2005*
Apply N fertilizer sources at the rate of 75 lb/acre to appropriate plots for late-summer application experiment.	8/15/2005*
Harvest plots for forage yield and retain subsamples for forage quality analysis from late-summer fertilized plots. Take soil cores from each plot to determine residual soil N and sulfate.	12/15/2005*
Analyze latest results & report findings to Fertilizer/Ag Lime Advisory Council	12/15/05*
Incorporate latest findings into soil testing reports, grazing school curriculum and educational workshops. Work with popular press on articles.	8/2008
Prepare updated MU guide on fertilization of pastures with different N sources.	9/2008
Prepare and submit an article on this research to a peer-reviewed journal.	10/2008

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

Year 3

Salary and Benefits	
Research Specialist (25% of $40,793)	$10,198
Benefits for Research Specialist	$ 3,212
Student labor for grinding, etc	$ 1,000
Benefits for student labor	$ 100
Total Salary and Benefits	$14,510
Operating Expenses	
Fertilizer, bags, repair parts for harvester and other field supplies	$ 1,000
NIR charges for forage quality (255 samples @ $10 each)	$ 2,550
Soil N analysis (510 samples @ $8 each)	$ 4,080
Travel to FSRC and SWC (mileage, lodging, and meals)	$ 1,700
Total Operating Expenses	$ 9,330

Total Proposal Request for Year #3 ***$23,840***