THE EFFECT OF NITROGEN SOURCES, RATES, AND APPLICATION METHODS ON BERMUDAGRASS FORAGE

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CHAPTER I

INTRODUCTION

The continually increasing cost of crop and livestock production makes it imperative that the farmer or rancher make the most efficient use of his time and resources to increase his profit margins. One such management decision is efficient fertilizer use to produce high yielding quality forages.

Most of the research investigating the use of nitrogen fertilizers on forages have been with solid sources such as ammonium nitrate, urea, and ammonium sulfate. More recently solution nitrogen sources have been investigated, but little research has been conducted involving a comparison of solid, liquid, and gas nitrogen sources.

Anhydrous ammonia, a high analysis nitrogen fertilizer in gaseous form, is the most economical source of nitrogen per pound of nitrogen, although the cost of application may be higher due to the depth of placement. One of the latest developments by United States Steel is putting anhydrous ammonia into the soil at a shallower depth in a liquid-vapor (Cold-Flo) form; thereby reducing the cost of application. This new technique may possibly make it economical and feasible for applying anhydrous ammonia to a forage type crop.

The purpose of this study was to determine the effects of different nitrogen sources, rates, and application methods on dry matter yields and percent nitrogen in bermudagrass forage.

CHAPTER II

LITERATURE REVIEW

The use of nitrogen fertilizers to increase forage production has been known for some time and when applied to bermudagrass, a high yielding, high quality forage can be produced. In a four-year study with Coastal bermudagrass, Fisher and Caldwell (1959) produced an average of 11.8 metric tons per hectare of 13% protein hay when fertilized with 1,120 kg N/ha annually. Wright (1965) reported yields of 9.1-10.9 metric tons of high quality hay from Midland bermudagrass, although he did not specify rates or application methods of fertilizer nitrogen. Referring to Coastal bermudagrass, Eichhorn (1974, p. 3) stated ". . . applications of nitrogen on this forage crop are a necessity for abundant forage production."

Nitrogen Sources

There are several different forms and sources of nitrogen fertilizer and it is essential to know which sources are more effective for forage production and forage quality. Although little research has been conducted comparing solid, liquid, and gas nitrogen sources, Rogers (1972) stated that most authors agree that different nitrogen sources are equally effective if applied under proper conditions.

Rogers (1972) reported from his own research there were no differences in forage yields when the sources were pooled. Hill and Tucker (1967) compared injected anhydrous ammonia, topdressed urea, and ammonium nitrate on bermudagrass sod and concluded yields were equal at lower rates of N, but at higher rates, anhydrous ammonia produced lower yields in the first clipping and higher yields in succeeding clippings. The lag in response was attributed to sod burn from escaping anhydrous ammonia. Bohl (1976) showed ammonium nitrate was superior to urea when 112 kg/ha or more were applied in a single application to bermudagrass. However, a split application of urea produced yields comparable to ammonium nitrate if applied at 112 kg N/ha or lower, and he concluded the reduction in yield from urea was primarily due to loss of nitrogen by volatilization.

Several authors have shown a difference in nitrogen sources. Eichhorn (1974) reported Coastal bermudagrass produced significantly higher yields of forage with prilled ammonium nitrate than with liquid urea-ammonium nitrate. Also, Burton and Jackson (1962) in a study with Coastal bermudagrass reported ammonium nitrate, ammonium sulfate, ammonium nitrate solution, and urea gave average relative hay yields of 100, 96.2, 98.3, 94.0, 92.3, and 81.6 percent, respectively.

The effect of nitrogen sources on forage quality of Coastal bermudagrass was investigated by Eichhorn (1974). Protein and N uptake by the forage were significantly higher for prilled ammonium nitrate than for liquid urea-ammonium nitrate.

Decker et al. (1971) reported higher N removal and higher percent recovery were obtained for NH_4NO_3 than for urea with Midland bermudagrass. With Coastal bermudagrass, Matocha et al. (1973) concluded that grass receiving $(NH_4)_2SO_4$ recovered the largest percentage of applied N, followed by NH_4NO_3, and with $(NH_2)_2CO$ recovering the least percentage of applied N. Also, Burton and Jackson (1962) reported percent N recovered, decreased with increasing rates of N for all sources (ammonium nitrate, ammonium sulfate, ammonium nitrate solution, urea, urea-ammonium nitrate solution) except anhydrous ammonia which gave a similar recovery regardless of rate on Coastal bermudagrass.

Rates

Most authors agree that forage yields increased with increasing rates of nitrogen (Rogers, 1972; Schon and Tesar, 1977; Alexander, 1958; Decker, 1965; Mathias et al., 1973; Doss et al., 1966; George et al., 1973; Dotzenko, 1961; Taliaferro et al., 1975; Burton et al., 1969; Hallock et al., 1965; Drake et al., 1963; Yungen et al., 1977). Decker et al. (1971) reported stands of Midland bermudagrass were not damaged by nitrogen rates up to 896 kg/ha provided adequate amounts of P and K were present and the soil did not become too acidic. Woodhouse (1969) and Burton et al. (1969) agreed that a rule of thumb for applying fertilizer was in a 9-1-4 ratio of N-P-K on Coastal bermudagrass. Holt and Fisher (1960) reported Coastal bermudagrass forage yields were increased with increasing N rates and resulted in decreased root top ratio. Root weights were maintained at about the same level with all N rates, and this was not a limiting factor in forage yield response.

Most of the literature reviewed, was in agreement that percent nitrogen content in forage grasses increases with increasing N rates (Dotzenko, 1961; Yungen et al., 1977; Doss et al., 1966; Eichhorn, 1974). Mathias et al. (1973) reported nitrogen content in Midland bermudagrass forage increased with increasing rates of nitrogen and was greater in the second harvest than in the first.

Matocha et al. (1973) and Mathias et al. (1973) showed that **an** inverse relationship exists between nitrogen rate and the efficiency of the plant in recovering N as measured by forage production.

