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Old World bluestem response to fire and nitrogen fertilizers

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Abstract

Old World bluestem (*Bothriochloa ischaemum* L.) is being extensively established on marginal farmland in the Southern Plains. This 4-year field study in western Oklahoma developed guidelines for burning and N fertilization of Old World bluestem on calcareous and noncalcareous soils. Plots were on 'Iron Master' Old World bluestem on a calcareous soil (Quinlan loam, shallow Typic Ustochrepts) and a noncalcareous soil (Carey loam, Typic Argiustolls). On each soil 4 blocks were split (spring burned, unburned) and N treatments (none, urea, ammonium nitrate) and time of N application (early, late) were randomly assigned within each burn treatment. Burning decreased ($P<0.01$) herbage yields by 6 to 30% per year. Nitrogen fertilizer broadcast at the rate of 50 kg N ha^{-1} increased herbage production about threefold. Ammonium nitrate fertilization resulted in 20% more herbage production than urea fertilization 1 year, and in equal production 2 years. The 4th year, application of ammonium nitrate in early April increased production by 20% compared to early April application of urea, urea was as effective as ammonium nitrate when either was applied in late April. Burning or calcareous soil had no adverse influence on the effectiveness of urea as compared to ammonium nitrate. Management implications for western Oklahoma and adjacent areas include: burn Old World bluestem only when necessary to remove substantial amounts of standing dead herbage, and broadcast urea 3 to 4 weeks after grass initiates growth when seasonal rains are more likely to move the urea into the soil, thereby decreasing potential for N loss by volatilization.

Key Words: urea, ammonium nitrate, calcareous soil, Southern Plains, *Bothriochloa ischaemum* L., nitrogen, nitrogen use efficiency

The primary grass being planted for improved pastures on marginal farmland in Oklahoma and west Texas is Old World bluestem (*Bothriochloa ischaemum* L.). This is a reflection of its relative ease of establishment, high forage and beef production potential, and a greatly increased seed supply (Dewald et al. 1985). Old World bluestem is also being established on some of the highly erodible land going into the USDA Conservation Reserve. The marginal farmland being seeded to grass is deficient in plant-available N as a result of up to 100 years of cultivation and erosion.

Management criteria for Old World bluestem in the Southern Plains, including burning and N fertilization, have largely been adopted from experience with weeping lovegrass (*Eragrostis curvula* (Schrader) Nees). Both species are introduced warm-season grasses. However, Old World bluestem is about 2 weeks later in spring growth and is adapted to medium textured soils. Weeping lovegrass is adapted to sandy soils and needs more exacting management to sustain palatability.

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Spring burning is a recommended practice on weeping lovegrass when substantial amounts of standing dead herbage are present (Rommann and McMurphy 1974, Dahl and Cotter 1984). Some producers spring burn weeping lovegrass and Old World bluestem whenever there is enough residue to carry a fire (author's observations). Benefits of burning weeping lovegrass include increased (Klett et al. 1971) or sustained (McIlvain and Shoop 1970) herbage production, greater palatability, and more uniform grazing. Timely burning of tall grass prairie in Kansas resulted in increased steer gain day^{-1} and gain ha^{-1} (Launchbaugh and Owensby 1978).

Many effects and interactions can result from burning (Wright and Bailey 1982). Of particular interest in N fertilizer use efficiency is that alkaline ash can raise the pH at the soil surface, thereby enhancing ammonia volatilization (Raison and McGarity 1978); and urease enzyme on vegetation and on the soil surface may be destroyed, delaying the conversion of urea to ammonium (Jackson and Burton 1962).

Nitrogen fertilization is needed to realize the forage and beef production potential of Old World bluestem established on marginal farmland (Rollins and Sims 1985). The common N fertilization practice is to broadcast ammonium nitrate or urea on Old World bluestem. With surface application there is potential for ammonia loss to volatilization which may be greater for urea than ammonium nitrate (Nelson 1982). Hargrove (1988) summarized studies on broadcast N application by stating, "In general, these studies show that for noncalcareous soils urea is inferior to ammonium salts as an N source, but for calcareous soils urea can be equal to or only slightly inferior to ammonium nitrate."

