Bluestem Forage Yield Response to Source, Rate, and Timing of Applied N, and Spring Burning

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ABSTRACT

Plains bluestem (*Bothriochloa ischaemum* L.) is one of the primary grass species used for pastureland in Oklahoma. Plains bluestem is popular due to its high forage and beef production potential. It is also used for soil conservation on highly erodible areas. Despite the current importance of this species, N fertilizer sources, rates, and timing have not been thoroughly evaluated. The objective of this study was to evaluate the response of bluestem forage production as a function of source, rate, and timing of applied N and spring burning. Two established bluestem pastures in Stillwater and Bessie, Oklahoma, were selected as experimental sites. A randomized complete block design with three replications was employed at both locations. Urea and ammonium nitrate were evaluated at rates of 56, 112, 224, and 448 kg N ha $^{-1}$. The effects of spring burning and time of application were also evaluated. Dry matter yield, protein, and N uptake response to applied N were linear up to 224 kg N ha $^{-1}$ for both sources with the maximum average (3-yr) yields being 4.6 Mg ha^{-1} and 3.8 Mg ha^{-1} at Stillwater and Bessie, respectively. No significant effects on production were found to exist due to N source or burning. Forage yields increased when N was applied in May vs. April. Nitrogen use efficiency rates were greatest when 112 kg N ha $^{-1}$ was applied in May (35.6% and 20% at Stillwater and Bessie, respectively). Economic analysis indicated that applying 112 kg N ha^{-1} in May resulted in net profits at both locations.

INTRODUCTION

Plains bluestem (*Bothriochloa ischaemum* L.) is one of the primary grass species being used for pastureland in Oklahoma. Plains bluestem is an erect, tufted, perennial, warm-season grass. Plains bluestem is popular due to its aggressiveness, persistence, and drought tolerance, as well as high beef and forage production potential. Plains bluestem has also been established on highly erodible land as part of the USDA Conservation Reserve Program. In many instances, farmland which has been seeded to grass is N deficient due to several years of cultivation and erosion. The external supply rates of limiting soil nutrients, such as N, have a major influence on primary productivity, species composition, and species diversity in terrestrial ecosystems (Wedin and Tilman, 1990). Berg (1990) found N fertilization to substantially increase forage production resulting in an average of 30 kg of forage being produced per kg N applied. Berg and Sims (1995) reported that N applied at 34 kg N ha^{-1} resulted in steer gains ranging from 2.3 to 4.3 kg yr^{-1}. Beef gain response to N fertilization may result not only from higher forage production, but also from higher quality forage. Various researchers including Berg and Sims (1995) and Stallcup et al. (1987) have found crude protein levels in bluestem hay to increase with increasing N fertilization. Spring burning is a pasture management practice used when substantial amounts of standing dead forage are present. Mitchell et al. (1994) reported increased quality and quantity of big bluestem (*Andropogon gerardi Vitman*) as a result of spring burning. One concern of pasture burning is that the rise in surface soil pH can increase N losses due to volatilization when N is applied as urea, thus lowering forage yields. However, the effect of spring burning has been found to lower bluestem forage yields regardless of N source used (Berg, 1993). This was attributed to creating drier growing conditions by using fire. Berg (1990) and Brejda et al. (1995) have both reported fertilizer N recovery in bluestem to average approximately 35%. The objective of this study was to evaluate the response of bluestem forage production as a function of source, rate, and timing of applied N and spring burning.