Application Methods

Most of the literature reviewed investigating nitrogen on forage grasses reported split applications of the nitrogen applied. Little work has been conducted comparing a split application with a single application. In a study comparing application methods on Coastal bermudagrass, Burton and Jackson (1962) concluded that splitting the N application failed to increase yields in years without heavy leaching rains. However, over a 5-year period with normal rainfall, splitting the N application significantly increased yields from all sources (ammonium nitrate, ammonium nitrate solution, ammonium sulfate, UAN solution, urea) except anhydrous ammonia. However, anhydrous ammonia was equal to the best source when applied in a single application in March but was inferior to most sources when split because of application injury and lag in response. Nass et al. (1975) showed in a study on the effects of ammonium nitrate application on barley, oats, and triticale grown as forages that a split application at seeding and stem elongation did not increase dry matter yields over the single application at seeding.

In this same 3-year study, Nass et al. (1975) concluded that a split application of N did not increase the crude protein concentration over the single application.

CHAPTER III

MATERIALS AND METHODS

Four locations were selected and field plots were established to evaluate the effects of nitrogen sources, rates, and application methods on bermudagrass (Cynodon dactylon L. Pers.) production. The location and soil classification of the experimental sites are listed in Table I. These locations were chosen to give a wide variation in soil and climatic conditions.

TABLE I

LOCATION AND SOIL CLASSIFICATION OF BERMUDAGRASS FIELD EXPERIMENTS

Location	Legal Description	Soil Classification
Haskell	NE, NE 33-15N-16E	Cumulic Hapludolls Verdigris silt loam
Muskogee	NE, SW 24-15N-19E	Cumulic Hapludolls Verdigris silt loam
Pauls Valley	SE, NE 34-4N-1W	Pachic Haplustolls Dale silt loam
Ringling	NE, NE 35-4S-5W	Udic Haplustolls Lucien fine sandy loam

Soil samples were taken from each location and analyzed by the Oklahoma State University Agronomic Services

Laboratory and results are reported in Table II. K_2O and P_2O_5 levels were adequate at all locations.

Nitrogen sources, percent N, and rates of application are shown in Table III. All the treatments received their first application of nitrogen when the study was initiated and the second application after the first harvest.

TABLE II

INITIAL SOIL TEST OF BERMUDAGRASS FIELD EXPERIMENTS

Location	pH	NO_3-N ppm	P ppm	K ppm
Haskell	6.6	4.5	43.5	187.0
Muskogee	6.8	5.5	65.5	433.5
Pauls Valley	6.9	2.5	59.0	183.0
Ringling	4.7	8.0	61.5	194.0

TABLE III

TREATMENTS ON BERMUDAGRASS EXPERIMENTS

Source	N %	Rate kg N/ha	Method of Application
Check	0	0	-
Anhydrous ammonia	82	112 + 112	Split
Anhydrous ammonia-CF	82	224	Single
UAN-28	28	224 + 112	Split
Urea	46	448	Single
Ammonium sulfate	21		

Twenty-one treatments were arranged in a randomized complete block design and replicated four times at each location. Individual plot sizes were 4.9 x 15.2 m with 7.6 m alleys between replications. Initial applications of the N fertilizers were March 14, 15, 20, and 21, 1978 at the Ringling, Pauls Valley, Haskell, and Muskogee locations, respectively.

Solid fertilizers (urea, ammonium sulfate) were applied with a Barber spreader and the urea ammonium nitrate solution (UAN-28) was applied by a Tote solution applicator. Anhydrous ammonia (AA) and anhydrous ammonia-Cold Flo (AA-CF) were injected into the soil with a small applicator especially designed for experimental work. Anhydrous ammonia-Cold Flo was applied by switching the high pressure hoses to the mini-pot converters which were attached to the same implement. The only difference between application of AA and AA-CF was the depth of placement, being 15-20 cm and 10-15 cm, respectively.

The experimental plots were clipped with a 90 cm Jeri mower and a 2.1 m swather for the first and second harvests, respectively, when the bermudagrass headed out. A measured swath (0.9 x 9.0 m and 2.1 x 6.0 m, first and second harvests, respectively) of forage was weighed to determine dry matter yield for each plot. Forage samples were used to determine percent dry matter and percent nitrogen. One sample was placed in a moisture-tight container, weighed, then dried by forced air at 60-65 C for 48 hours in a porous container and reweighed to determine percent dry matter. Another sample was dried by the method described above and ground to pass through a 200 mesh screen for use in a modified microkjeldahl procedure for determining N.

The modified microkjeldahl procedure consisted of a 250 ±3 mg sample of dried plant material (60 C for 2-4 hours) being placed in the bottom of a BD-40 digestion tube after 2.1 g of $K_2SO_4 \cdot CuSO_4 \cdot Se$ (100:10:1 ratio) catalyst mix was added. Seven milliliters of concentrated H_2SO_4 were added. After the sample was thoroughly wet, 1 ml of 30% H_2O_2 was added. After the reaction ceased, the sample was placed in a Tecator BD-40 block digester, preheated to 420 C for one hour. The sample was removed, cooled, and approximately 15 ml of deionized water was added. Nitrogen was determined by steam distillation into a boric acid indicator solution and titrating with a dilute HCl (Bremner, 1965).

The standard deviation (Steel and Torrie, 1960) of a 2% N standard run 19 times through the procedure described above was 0.05 with a mean of 2.01.

The average temperature and total precipitation by month for January through August 1978 is reported in Table IV (Mitchell, 1978). Data were taken from the weather station reports nearest the experimental sites.

Data for this study were analyzed using the SAS computer programming (Service, 1972) and Duncan's new multiple range test (Steel and Torrie, 1960).