This study was designed to determine the effects of burning and urea versus ammonium nitrate fertilization on Old World bluestem herbage production and N use efficiency. The interactions soils × N sources and burning × N sources were also of major interest since both soil pH and burning could affect ammonia volatilization loss from broadcast N fertilizer.

Materials and Methods

This study was conducted on 2 soils over 4 growing seasons at the USDA-ARS Southern Plains Range Research Station near Woodward in northwestern Oklahoma. The land had been in wheat (*Triticum aestivum* L.) or sorghum (*Sorghum bicolor* (L.) Moench) production for an estimated 80 to 90 years. Prior to cultivation, the land probably supported a mixed grass prairie with blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) sideoats grama (*B. curtipendula* (Michaux) Torrey), and little bluestem (*Schizachyrium scoparium* (Michaux) Nash) as dominants.

Plots were established in 1986 on uniform stands of 'Iron Master' Old World bluestem planted in 1984 on a calcareous Quinlan loam (loamy, mixed, thermic, shallow Typic Ustochrepts) and on a noncalcareous deeper Carey loam (fine silty, mixed, thermic, Typic Argiustolls). These soils are members of a topographic sequence with Quinlan loam on an upper 3% southeast slope and Carey

Table 1. Herbage yield of Old World bluestem as affected by burning, soils, N sources, and time of N application.

Nitrogen treatment	1986 Burn	1986 No burn	1987 Burn	1987 No burn	1988 Burn	1988 No burn	1989 Burn	1989 No burn	Avg ov years and burn trts.
	Herbage yield (kg ha^{-1})								
	Quinlan soil								
No N	460	630	270	550	670	1080	650	810	640
Urea early	1650	1520	1290	1660	1920	2350	2620	2620	1950
Urea late	1570	1650	1590	2120	2180	2510	3620	3850	2390
Ammonium nitrate early	1740	1780	1200	1880	1890	2440	3140	3280	2170
Ammonium nitrate late	1780	1940	1420	1990	1990	2790	3250	3550	2340
	Carey soil								
No N	750	950	430	740	910	1350	1020	1330	940
Urea early	1960	1980	1950	2190	3030	3170	3480	3660	2680
Urea late	2040	1930	2020	2340	2850	2820	4470	4690	2900
Ammonium nitrate early	2120	2870	1840	2510	2510	3350	4060	4390	2960
Ammonium nitrate late	2310	2760	1960	2500	2500	3350	4130	4390	2990
L.S.D. between burn trts.	390		360		420		210		
L.S.D. among N trts.	250	250	210	210	320	320	330	330	255
Avg over N trts. and soils	1640	1800	1400	1850	2050	2520	3040	3260	

loam on a lower 2% slope. These soils, developed in Permian redbed material, were about 100 m apart with Woodward loam occupying most of the intervening slope.

The Quinlan loam contained an average of 26 g $CaCO_3$ kg^{-1} (acid neutralization method, Soltanpour and Workman 1981) in the surface 10 cm (pH 7.6, saturated paste method, Soltanpour and Workman 1981) and 47 g $CaCO_3$ kg^{-1} in the 10 to 20-cm depth increment (pH 7.6). In contrast, the Carey loam was non-calcareous (no effervescence upon application of HCl) with pH averaging 6.9 in the surface 10 cm, and 7.1 in the 10- to 20-cm increment. The soils of a depth of 20 cm contained similar amounts of N and plant available P and K. Total N averaged 0.8 g N kg^{-1} (kjeldahl procedure, Bremner and Mulvaney 1982), nitrate N averaged 1 mg N kg^{-1} (2 M KCl extract, Keeney and Nelson 1982) and ammonium N averaged 4 mg N kg^{-1} (2 M KCl extract, Keeney and Nelson 1982). Plant available P (NH_4HCO_3 extraction, Soltanpour and Workman 1981) tested high, averaging 27 mg P kg^{-1}. Extractable K (1.0 N NH_4 acetate extraction, Knudsen et al. 1982) also tested high, averaging 520 mg K kg^{-1}.

The bluestem was not fertilized or harvested in 1984 or 1985. In March 1986, standing dead herbage was cut to a stubble height of 7 cm and removed from the plot areas. A split-split plot design was used. Soils contributed main plot effects. Four blocks on each soil were randomly split into burned and unburned treatments, and N treatments (none, urea, ammonium nitrate) and time of N application (early, late) were randomly assigned within each burn treatment.