MATERIALS AND METHODS

Two established bluestem pastures in Oklahoma were selected as experimental sites. One location was the Oklahoma State University Animal Science Experiment Station west of Stillwater, Oklahoma, on a Darnell loam soil. The second site was at the Klemme Range Research Station west of Bessie, Oklahoma, on a St. Paul silt loam soil. Initial soil test characteristics for both locations are reported in Table 1. A randomized complete block experimental design with three replications was employed at both sites. Plot size was 3.0 m by 7.6 m. Two N sources, urea and ammonium nitrate, were evaluated at rates of 56, 112, and 224 kg N ha^{-1}. An additional rate of 448 kg N ha^{-1} for each source was added to the treatment structure at both locations in the spring of 1995. The interaction of N rate (56 and 112 kg N ha^{-1}) by source (urea and ammonium nitrate) and management (burning in early spring vs. no burning) was also evaluated. The effect of N timing was examined using two treatments (56 and 112 kg N ha^{-1} as urea) applied in May. All other treatments were broadcast in April. Treatment structure employed at both locations is reported in Table 2. Dead forage in non-burned plots was mowed prior to fertilizer application using a custom-built forage harvester (Norton et al., 1995) and collected biomass was removed from the experimental area. Burning was not accomplished at Bessie in any year due to lack of biomass present. However, standing dead forage was removed from all plots using the forage harvester. Nitrogen applications were made using a conventional fertilizer spreader. Treatment application and harvest dates for both locations are reported in Table 3. Weed control was administered at Bessie using 2,4-D at the time of the April 1995 fertilizer applications. Weed control at Stillwater was not required. A total of seven and five harvests were collected at Stillwater and Bessie, respectively, over a 3-yr period. A 7.30 m^2 area was harvested at a height of 7.62 cm from each plot using the forage harvester and subsampled for moisture and total N analysis. Total N in the forage was determined using a 'Carlo-Erba 1500' dry combustion analyzer. Total N uptake was subsequently calculated in order to evaluate nitrogen use efficiency for each treatment. Significant treatment differences were determined using analyses of variance and single degree of freedom non-orthogonal contrasts (SAS, 1990).

RESULTS AND DISCUSSION

<u>Stillwater</u>

Analysis of variance and treatment means for yield, protein, and total N uptake are reported in Table 4. No significant differences in bluestem forage yield could be attributed to source of fertilizer N. The effect of spring burning on total production was also found to be non-significant. A highly significant dry matter yield response to applied N up to 224 kg N ha^{-1} was found (Figure 1). The maximum yielding treatment (3-yr average) was 224 kg N ha^{-1} as urea applied in April on non-burned plots (4.6 Mg ha^{-1}). The addition of a 448 kg ha^{-1} rate resulted in decreased yields (Figure 1). This indicates that 448 kg N ha^{-1} is beyond the rate required for maximum yield by bluestem. Yield levels were significantly greater at the 56 and 112 kg N ha^{-1} rates when urea was applied to non-burned plots in May as compared to April (Figure 2). Protein levels also increased with increasing N rate (Figure 3). Total N uptake was also significantly affected by N rate (Figure 4). Total N uptake was significantly greater when N was applied in May vs. April (Figure 4). No weeds were observed at Stillwater in the plots receiving N rates greater than 56 kg ha^{-1}. However, weed presence in the surrounding pasture was evident. This suggests that fertilizer use in bluestem can result in suppression of undesirable weed species by increasing the competitiveness of the grass. Nitrogen use efficiency was greatest when 112 kg N ha^{-1} was applied in May (35.6%).

<u>Bessie</u>

Results at Bessie were similar to those at Stillwater. Analysis of variance and treatment means for yield, protein, and total N uptake are reported in Table 5. Non-burned plots showed a significant response to applied N up to 224 kg N ha^{-1} for both sources with the highest yielding treatment being 224 kg N ha^{-1}, as urea applied in April, which produced an average of 3.8 Mg ha^{-1} over the 3-yr period (Figure 1). As was the case at Stillwater, the addition of the 448 kg ha^{-1} rate resulted in a yield decrease. Results from Bessie also indicated a significant increase in yield due to application of 112 kg N ha^{-1} in May vs. April (Figure 2). Total annual rainfall at Bessie was less than the normal average (76.6 cm) in both 1994 (65.2 cm) and 1996 (72.2 cm). A very dry growing season in 1994 (19.3 cm) contributed to the low average yields compared with those of Stillwater which received annual rainfall close to or exceeding normal each year of the study (94.3 cm). No significant difference in yield was found to exist due to source of applied N. The effect on protein content was consistent with that found at Stillwater (Figure 3). Applying N in May at the 112 kg ha^{-1} rate resulted in significantly higher protein levels vs. April applications (Figure 3). Total N uptake at Bessie was also significantly affected by N rate with no regard to source (Figure 4), but resulted in much lower amounts compared with Stillwater. This resulted in Bessie having lower N use efficiency rates than Stillwater. Nitrogen use efficiency at Bessie was greatest when 112 kg N ha^{-1} was applied in May (20%).