TABLE IV

CLIMATOLOGICAL DATA

Location	January	February	March	April	May	June	July	August
<u>Haskell-Muskogee</u>								
Ave. Temp. (°C)	-2.4 (-6.2)*	-0.2 (-6.6)	9.0 (-1.2)	17.7 (0.9)	20.6 (-0.3)	25.1 (-0.2)	30.3 (1.3)	28.8 (1.2)
Mo. Precip. (cm)	2.95 (-1.82)*	6.18 (0.2)	8.42 (0.55)	9.95 (-2.25)	11.95 (-2.65)	14.82 (1.95)	2.92 (-5.5)	4.05 (-3.6)
<u>Pauls Valley</u>								
Ave. Temp. (°C)	-1.3 (-7.8)	0.4 (-6.7)	10.6 (-0.2)	19.0 (1.5)	21.4 (-0.3)	26.2 (-0.1)	32.1 (3.4)	28.4 (0)
Mo. Precip. (cm)	2.5 (-1.08)	6.85 (2.32)	4.98 (-0.72)	7.35 (-1.4)	20.35 (6.35)	9.9 (0.18)	1.95 (-4.45)	1.35 (-5.15)
<u>Ringling</u>								
Ave. Temp. (°C)	0 (-5.6)	0.9 (-7.3)	11.3 (-0.6)	19.4 (1.2)	21.9 (-0.3)	26.3 (-0.2)	30.8 (1.9)	27.7 (-1.2)
Mo. Precip. (cm)	1.88 (-1.65)	6.05 (2.2)	7.02 (2.48)	1.88 (-6.08)	23.25 (10.4)	9.4 (0.72)	0.65 (-5.95)	5.82 (0.08)

*Numbers in parenthesis are departures from normal.

CHAPTER IV

RESULTS AND DISCUSSION

Nitrogen content and dry matter yield of bermudagrass as affected by nitrogen sources, rates, and application methods at each location are discussed from the data obtained.

Haskell Experiment

The soil was very moist when this study was initiated March 20, 1978. The remainder of the season was extremely dry, especially in July and August (Table IV). Bermudagrass was clipped June 8 and 9 for the the first harvest and August 16 for the second harvest.

Dry matter yield and percent nitrogen means as influenced by N sources are reported in Table V. There were no significant differences in yields of bermudagrass the first harvest but ammonium sulfate produced a significant increase in yield over other N sources in the second harvest. Nitrogen percent in the bermudagrass forage was higher with ammonium sulfate and UAN-28 in the first harvest even though there were no differences in yield. Nitrogen sources had no effect on percent nitrogen in the second harvest.

Nitrogen removal in forage (dry matter yield x percent N) expressed as percent of maximum reference to sources is shown in Table VI. Anhydrous ammonia-CF and urea were not as effective as the other N sources for nitrogen removal.

TABLE V

EFFECT OF N SOURCES ON YIELD AND % N OF BERMUDAGRASS HASKELL-1978

N Sources	Harvest 1		Harvest 2	
	Dry matter kg/ha	% N	Dry matter kg/ha	% N
Anhydrous ammonia	6131	2.15	2558	1.44
Anhydrous ammonia-CF	5951	1.92	2250	1.28
UAN-28	6338	2.25	2815	1.31
Urea	6256	2.00	2330	1.24
Ammonium sulfate	6611	2.36	3960	1.38
LSD (.05)	932	0.21	727	0.23

TABLE VI

EFFECT OF N SOURCES ON REMOVAL OF NITROGEN IN FORAGE HASKELL-1978

N Sources	Harvest 1		Harvest 2	
	Removed kg/ha	%	Removed kg/ha	%
Anhydrous ammonia	132	84.6	37	67.3
Anhydrous ammonia-CF	114	73.1	29	52.7
UAN-28	143	91.7	37	67.3
Urea	125	80.1	29	52.7
Ammonium sulfate	156	100.0	55	100.0

Effect of nitrogen rates on dry matter yield and nitrogen content in forage are shown in Table VII. Dry matter yield produced by 448 kg N/ha was significantly higher than the yield produced by 112 kg N/ha, but was not different from the yield produced with the 224 kg N/ha application.

TABLE VII

EFFECT OF N RATES ON YIELD AND
% N OF BERMUDAGRASS
HASKELL-1978

Rates kg/ha	Harvest 1 Dry matter kg/ha	Harvest 1 % N	Harvest 2 Dry matter kg/ha	Harvest 2 % N	Harvest 1+2 Dry matter kg/ha	Harvest 1+2 % N
112	5847	1.90				
224	6167	1.95	2172	1.27	8339	1.61
336*					9078	1.79
448	6758	2.53	3393	1.39	10152	1.96
LSD (0.05)	722	0.17	460	0.15	941	0.11

*This was a split application of 224 and 112 kg/ha.

The higher rate was also superior in percent nitrogen in forage in both harvests, however, differences were greater in the forage of the first harvest. Nitrogen content in forage was higher for all sources in the first harvest as compared to the second harvest, believed to be due to the maturity of the harvested forage.

Nitrogen removed in forage in treated plots minus nitrogen removed in the check treatment divided by rate applied, and expressed as percent applied is shown in Table VIII. Although it is realized that some nitrogen

TABLE VIII

EFFECT OF N RATES ON REMOVAL OF NITROGEN IN FORAGE HASKELL-1978

	Harvest 1		Harvest 2		Harvest 1+2	
Rates kg/ha	Removed kg/ha	% recovery	Removed ka/ha	% recovery	Removed kg/ha	% recovery
112	111	46.4				
224	120	27.2	28	8.9	134	32.1
336					162	29.8
448	171	25.0	47	8.7	199	30.6

would be removed from the soil and not just from nitrogen applied, this is an indication of the efficiency of nitrogen recovery. The lower rates of applied nitrogen resulted in a greater efficiency of nitrogen recovery in the first harvest.

There were no significant differences between split or initial application of nitrogen fertilizers; however, the split application showed a greater nitrogen content in the forage (Table IX).

TABLE IX

EFFECT OF APPLICATION METHODS ON YIELD AND % N OF BERMUDAGRASS HASKELL-1978

Application Method	Dry matter kg/ha	% N
Initial (224 kg N/ha)	8339	1.61
Split (112 + 112 kg N/ha)	8342	1.74
LSD (0.05)	1049	0.12

The effects of nitrogen sources and rates on yield and percent nitrogen of bermudagrass at Haskell are reported in Table X. There were no significant differences in dry matter yield in the first harvest, although higher rates showed higher percent nitrogen. In the second harvest, urea and AA-CF were lower in yield at the 224 kg N/ha rate which was probably due to the low nitrogen efficiency as seen in Table VI. Also, ammonium sulfate was significantly greater in yield production at the 448 kg N/ha rate which may be due to sulfur response; however, rarely is a response to sulfur observed in Oklahoma (Westerman, 1979). This may be due to the loss of the other N sources, whereas ammonium sulfate is less prone for loss.