Plots were burned in the spring when the first green shoots were about 1 cm long. Burning dates were 13 March 1986, 30 March 1987, 6 April 1988, and 31 March 1989. The early application of N fertilizer was 1 to 5 days after burning. The late N application was 21 to 23 days after the early N application. Nitrogen was broadcast at the rate of 50 kg N ha^{-1} yr^{-1}. This rate is within the linear herbage production response to fertilizer N found on similar soils (Berg 1990).

Herbage in an 1.25 × 7.75-m area within each 3 × 9-m plot was cut with a sicklebar harvester and weighed. Subsamples were dried at 60° C for moisture and N analysis (kjeldahl procedure, Bremner and Mulvaney 1982). Cuttings in 1986 and 1987 were made at early head emergence in mid-June, in mid-July, and in December. Because of a spring drouth in 1988, herbage was harvested twice, at full head stage in July and in December. In 1989, herbage was harvested in July and late November. Cutting height was 10 cm for growing season harvests and 7 cm at dormant season harvests. Herbage and N yields reported are the sum of growing season and dormant harvests. Treatments were repeated on the same plots over each of the 4 years. The entire plot area was mown on each harvest date and all harvested herbage was discarded.

Ground cover by dead plus living plant material was measured yearly in early April on unburned urea-fertilized plots by recording hits at 2.5-cm intervals on a tape stretched diagonally across each plot (300 points/plot). Soil temperatures were measured on burned and unburned N-fertilized treatments on 18 April 1989 by inserting thermometers 10 cm deep in 3 interspaces between grass crowns in each replication.

Annual precipitation was near the long-term average of 600 mm during the study with 690 mm in 1986, 740 mm in 1987, 580 mm in 1988, and 620 mm in 1989. The normal precipitation pattern consists of a dry winter with 90 mm of precipitation from November through February, 40 mm in March, 60 mm in April, 100 mm in May, 80 mm in June, and near 60 mm monthly from July through October.

Analysis of variance of data from the split-split plot design was conducted over years and for each year. Analysis of variance was also conducted for each year, omitting the no N treatment in order to separate out the N source and time of N application interactions. Least significant differences were calculated at the 0.05 probability level.

Results and Discussion

Herbage Yields

Nitrogen fertilization increased herbage yields about threefold (Table 1). Yields increased with years of fertilization (Table 1), indicating a residual effect from N application; however, variation in growth stage at harvest and above-normal 1989 precipitation confound this relationship. Treatment effects are presented by year because all year × treatment interactions were significant in the combined analysis ($P<0.05$).

Burning

Burning reduced herbage yields (Tables 1, 2). Unburned treatments averaged 8, 30, 21, and 6% more herbage production than burned treatments in 1986, 1987, 1988, and 1989, respectively. Burning reduced herbage yields on no-N treatments by nearly the same amount as on N-fertilized treatments (Table 1), indicating that the lower herbage yields with burning were not primarily due to enhancement of ammonia volatilization from both N sources by alkaline ash. Studies in similar Great Plains climatic regimes found burning often reduced grass yields in mixed and short grass prairies

Table 2. **Results of analysis of variance of herbage and N yields of Old World bluestem as affected by soils, burning, N sources, and time of N application. Data from the no-N treatment were omitted from the analysis.**

Source	1986 Herbage yield	1986 N yield	1987 Herbage yield	1987 N yield	1988 Herbage yield	1988 N yield	1989 Herbage yield	1989 N yield
S (soil)	***	***	***	***	***	***	***	***
B (burn)	**	NS	***	***	***	***	***	***
S × B	*	NS	NS	NS	NS	NS	NS	NS
N (N source)	***	***	NS	NS	NS	NS	*	*
T (time N applied)	NS	**	***	***	NS	NS	***	***
N × T	NS	NS	NS	**	NS	NS	***	***
S × N	**	**	NS	*	NS	NS	NS	NS
S × T	NS	NS	*	**	**	**	NS	NS
S × N × T	NS	NS	NS	NS	NS	**	NS	NS
B × N	***	***	**	**	***	***	NS	NS
B × T	NS	NS	NS	NS	NS	NS	NS	NS
B × N × T	NS	NS	NS	*	NS	*	NS	NS
S × B × N	**	*	NS	NS	*	*	NS	NS
S × B × T	NS	NS	NS	NS	NS	NS	NS	NS
S × B × N × T	NS	NS	NS	NS	NS	NS	NS	NS

*,**,***significant a 0.05, 0.01, and 0.001 levels, respectively.