ECONOMIC ANALYSIS

Cost analysis for each location was performed to determine if any of these treatments would be economically feasible. A selling price for bluestem hay was determined to be \$55.13 Mg^{-1}. Bale weight was presumed to be 454 kg. Costs associated with bluestem hay production were fertilizer (ammonium nitrate-\$.533 kg N^{-1}, urea-\$.573 kg N^{-1}), application (\$4.94 ha^{-1}), swathing (\$24.69 ha^{-1} $cutting^{-1}$), and baling (\$10 $bale^{-1}$). The Stillwater location resulted in both May applications (56 and 112 kg N ha^{-1} as urea) resulting in net returns of \$91.36 and \$76.54 ha^{-1}, respectively. Check plots (0 N applied) averaged a net return of \$58.02 ha^{-1}. At Bessie, the 112 kg N ha^{-1} as urea in May was the only treatment, including checks, resulting in a net return (\$9.88 ha^{-1}). Fertilization of bluestem also increased protein levels, resulting in a higher quality hay being produced.

CONCLUSIONS

Applications of N fertilizer to bluestem increased yield, protein, and N uptake up to 224 kg N ha^{-1}. Nitrogen use efficiency rates were greatest when 112 kg N ha^{-1} was applied in May. Maximum efficiency rates at Stillwater and Bessie were 35.6% and 20%, respectively. Fertilizer applied in May (56 and 112 kg N ha^{-1}) at Stillwater resulted in net returns of \$91.36 and \$76.54 ha^{-1}, respectively. A May application of 112 kg N ha^{-1} at Bessie resulted in a net return of \$9.88 ha^{-1}. Although these returns were based on commercial hay production, and would be much greater in a pasture situation, increased fertility of bluestem pastures can be beneficial in other ways. Reduced weed pressure was observed in plots receiving N rates greater than 56 kg N ha^{-1}. However, weed presence in the surrounding pasture was evident. This suggests that fertilizer use in bluestem can result in suppression of undesirable weed species by increasing the competitiveness of the grass. Increased N uptake and protein levels in bluestem hay were also shown to be a result of N fertilization.

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Table 1. Initial soil test characteristics for Stillwater and Bessie, OK.

Location	%C	%N	NH_4-N	NO_3-N	P	K	pH
			------------mg kg^{-1}------------				
Stillwater	1.70	0.16	7.30	1.61	6.03	222	6.3
Bessie	0.95	0.10	8.27	1.73	5.04	233	7.7

%C (organic C), %N (total N) - dry combustion; NH_4-N, NO_3-N - 2M KCl extract; P, K - Mehlich III; pH - 1:1 soil-water.

Table 2. Treatment structure employed at Bessie and Stillwater, OK.

Treatment	N Rate (kg ha^{-1})	N Source	Time of Application	Spring Burning
1.	0	--	--	--
2.	54	AN	April	--
3.	112	AN	April	--
4.	224	AN	April	--
5.	54	UR	April	--
6.	112	UR	April	--
7.	224	UR	April	--
8.	0	--	April	Yes
9.	54	UR	April	Yes
10.	112	UR	April	Yes
11.	54	AN	April	Yes
12.	112	AN	April	Yes
13.	54	UR	May	--
14.	112	UR	May	--
15.	448	AN	April	--
16.	448	UR	April	--

AN-ammonium nitrate (34-0-0), UR-urea (46-0-0)

Table 3. Dates for fertilizer N applications and forage harvests at Bessie and Stillwater, OK.

Location	Year	Burned	April N applied	May N applied	Forage Harvests
Bessie	1994	--	4-20	5-1	6-23
Bessie	1995	--	5-2	5-18	7-20, 10-5
Bessie	1996	--	4-25	5-15	7-2, 10-16
Stillwater	1994	3-29	4-25	5-9	6-17, 8-8, 10-16
Stillwater	1995	3-31	4-28	5-15	7-6, 10-4
Stillwater	1996	3-30	4-29	5-16	7-1, 9-23

Table 4. Analysis of variance, associated contrasts, and average treatment means (1994-1996) for yield, protein, and total N uptake, Stillwater, OK.