There were no significant differences in nitrogen content of the forage in the second harvest. The check treatment was significantly lower in dry matter yield in both harvests and percent nitrogen in the first harvest. There was no significant difference in percent nitrogen in the second harvest which was due to the extreme dry weather conditions.

TABLE X

EFFECT OF N SOURCES AND RATES ON YIELD AND % N OF BERMUDAGRASS HASKELL-1978

N Source	N Rate kg/ha	Harvest 1 Dry matter yield kg/ha	Harvest 1 % N	Harvest 2 Dry matter yield kg/ha	Harvest 2 % N
Check	0	3858^{b*}	1.54^{e}	735^{e}	1.14^{a}
Ammonium sulfate	112	6260^{a}	1.88^{de}		
Anhydrous ammonia	112	5721^{a}	1.98^{d}		
Anhydrous ammonia-CF	112	5307^{ab}	1.81^{de}		
UAN-28	112	5822^{a}	1.88^{de}		
Urea	112	6124^{a}	1.96^{d}		
Ammonium sulfate	224	6288^{a}	2.28^{c}	3053^{b}	1.26^{a}
Anhydrous ammonia	224	6002^{a}	1.94^{d}	2278^{bcd}	1.50^{a}
Anhydrous ammonia-CF	224	5990^{a}	1.75^{de}	1756^{cde}	1.22^{a}
UAN-28	224	6641^{a}	2.04^{cd}	2375^{bcd}	1.25^{a}
Urea	224	5914^{a}	1.76^{de}	1396^{de}	1.14^{a}
Ammonium sulfate	448	7286^{a}	2.93^{a}	4866^{a}	1.50^{a}
Anhydrous ammonia	448	6670^{a}	2.43^{bc}	2839^{bc}	1.38^{a}
Anhydrous ammonia-CF	448	6556^{a}	2.19^{c}	2742^{bc}	1.34^{a}
UAN-28	448	6550^{a}	2.82^{ab}	3254^{b}	1.37^{a}
Urea	448	6730^{a}	2.27^{c}	3264^{b}	1.34^{a}

*Numbers within columns with different letters are significantly different at the 5% level.

Muskogee Experiment

This study was initiated on March 21, 1978. The soil was very moist during March and extremely dry in the remainder of the study (Table IV). The bermudagrass plots were clipped May 1, June 1 and 2 for the first harvest and August 15 for the second harvest.

Effects of nitrogen sources on dry matter yield and percent nitrogen are shown in Table XI. The low response on the yields for AA and AA-CF in the first harvest was believed to be due to loss of anhydrous ammonia from an inadequate soil seal. For the second harvest, there were no

TABLE XI

EFFECT OF N SOURCES ON YIELD AND % N OF BERMUDAGRASS MUSKOGEE-1978

N Source	Harvest 1 Dry matter kg/ha	Harvest 1 % N	Harvest 2 Dry matter kg/ha	Harvest 2 % N
Anhydrous ammonia	4927	2.26	2190	1.65
Anhydrous ammonia-CF	4798	2.19	1853	1.61
UAN-28	5947	1.97	1935	1.63
Urea	6011	1.88	2012	1.66
Ammonium sulfate	6203	2.20	2410	1.75
LSD (0.05)	767	0.14	579	0.18

significant differences between nitrogen sources. The percent nitrogen in the forage was higher for the anhydrous sources and ammonium sulfate in harvest one, but there were no significant differences in nitrogen content in the forage for the second harvest; although, the nitrogen content was lower for all sources in the second harvest.

Nitrogen removed in forage (by source) and expressed as a percent of the maximum removed is shown in Table XII. Urea, AA, and AA-CF were less efficient in utilization of the nitrogen especially in the first harvest. For AA and AA-CF, this may have been due to the loss of anhydrous ammonia because of an inadequate soil seal behind the shank of the applicator.

TABLE XII

EFFECT OF N SOURCES ON REMOVAL OF NITROGEN IN FORAGE MUSKOGEE-1978

N Source	Harvest 1 Removed kg/ha	Harvest 1 %	Harvest 2 Removed kg/ha	Harvest 2 %
Anhydrous ammonia	111	82	36	86
Anhydrous ammonia-CF	105	77	30	71
UAN-28	117	86	32	76
Urea	113	83	33	79
Ammonium sulfate	136	100	42	100

In general, as the rate of nitrogen increased, there was an increase in dry matter yield and percent nitrogen (Table XIII). However, in the first harvest, there were no significant differences between the 224 and the 448 kg N/ha rates. Combining yields from harvest one and two, there

TABLE XIII

EFFECT OF N RATES ON YIELD AND % N OF BERMUDAGRASS MUSKOGEE-1978

Rates kg/ha	Harvest 1 Dry matter kg/ha	Harvest 1 % N	Harvest 2 Dry matter kg/ha	Harvest 2 % N	Harvest 1+2 Dry matter kg/ha	Harvest 1+2 % N
112	4826	1.74				
224	5773	2.05	1719	1.54	7491	1.80
336*					7944	1.94
448	6133	2.51	2442	1.78	8575	2.14
LSD (0.05)	594	0.11	366	0.11	801	0.06

*This was a split application of 224 and 112 kg/ha N.

were no differences between the 224 and 336 kg N/ha rates or between the 336 and the 448 kg N/ha rates.

The percent recovery of the nitrogen applied, calculated from nitrogen removed in forage in treated plots minus nitrogen removed in check treatment divided by rate applied, is shown in Table XIV. The lower rates were more efficient in recovering applied nitrogen in the first harvest and when harvests were combined. This was due to the extremely dry summer season.

There were no significant differences between initial and split applications on dry matter yield or percent nitrogen (Table XV).

Generally, there was little difference between 224 and 448 kg H/ha on yield in either harvest as shown in Table XVI, although the percent nitrogen tended to increase with rate.