(Launchbaugh 1973, Wright 1986). These authors recommended burning mixed and short grass prairies only to reduce substantial litter build-up or to control undesirable plants.

Burn × N-source was a significant interaction in 3 of 4 years (Table 2) when yields were proportionally less with ammonium nitrate on burned than unburned treatments compared to these treatments with urea fertilization. These results were unexpected in that burning apparently resulted in greater ammonia loss from ammonium nitrate than from urea. Raison and McGarity (1978) found a faster initial rate of ammonia loss from ammonium sulfate than urea in ash treated soil, but after 6 days ammonia loss from urea was greater.

Lower herbage yields with burning may be related to developing a drier site. Soil temperatures at 10 cm on 18 April 1989 (18 days after burning) were significantly higher ($P<0.01$) under burned plots (9.2° C) than under unburned plots (7.5° C). Ground cover by dead and living plant material measured in early April of each year on unburned N-fertilized plots averaged 85%. No attempt was made to measure ground cover on burned plots.

Soils

The deeper Carey soil was always more productive than the Quinlan soil (Tables 1 and 2). However, the difference in productivity was not as great as might be expected, probably because N was still a limiting factor because N was applied at a rate where the herbage production response to N was linear.

Since ammonia volatilization is enhanced by higher soil pH, my hypothesis was that urea would be a less productive N source than ammonium nitrate when broadcast on the calcareous soil compared to the relative productivity from these N sources on the noncalcareous soil. This did not occur. In 3 of 4 years the soil × N-source interaction was not significant (Table 2). And in 1986, when the interaction was significant, urea was less effective in enhancing herbage production than ammonium nitrate on the noncalcareous soil than on the calcareous soil (Table 1). These results are in agreement with Hargrove's (1988) generalization that urea can be inferior to ammonium nitrate when broadcast on noncalcareous soils but equal or only slightly inferior on calcareous soils.

The soil × burn interaction was significant only in 1986 when herbage production on the Carey soil was 13% greater on the unburned than the burned treatment compared to only a slight difference in these treatments on the Quinlan soil (Tables 1 and 2). These relatively small differences in 1 year and no differences the other 3 years indicate that soil had little effect on yields as affected by burning treatments. The soil × time of N application interaction

Table 3. **Nitrogen yield in Old World bluestem herbage as affected by burning, soils, nitrogen sources, and time of N application.**

Nitrogen treatment	1986 Burn	1986 No burn	1987 Burn	1987 No burn	1988 Burn	1988 No burn	1989 Burn	1989 No burn	Avg ov years and burn trts.
	Nitrogen yield (kg ha^{-1})								
	Quinlan soil								
No N	3.7	4.8	1.6	3.8	3.0	5.2	2.8	3.8	3.6
Urea early	15.2	13.7	10.4	14.1	10.6	12.6	13.9	15.1	13.2
Urea late	17.1	16.3	14.8	21.2	13.0	14.4	21.3	23.1	17.6
Ammonium nitrate early	16.7	16.5	9.5	16.3	11.3	14.0	18.0	18.8	15.2
Ammonium nitrate late	18.3	20.0	12.3	18.3	11.1	16.0	18.3	21.1	16.9
	Carey soil								
No N	5.5	7.1	2.5	5.0	3.8	6.6	4.9	6.5	5.2
Urea early	17.8	16.5	17.5	19.2	18.1	19.1	18.6	19.6	18.3
Urea late	18.9	17.4	18.3	22.7	17.7	16.1	26.0	28.9	20.7
Ammonium nitrate early	19.5	26.4	15.9	22.9	15.0	19.3	22.6	25.6	20.9
Ammonium nitrate late	22.2	26.4	17.8	23.9	15.3	21.0	23.7	27.3	22.2
L.S.D. between burn trts.	3.9		3.2		3.1		3.3		
L.S.D. among N trts.	3.1	3.1	1.9	1.9	1.9	1.9	2.4	2.4	1.9
Avg over N trts. and soils	15.5	16.5	12.1	16.7	11.9	14.4	17.0	19.0	

Table 4. Nitrogen concentrations in Old World bluestem herbage from burned and unburned treatments averaged over soils, N sources, and time of N application treatments.