Source of variation	df	Yield, Mg ha^{-1}	Protein, %	N uptake, kg ha^{-1}
		----------------Mean Squares----------------------		
Rep	2	22290.60	0.61	26.19
Trt	15	1447374.70***	10.34**	406.90***
Error	28	128776.40	4.34	21.83
Contrasts				
AN_lin	1	5132787.93***	15.71***	1166.37***
UR_lin	1	4212373.86***	10.56***	688.39***
burn_noburn	1	8540.92	0.07	3.62
AN vs UR	1	250947.55	1.47	20.84
April vs May	1	873341.21**	0.55	172.63**

--Treatment Means-----------------------------------

Treatment	Yield, Mg ha^{-1}	Protein, %	N uptake, kg ha^{-1}
1	2.1	6.8	24.2
2	2.9	7.2	35.0
3	3.5	8.0	47.2
4	3.8	9.2	56.8
5	2.8	7.2	32.8
6	3.7	7.9	48.2
7	4.6	8.5	65.1
8	2.1	6.8	22.5
9	3.0	7.3	34.8
10	3.7	7.8	46.5
11	2.3	7.2	26.7
12	3.9	7.8	50.7
13	2.1	9.6	50.7
14	4.2	8.8	55.4
15	2.1	9.6	50.7
16	2.9	9.5	59.6

***, **- significant at the 0.001 and 0.01 probability levels respectively.

Table 5. Analysis of variance, associated contrasts, and average treatment means (1994-1996) for yield, protein, and total N uptake, Bessie, OK.

Source of variation	df	Yield, Mg ha^{-1}	Protein, %	N uptake, kg ha^{-1}
		----------------Mean Squares---------------------		
Rep	2	554147.20	22.96*	18.10
Trt	15	1141344.40***	21.34***	244.57***
Error	28	268723.20	7.07	39.93
Contrasts				
AN_lin	1	5123373.52***	20.53***	678.12***
UR_lin	1	1004852.58***	31.95***	237.40***
burn_noburn	1	54761.81	0.09	9.47
AN vs UR	1	131555.09	7.34*	1.14
April vs May	1	833604.62*	7.37*	113.59*

--------------------------------------Treatment Means----------------------------------

Treatment	Yield, Mg ha^{-1}	Protein, %	N uptake, kg ha^{-1}
1	1.2	6.1	11.5
2	1.7	7.0	17.1
3	2.7	7.5	31.1
4	2.9	9.4	39.3
5	1.9	7.2	19.8
6	2.2	6.6	22.5
7	3.8	8.1	47.0
8	1.4	6.0	14.3
9	1.7	6.8	16.2
10	2.5	7.6	27.3
11	2.4	6.9	24.5
12	2.4	8.0	28.4
13	2.0	7.5	20.8
14	3.3	7.5	35.4
15	3.0	9.8	64.0
16	2.5	8.9	51.5