TABLE XIV

EFFECT OF N RATES ON REMOVAL OF NITROGEN IN FORAGE MUSKOGEE-1978

Rates kg/ha	Harvest 1 Removed kg/ha	Harvest 1 % recovery	Harvest 2 Removed kg/ha	Harvest 2 % recovery	Harvest 1+2 Removed kg/ha	Harvest 1+2 % recovery
112	84	51.8				
224	118	41.1	26	6.2	135	43.8
336					154	34.8
448	154	28.6	43	6.9	184	32.8

TABLE XV

EFFECT OF APPLICATION METHODS ON YIELD AND % N OF BERMUDAGRASS MUSKOGEE-1978

Application method	Dry matter kg/ha	% N
Initial (224 kgN/ha)	7491	1.80
Split (112 + 112 kg N/ha)	6828	1.80
LSD (0.05)	833	0.07

The check treatment was significantly lower in dry matter yield than all nitrogen treatments in the first harvest, but was not significantly different for yield from 224 kg N/ha in the second harvest, which was due to the extreme dry weather conditions during the study. The percent nitrogen was significantly lower for the check treatment

TABLE XVI

EFFECT OF N SOURCES AND RATES ON YIELD AND % N OF BERMUDAGRASS MUSKOGEE-1978

N Source	Rate kg/ha	Harvest 1 Dry matter yield kg/ha		Harvest 2 Dry matter yield kg/ha	% N
Check	0	1708^{f*}	1.53^{i}	931^{d}	1.25^{e}
Ammonium sulfate	112	6041^{bc}	1.65^{ghi}		
Anhydrous ammonia	112	4388de	1.95^{ef}		
Anhydrous-ammonia-CF	112	3934^{e}	1.81^{fg}		
UAN-28	112	5123^{bcde}	1.76^{fghi}		
Urea	112	4642^{cde}	1.53^{hi}		
Ammonium sulfate	224	6184^{bc}	2.20^{de}	1573^{cd}	1.60^{abcd}
Anhydrous ammonia	224	5176^{bcde}	2.23^{de}	1547^{cd}	1.46^{de}
Anhydrous ammonia-CF	224	5330^{bcde}	2.22^{de}	1649^{cd}	1.61^{abcd}
UAN-28	224	6582^{ab}	1.83^{fg}	1612^{cd}	1.47^{cde}
Urea	224	5592^{bcd}	1.80^{fgh}	2031^{bc}	1.56^{bcd}
Ammonium sulfate	448	6384^{ab}	2.75^{a}	3068^{a}	1.89^{a}
Anhydrous ammonia	448	5216^{bcde}	2.61^{ab}	2833^{ab}	1.83^{ab}
Anhydrous ammonia-CF	448	5130^{bcde}	2.55^{abc}	2056^{bc}	1.60^{abcd}
UAN-28	448	6136^{bc}	2.32^{bcd}	2258^{abc}	1.80^{ab}
Urea	448	7799^{a}	2.30^{cd}	1993^{bc}	1.77^{abc}

*Numbers within columns with different letters are significantly different at the 5% level.

from all other treatments except for urea, UAN-28, and ammonium sulfate at the 112 kg/ha rate in the first harvest and for anhydrous ammonia and UAN-28 in the second harvest.

Pauls Valley Experiment

This study was initiated March 15, 1978. The soil was extremely dry during July and August (Table IV). The bermudagrass was clipped June 12 and 13 for the first harvest

harvest and August 18 for the second harvest.

Dry matter yield was significantly lower for the anhydrous sources in both harvests (Table XVII) which probably was due to loss of anhydrous ammonia caused by an inadequate soil seal during application. Due to the shallower placement of anhydrous ammonia-CF, a greater loss probably occurred. The loss of anhydrous ammonia resulted in a lower percent nitrogen for anhydrous ammonia and anhydrous ammonia-CF in both harvests. A loss of urea may have occurred by volatilization due to the moist conditions when applied and subsequent drying conditions, although urea was not significantly different from ammonium sulfate for dry matter yield in either harvest.

TABLE XVII

EFFECT OF N SOURCES ON YIELD AND % N OF BERMUDAGRASS PAULS VALLEY-1978

	Harvest 1		Harvest 2	
N Source	Dry matter kg/ha	% N	Dry matter kg/ha	% N
Anhydrous ammonia	4066	1.87	727	1.08
Anhydrous ammonia-CF	3273	1.56	471	1.01
UAN-28	5383	2.01	2390	1.25
Urea	4728	1.91	1601	1.22
Ammonium sulfate	5299	2.15	2230	1.35
LSD (0.05)	574	0.17	694	0.15

Nitrogen removed in the forage (by source) and expressed as a percent of the maximum is shown in Table XVIII. The lower percent of nitrogen removed in both harvests for the anhydrous sources and urea is believed to be due to the loss of anhydrous ammonia vapor and by volatilization, respectively.

TABLE XVIII

EFFECT OF N SOURCES ON REMOVAL OF NITROGEN IN FORAGE PAULS VALLEY-1978

N Source	Harvest 1 Removed kg/ha	Harvest 1 %	Harvest 2 Removed kg/ha	Harvest 2 %
Anhydrous ammonia	76	66.7	8	26.7
Anhydrous ammonia-CF	51	44.7	5	16.7
UAN-28	108	94.7	30	100.0
Urea	90	78.9	20	66.7
Ammonium sulfate	114	100.0	30	100.0

Increasing N rate significantly increased dry matter yield and percent nitrogen in the forage (Table XIX).

Nitrogen removed in the forage in treated plots minus nitrogen removed in check treatment, divided by the rate applied, and expressed as a percentage is shown in Table XX. Only during the first harvest were the lower rates more efficient for nitrogen recovery. The 448 kg N/ha resulted

TABLE XIX

EFFECT OF N RATES ON YIELD AND
% N OF BERMUDAGRASS
PAULS VALLEY-1978

Rates kg/ha	Harvest 1 Dry matter kg/ha	Harvest 1 % N	Harvest 2 Dry matter kg/ha	Harvest 2 % N	Harvest 1+2 Dry matter kg/ha	Harvest 1+2 % N
112	3485	1.47				
224	4489	1.85	788	1.06	5277	1.45
336*					5941	1.71
448	5675	2.38	2179	1.31	7854	1.84
LSD (0.05)	445	0.13	439	0.10	659	0.09

*This was a split application of 224 and 112 kg/ha of N.

