Alternative Nitrogen Fertilizers for Tall Fescue Pastures

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

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

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

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

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

Procedures:
Experiment 1 (Spring applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-March at the Southwest Research and Education Center near Mount Vernon, MO and at the Bradford Research and Extension Center near Columbia, MO. Products were tested in 2005, 2006, and 2007 at Mt. Vernon and in 2006 and 2007 at Columbia. The sources of N are listed in Table 1 and include several urea based products already on the market, mixtures of some of these products, as well as untreated urea, ammonium sulfate, and ammonium nitrate as checks. The 75 lb/acre N rate was selected because it is a common fertilization rate for producers. Soil P and K levels were maintained at levels recommended by the University of Missouri Soil Testing Laboratory.

Experiment 2 (Late-summer applied N treatments).
Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-August at the same locations (but different plot areas) as described above for Experiment 1. The same sources of N were used as in Experiment 1. Our focus for this experiment was on autumn growth for stockpiling or deferred grazing regimes.

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

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

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

Results:
Experiment 1
<u>Forage Yield</u>. Our data show that only the initial harvest responded to N applied in March. Between 60 and 80% of the annual dry matter was harvested at the initial sampling date in May and few treatment differences were measured in the two subsequent harvests; thus yields are only shown for the initial harvest each year (Table 2). We hypothesized that the "coated urea" products might have yielded greater than uncoated urea products in the summer or autumn after application because of their slow N release activity. But typically, this was not the case.

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

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

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

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

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

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

Experiment 2

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

Conclusions:

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

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

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

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

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

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

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

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

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

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

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

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

Budget for 2008

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