***, **, *- significant at the 0.001, 0.01, and 0.05 probability levels respectively.

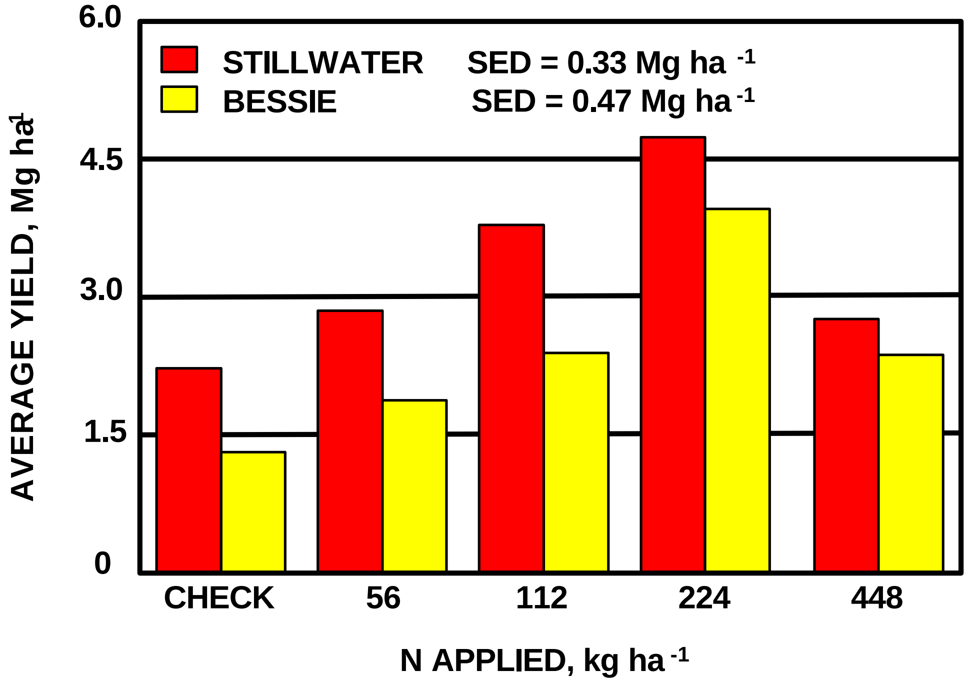

Figure 1. Average bluestem forage yield response to applied N fertilizer at Stillwater and Bessie, OK, 1994 to 1996.

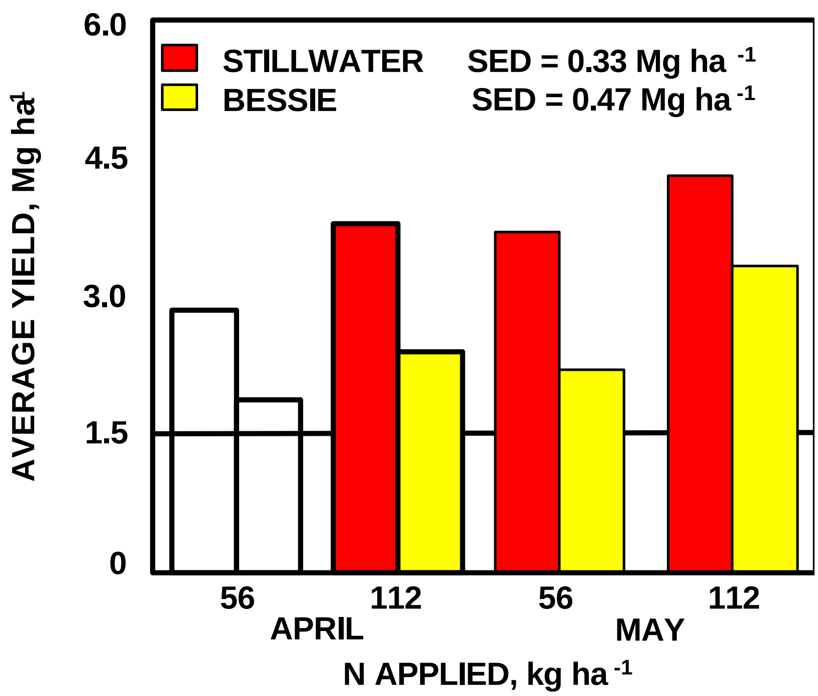

Figure 2. Bluestem forage yield response to time of fertilizer application (April vs. May).