TABLE XX

EFFECT OF N RATES ON REMOVAL
OF NITROGEN IN FORAGE
PAULS VALLEY-1978

Rates kg/ha	Harvest 1 Removed kg/ha	Harvest 1 % Recovery	Harvest 2 Removed kg/ha	Harvest 2 % Recovery	Harvest 1+2 Removed kg/ha	Harvest 1+2 % Recovery
112	51	35.7				
224	83	32.1	8	2.7	77	29.5
336					102	27.1
448	135	27.7	29	6.0	145	29.9

in a higher percent recovery for the second harvest, but when the harvests were combined, there was little difference between rates.

Initial application of 224 kg N/ha produced significantly more forage than split application of 112 + 112 kg N/ha, although there were no significant differences in the percent nitrogen of the forage (Table XXI).

TABLE XXI

EFFECT OF APPLICATION METHODS ON YIELD AND % N OF BERMUDAGRASS PAULS VALLEY-1978

Application method	Dry matter kg/ha	% N
Initial (224 kg N/ha)	5277	1.45
Split (112 + 112 kg N/ha)	4188	1.49
LSD (0.05)	395	0.09

Data in Table XXII shows the effect of nitrogen sources and rates influencing dry matter yield and percent nitrogen. Although there were differences among sources within rates, in general, the higher rates produced greater yields and increased the nitrogen content in the forage. The check treatment was significantly lower in yield for all N treatments in the first harvest. However, due to the extreme dry weather, there was little difference for dry matter production in the second harvest and percent nitrogen in the check treatment was not significantly different

TABLE XXII

EFFECT OF N SOURCES AND RATES ON YIELD AND % N OF BERMUDAGRASS PAULS VALLEY-1978

N Source	Rate kg/ha	Harvest 1 Dry matter yield kg/ha	Harvest 1 % N	Harvest 2 Dry matter yield kg/ha	Harvest 2 % N
Check	0	689^{h*}	1.62^{efgh}	223^{b}	0.83^{e}
Ammonium sulfate	112	4090^{cdef}	1.56^{efgh}		
Anhydrous ammonia	112	3505^{fg}	1.53^{fgh}		
Anhydrous ammonia-CF	112	2664^{g}	1.37^{h}		
UAN-28	112	3906^{e}	1.48^{gh}		
Urea	112	3259^{fg}	1.43^{h}		
Ammonium sulfate	224	5937^{b}	2.10^{bcd}	1150^{b}	1.13^{cd}
Anhydrous ammonia	224	3467^{fg}	1.86^{def}	383^{b}	0.98^{de}
Anhydrous ammonia-CF	224	3169^{fg}	1.51^{gh}	355^{b}	0.99^{de}
UAN-28	224	4747^{bcde}	1.89^{cde}	1291^{b}	1.05^{cde}
Urea	224	5126^{bcd}	1.88^{cde}	763^{b}	1.14^{cd}
Ammonium sulfate	448	5870^{b}	2.78^{a}	3310^{a}	1.57^{a}
Anhydrous ammonia	448	5227^{bc}	2.21^{bc}	1071^{b}	1.19^{bcd}
Anhydrous ammonia-CF	448	3984^{def}	1.80^{defg}	588^{b}	1.03^{de}
UAN-28	448	7495^{a}	2.66^{a}	3489^{a}	1.44^{ab}
Urea	448	5798^{b}	2.44^{ab}	2438^{a}	1.30^{bc}

*Numbers within columns with different letters are significantly different at the 5% level.

from some of the low yielding treatments.

Ringling Experiment

This study was initiated March 14, 1978, on a moist sandy loam soil. Unlike the other locations, this site had not been grazed off by cattle and was covered by dry winter grasses which in combination with the cool spring temperature is believed to have resulted in a delayed growth of the bermudagrass. The remainder of the season was extremely dry. Bermudagrass was clipped June 20 and August 21 for the first and second harvest, respectively.

There were no significant differences in dry matter yield between sources for harvest one (Table XXIII). In havest two, UAN-28 was superior to urea. Ammonium sulfate

TABLE XXIII

EFFECT OF N SOURCES ON YIELD AND
% N OF BERMUDAGRASS
RINGLING-1978

	Harvest 1		Harvest 2	
N Source	Dry matter kg/ha	% N	Dry matter kg/ha	% N
Anhydrous ammonia	1493	2.28	1603	2.46
Anhydrous ammonia-CF	1456	2.33	1598	2.55
UAN-28	1483	2.30	1749	2.46
Urea	1684	2.36	1234	2.60
Ammonium sulfate	1675	2.61	1528	2.46
LSD (0.05)	290	0.18	497	0.16

was superior in forage nitrogen content in the first harvest, but there were no significant differences in the second harvest.

Nitrogen removed in forage (by source) and expressed as percent of the maximum removed is reported in Table XXIV. Ammonium sulfate was superior to all the other N sources in

TABLE XXIV

EFFECT OF N SOURCES ON REMOVAL
OF NITROGEN IN FORAGE
RINGLING-1978

N Source	Harvest 1		Harvest 2	
	Removed kg/ha	%	Removed kg/ha	%
Anhydrous ammonia	34	77.3	39	90.7
Anhydrous ammonia-CF	34	77.3	41	95.3
UAN-28	34	77.3	43	100.0
Urea	40	90.9	32	74.4
Ammonium sulfate	44	100.0	38	88.4

the first harvest, but there was little difference in the second harvest except for urea.