Year	Initial cutting			Second cutting			Aftermath		
	Burned	Unburned	P	Burned	Unburned	P	Burned	Unburned	P
	------- (mg N g^{-1}) -------			------- (mg N g^{-1}) -------			------- (mg N g^{-1}) -------		
1986	12.1	11.1	0.001	7.1	7.2	0.23	3.6	3.6	0.78
1987	12.1	10.7	0.001	8.1	9.2	0.001	3.9	3.9	0.56
1988	8.5	8.0	0.001		No cutting		2.6	2.9	0.001
1989	7.0	7.2	0.15		No cutting		3.5	3.8	0.001

was significant in 1987 and 1988 when late N application averaged 14% greater yields than early N application on the Quinlan soil; whereas, yields on the Carey soil averaged the same for early or late N application (Table 1). Thus, later N application (3 to 4 weeks after spring greenup) appears to be more important on the shallow calcareous Quinlan soil.

N Sources

Yields were 20% greater with ammonium nitrate than with urea in 1986 and 4% in 1989 (Table 1). The 2 N sources produced no significant difference in herbage yields in 1987 or 1988.

The N-source × time of application interaction was significant in 1989 when late urea application resulted in 26% greater herbage yield than early urea application, whereas time of ammonium nitrate application had little effect on yields. Only 1 mm of precipitation fell in the 20 days following early N application on 5 April 1989. This apparently enhanced conditions for ammonia volatilization from early urea application. In contrast, 25 mm of precipitation fell 6 days after the late N application on 29 April.

Time of N Application

Late N application produced significantly greater herbage yields than early application in 1987 and 1989 with the increase averaging 13% (Tables 1 and 2). In 1989, the increased yield with late N application was much greater with urea than ammonium nitrate, causing the significant N-source × time of N application interaction. Waiting to broadcast N fertilizer until 3 to 4 weeks after grass greenup is recommended, especially when urea is used. This later application favors the probability of receiving seasonal rainfall to move urea into the soil, thereby decreasing potential for N loss by volatilization.

Nitrogen Yields

The overall effect of soils, N sources, time of N application, and their interactions on herbage N yields (Table 3) were similar to those on herbage yields (Tables 1, 2). An exception was that burning did not significantly affect herbage N yield in the first year (1986), whereas burning reduced herbage yields. Nitrogen concentration in the initial cutting was greater with burning for the first 3 years (Table 4). Enhanced N concentration in initial growth after burning is commonly reported (Daubenmire 1968). In this study (Table 4) the enhancement appears to be short lived since subsequent cuttings on the burning treatment had N concentrations similar to or less than on the unburned treatment. Nitrogen yields in herbage were significantly greater for the unburned treatment over the last 3 years (Tables 2 and 3).

Fertilizer N use efficiency over the 4 harvest years was calculated (data from Table 3) by subtracting the amount of N harvested in no-N treatments from N harvested in N-fertilized treatments then dividing by the rate of N applied. The apparent overall fertilizer N use efficiency in herbage harvested averaged 24% for the Quinlan soil and 31% for the Carey soil. The greatest fertilizer N use efficiency was 37% for ammonium nitrate applied on Carey soil where the residue was not burned. This fertilizer N use efficiency is within the range of 33 to 40% found in another western Oklahoma study (Berg 1990), and is on the low end of the range reported for warm-season (Wilkinson and Langdale 1974) and cool-season (Wedin 1974, Power 1983) grasses. Most of the quantity of N applied as ammonium nitrate to Old World bluestem in the Oklahoma study was accounted for in herbage, plant residues including roots, and the top 10 cm of soil (Berg 1990).

Management Implications

Old World bluestem in western Oklahoma and adjacent areas should be burned only when it is necessary to remove substantial amounts of standing dead herbage or to control specific undesirable plant species. The effect of burning Old World bluestem on cattle gain in this region needs to be determined.

Since urea is less expensive and more readily available than ammonium nitrate, it will commonly be used on grasses. However, in some years, forage production will be less with broadcast urea than with ammonium nitrate. Delaying urea application until 3 to 4 weeks after Old World bluestem starts spring green up should increase the chances for more effective use of this fertilizer.

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