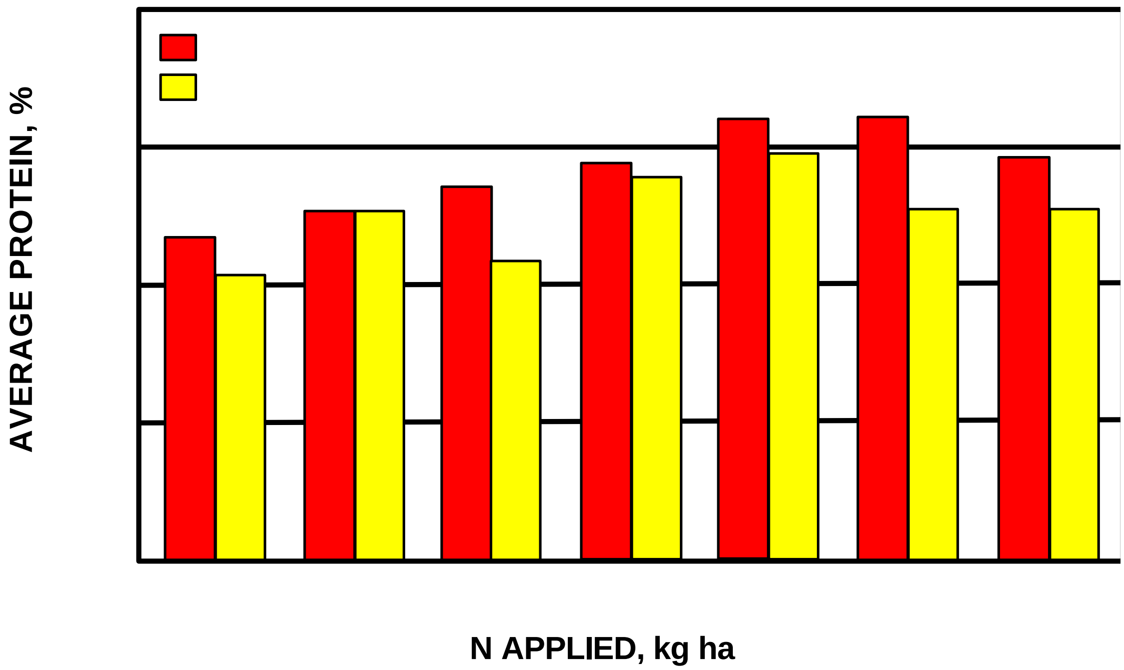

Figure 3. Average protein content of bluestem forage, 1994 to 1996.

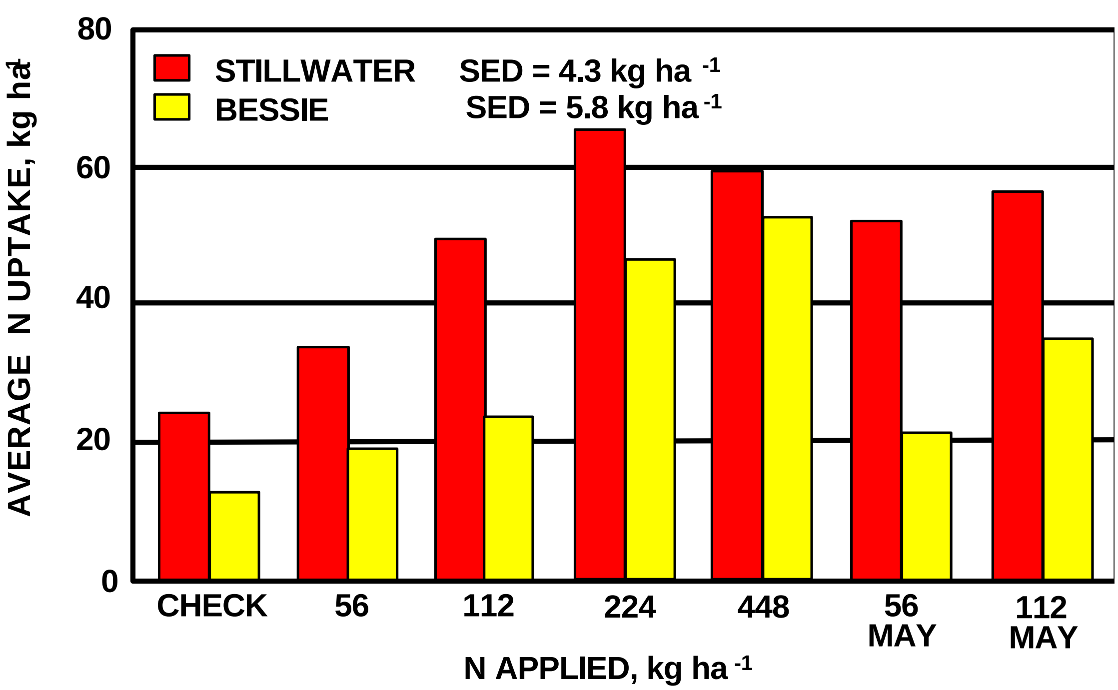

Figure 4. Average nitrogen uptake, Stillwater and Bessie, OK, 1994 to 1996.