Effects of N rates are shown in Table XXV. There were little differences between N rates for dry matter yield

TABLE XXV

EFFECT OF N RATES ON YIELD AND
% N OF BERMUDAGRASS
RINGLING-1978

Rates	Harvest 1		Harvest 2		Harvest 1+2	
kg/ha	Dry matter kg/ha	% N	Dry matter kg/ha	% N	Dry matter kg/ha	% N
112	1526	2.22				
224	1429	2.34	1483	2.54	2912	2.44
336*					2833	2.49
448	1719	2.57	1601	2.48	3321	2.52
LSD (0.05)	224	0.14	315	0.10	363	0.07

*This was a split application of 224 and 112 kg/ha of N.

except where harvests were combined and the 448 kg N/ha rate was superior to the other rates. The higher rate also showed higher percent nitrogen in the first harvest, but there were no differences between harvests.

Nitrogen removed in forage in treated plots minus nitrogen removed in check treatment, divided by rate applied and expressed as a percentage is shown in Table XXVI. There

TABLE XXVI

EFFECT OF N RATES ON REMOVAL OF NITROGEN IN FORAGE RINGLING-1978

Rates kg/ha	Harvest 1		Harvest 2		Harvest 1+2	
	Removed kg/ha	% Recovery	Removed kg/ha	% Recovery	Removed kg/ha	% Recovery
112	34	2.7				
224	33	0.9	38	0.9	71	1.8
336					71	1.2
448	44	2.9	40	0.9	84	3.8

was little difference between the 112 and the 448 kg N/ha rate in the first harvest which were superior to the 224 kg N/ha rate. There were no differences between rates in the second harvest and when harvests were combined, the 448 kg N/ha rate showed a greater recovery.

There were no significant differences between initial application and split applications on dry matter yield and percent nitrogen in forage (Table XXVII).

TABLE XXVII

EFFECT OF APPLICATION METHODS ON YIELD AND % N OF BERMUDAGRASS RINGLING-1978

Application method	Dry matter kg/ha	% N
Initial (224 kg N/ha)	2912	2.44
Split (112 + 112 kg N/ha)	2651	2.44
LSD (0.05)	371	0.09

In general, there were no differences between sources and rates on dry matter yield shown in Table XXVIII, and few differences between percent nitrogen which is believed to be due to the delayed bermudagrass growth and the extreme dry weather conditions.

All Locations

Data from the Haskell, Muskogee, Pauls Valley, and Ringling locations were combined and the effect of nitrogen sources on dry matter yield and percent nitrogen is shown in Table XXIX. The anhydrous sources of N were significantly lower in yield than the other sources of N in the first harvest and in the second harvest except for urea. The

TABLE XXVIII

EFFECT OF N SOURCES AND RATES ON YIELD
AND % N OF BERMUDAGRASS
RINGLING-1978

		Harvest 1		Harvest 2	
N Source	Rate kg/ha	Dry matter yield kg/ha	% N	Dry matter yield kg/ha	% N
Check	0	1599^{abc*}	1.91^{d}	1428^{a}	2.52^{ab}
Ammonium sulfate	112	1695^{abc}	2.32^{bc}		
Anhydrous ammonia	112	1577^{abc}	2.22^{bcd}		
Anhydrous ammonia-CF	112	1416^{abc}	2.17^{cd}		
UAN-28	112	1548^{abc}	2.27^{bcd}		
Urea	112	1397^{abc}	2.14^{cd}		
Ammonium sulfate	224	1395^{abc}	2.58^{ab}	1331^{a}	2.58^{ab}
Anhydrous ammonia	224	1318^{bc}	2.16^{cd}	1501^{a}	2.49^{ab}
Anhydrous ammonia-CF	224	1502^{abc}	2.37^{bc}	1576^{a}	2.61^{ab}
UAN-28	224	1183^{c}	2.26^{bcd}	1702^{a}	2.50^{ab}
Urea	224	1748^{abc}	2.34^{bc}	1306^{a}	2.52^{ab}
Ammonium sulfate	448	1937^{a}	2.94^{a}	1726^{a}	2.34^{b}
Anhydrous ammonia	448	1585^{abc}	2.48^{bc}	1705^{a}	2.44^{ab}
Anhydrous ammonia-CF	448	1450^{abc}	2.44^{bc}	1619^{a}	2.49^{ab}
UAN-28	448	1718^{abc}	2.36^{bc}	1796^{a}	2.42^{ab}
Urea	448	1906^{ab}	2.60^{ab}	1163^{a}	2.69^{a}

TABLE XXIX

EFFECT OF N SOURCES ON YIELD
AND % N OF BERMUDAGRASS
ALL LOCATIONS-1978

	Harvest 1		Harvest 2	
N Source	Dry matter kg/ha	% N	Dry matter kg/ha	% N
Anhydrous ammonia	4154	2.13	1770	1.66
Anhydrous ammonia-CF	3869	2.00	1543	1.61
UAN-28	4788	2.13	2222	1.66
Urea	4670	2.04	1794	1.68
Ammonium sulfate	4947	2.33	2532	1.74
LSD (0.05)	344	0.09	348	0.08

percent nitrogen for anhydrous ammonia-CF was significantly lower in the first harvest than the other sources of N except for urea and only ammonium sulfate was significantly higher in the second harvest. All sources were higher in percent nitrogen in the first harvest compared to the second harvest.

The nitrogen removed in the forage (by source) for all locations and expressed as a percent of the maximum removed is reported in Table XXX. Anhydrous sources were lower in nitrogen removal in both harvests and urea was lower than UAN-28 and ammonium sulfate in the second harvest.

TABLE XXX

EFFECT OF N SOURCES ON REMOVAL OF NITROGEN IN FORAGE ALL LOCATIONS-1978

N Source	Harvest 1		Harvest 2	
	Removed kg/ha	%	Removed kg/ha	%
Anhydrous ammonia	88	76.5	29	65.9
Anhydrous ammonia-CF	77	67.0	25	56.8
UAN-28	102	88.7	37	84.1
Urea	95	82.6	30	68.2
Ammonium sulfate	115	100.0	44	100.0

An increase in rate of nitrogen applied increased dry matter yield and percent nitrogen for both harvests and when harvests were combined for all locations as shown in Table XXXI.

TABLE XXXI

EFFECT OF N RATES ON YIELD AND
% N OF BERMUDAGRASS
ALL LOCATIONS-1978

Rates	Harvest 1		Harvest 2		Harvest 1+2	
kg/ha	Dry matter kg/ha	% N	Dry matter kg/ha	% N	Dry matter kg/ha	% N
112	3921	1.84				
224	4464	2.05	1540	1.60	6005	1.83
336*					6449	1.98
448	5071	2.50	2404	1.74	7475	2.12
LSD (0.05)	266	0.07	220	0.05	385	0.04

*This was a split application of 224 and 112 kg/ha of N.

Nitrogen removed in forage in treated plots minus nitrogen removed in check treatment, divided by rate applied and expressed as percent applied is shown in Table XXXII. Lower rates had a greater percent recovery in the first harvest, but the 448 kg N/ha rate had a greater percent recovery in the second harvest. When harvests were combined, there was little difference between the 336 and 448 kg N/ha rates; however, they were lower than the 224 kg N/ha rate.

TABLE XXXII

EFFECT OF N RATES ON REMOVAL OF NITROGEN IN FORAGE ALL LOCATIONS-1978

Rate kg/ha	Harvest 1 Removed kg/ha	Harvest 1 % Recovery	Harvest 2 Removed kg/ha	Harvest 2 % Recovery	Harvest 1+2 Removed kg/ha	Harvest 1+2 % Recovery
112	72	35.7				
224	92	26.9	25	5.8	110	29.9
336					128	25.3
448	127	21.1	42	6.7	158	25.7

For all locations, the effect of application methods reported in Table XXXIII showed that an initial application produced a higher dry matter yield than a split application, but there was no difference in the forage nitrogen content.

TABLE XXXIII

EFFECT OF APPLICATION METHODS ON YIELD AND % N OF BERMUDAGRASS ALL LOCATIONS-1978

Application method	Dry matter kg/ha	% N
Initial (224 kg N/ha)	6005	1.83
Split (112 + 112 kg N/ha)	5502	1.87
LSD (0.05)	378	0.04

The interaction between nitrogen sources and rates is shown in Table XXXIV. In general, higher rates had a greater yield and were higher in nitrogen content in the forage, although there were some differences within sources. The check treatment was significantly inferior for dry matter yield and percent nitrogen in both harvests except in the first harvest for the percent nitrogen of urea and anhydrous ammonia-CF at the 112 kg N/ha rate.

TABLE XXXIV

EFFECT OF N SOURCES AND RATES ON YIELD AND % N OF BERMUDAGRASS ALL LOCATIONS-1978

		Harvest 1		Harvest 2	
N Source	Rate kg/ha	Dry matter yield kg/ha	% N	Dry matter yield kg/ha	% N
Check	0	1964^{j*}	1.65^{i}	829^{e}	1.44^{e}
Ammonium sulfate	112	4522^{defg}	1.85^{fgh}		
Anhydrous ammonia	112	3798^{hi}	1.92^{efgh}		
Anhydrous ammonia-CF	112	3330^{i}	1.79^{ghi}		
UAN-28	112	4100^{efgh}	1.85^{fgh}		
Urea	112	3856^{ghi}	1.77^{hi}		
Ammonium sulfate	224	4951^{abcd}	2.29^{cd}	1822^{cd}	1.64^{bcd}
Anhydrous ammonia	224	3990^{fghi}	2.04^{e}	1427^{d}	1.61^{d}
Anhydrous ammonia-CF	224	3998^{fghi}	1.96^{efg}	1334^{d}	1.61^{d}
UAN-28	224	4788^{bcde}	2.00^{ef}	1745^{cd}	1.57^{d}
Urea	224	4595^{def}	1.94^{efgh}	1374^{d}	1.59^{d}
Ammonium sulfate	448	5369^{abc}	2.85^{a}	3242^{a}	1.82^{a}
Anhydrous ammonia	448	4675^{cdef}	2.43^{bc}	2112^{c}	1.71^{abcd}
Anhydrous ammonia-CF	448	4280^{defgh}	2.24^{d}	1751^{cd}	1.62^{cd}
UAN-28	448	5475^{ab}	2.54^{b}	2699^{ab}	1.76^{abc}
Urea	448	5558^{a}	2.40^{bcd}	2215^{bc}	1.78^{ab}

*Numbers within columns with different letters are significantly different at the 5% level.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this study were to determine the effects of different nitrogen sources, rates, and application methods on dry matter yields and percent nitrogen of bermudagrass forage.

Five sources of nitrogen (urea, UAN-28, ammonium sulfate, anhydrous ammonia, anhydrous ammonia-Cold Flo) were applied at five rates at four locations (Haskell, Muskogee, Pauls Valley, Ringling). The study was initiated in March and cool temperatures resulted in delayed growth of the bermudagrass. After May, the remainder of the study period averaged above normal air temperatures and below normal precipitation which resulted in only two harvests of the bermudagrass forage. Therefore, the data presented are far below normal forage production.

The following conclusions were based on the results and the statistical analyses of the data obtained from these experiments. In general, the different nitrogen sources are equally effective for dry matter production if used under the proper conditions and applied correctly. Most of the sources are equally effective for percent nitrogen in the forage; however, there may be a slight advantage to ammonium sulfate compared to urea. Two of the locations showed a loss of anhydrous ammonia believed to be due to inadequate soil seal and the Pauls Valley location showed a loss of urea which is believed to be due to volatilization. There was a definite advantage in the percent nitrogen of the forage for all sources in the first harvest over the second harvest believed to be due to the extreme dry weather.

When all the locations were combined, there was an increase in forage dry matter yields and nitrogen content of the forage for each increment increase in the N rate.

In agreement with Burton and Jackson (1962), there was no advantage of a split application of N over a single application of nitrogen during this dry summer of 1978. Actually when the locations were combined, there was a greater dry matter production from the single application of nitrogen.

Ammonium sulfate was the most efficient source for removal of nitrogen in the forage and anhydrous ammonia-CF was the least efficient, believed to be due to the shallow placement and greater loss of the anhydrous ammonia vapor.

Nitrogen recovery was generally higher for the lower rates of applied N and were greater for all rates in the first harvest compared to the second harvest.

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