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Nitrogen fertilization of a native grass planting in western Oklahoma

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Abstract

Native warm-season grass mixtures have been established on the Southern Plains under the USDA Conservation Reserve Program. We studied responses to N fertilizer on such pastures in western Oklahoma over a 4-year period. Experimental pastures were previously cultivated fields with loamy soils seeded to a mixture of native warm-season grasses. Fertilizer treatments were 0 and 35 kg N ha^{-1} year^{-1} as ammonium nitrate. Pastures were intensively grazed from early June to early August over 4 years. Stocking rates averaged 52 and 104 AUD ha^{-1} for the 0 and 35 kg N ha^{-1} treatments, respectively. These stocking rates are heavy for seasonal grazing in this region. Responses measured included forage mass and nutritive value before and after grazing, plant basal area, and livestock performance. Precipitation was variable but generally favorable over the study period. Peak forage mass was increased by N fertilization (2,480 versus 4,030 kg ha^{-1}; $P < 0.01$), producing 45 kg forage per kg N applied. Nitrogen fertilization increased crude protein concentration in June (8.2 versus 10.3%; $P < 0.05$) and August (4.1 versus 4.6%; $P < 0.05$), but had inconsistent effects on in vitro dry matter digestibility. Total vegetative cover and basal cover of blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths) increased in the fertilized pastures. Average daily steer gain was not different between treatments (0.96 versus 1.02 kg hd^{-1} day^{-1}) even though stocking rates were substantially higher on fertilized pastures. Steer gain ha^{-1} was increased by fertilization (83 versus 176 kg ha^{-1}, $P < 0.01$). This resulted in a fertilizer N use efficiency of 2.7 kg steer gain per kg N applied. Nitrogen fertilization combined with intensive summer grazing provided a net return of $0.65 to $0.94 per kg N applied.

Key Words: revegetation, Southern Great Plains, *Bouteloua*, nutrient management, livestock production

Native warm-season grass mixtures have been established on the Southern Plains under the USDA Conservation Reserve Program. These plantings were largely on marginal farmland cultivated for 50 to 100 years. Haas et al. (1957) found that cultivation and erosion greatly reduced N and organic matter in soils farmed for many years in the Great Plains. Substantial yield increases from N fertilization of native grasses reestablished on farmland were found in clipping studies in western Kansas (Launchbaugh 1962) and Oklahoma (Berg 1995). Nitrogen fertilization is a common practice on introduced pastures in the Southern Plains (Dahl and Cotter 1984, Berg and Sims 1995), however; native grasslands are seldom fertilized. Fertilization of 'WW-Spar' Old World bluestem (*Bothriochloa ischaemum* (L.) Keng. var. *ischaemum* (Hack.) Celarier and Harlan) at 34 kg N ha^{-1} year^{-1} in western Oklahoma increased steer gain from 112 to 220 kg ha^{-1} year^{-1} for an average N fertilizer use efficiency of 3.2 kg steer gain per kg N applied (Berg and Sims 1995).

The objective of this study was to determine the effect of N fertilizer on a livestock-forage system based on native warm-season grasses established on retired cropland. We studied the impact of annual fertilization on forage production, forage nutritive value, plant species composition, and livestock production.

Materials and Methods

This study was conducted from 1993 through 1996 at the USDA-ARS Southern Plains Range Research Station near Woodward in northwestern Oklahoma (36°27'N, 99°23'W, elev. 625 m). The experimental site was cultivated and cropped annually for about 90 years since the original mixed-grass prairie was plowed. The soils were a complex of Enterprise fine sandy loam and Woodward loam (coarse silty, mixed thermic Typic Ustochrepts) on slopes of 3 to 8% that were contour terraced. Soil samples taken to 15 cm averaged 5.5 g organic C kg^{-1} (Mebius method; Nelson and Sommers 1982), 0.58 g N kg^{-1} (kjeldahl procedure; Bremner 1996), and pH 6.9 (1:1; wt:wt). Extractable nitrate (KCl extraction, Cd-reduction; Mulvaney 1996) tested low at 0.8 mg N kg^{-1}, as did extractable ammonium (steam distillation; Kenney and Nelson 1992) at 2.4 mg N kg^{-1}. Extractable P and K (Mehlich 3 extract; Mehlich 1984) were adequate averaging 35 mg P kg^{-1} and 255 mg K kg^{-1}.

A mixture of 'Hachita' blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths), 'El Reno' sideoats grama (*B. curtipendula* (Michx.) Torr.), 'Cimarron' little bluestem (*Schizachyrium scoparium* (Michx.) Nash), 'Woodward' sand bluestem (*Andropogon hallii* Hack.), 'Cheyenne' indiangrass (*Sorghastrum nutans* (L.) Nash) and 'Blackwell' switchgrass (*Panicum virgatum* L.) was seeded in May 1990 at a total rate of 209 pure live seeds m^{-2}. The relative species composition of the seed mixture was: blue grama 29%, sideoats grama 18%, little bluestem 29%,

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sand bluestem 10%, indiangrass 8%, and switchgrass 5%. An October 1990 establishment inventory within 1,000 random placements of a 0.5 m^2 quadrat indicated the following plant densities (plants m^{-2}): blue grama 3.5, sideoats grama 2.1, little bluestem 1.5, sand bluestem 0.3, indiangrass 0.2, and switchgrass 0.3. The planting was not grazed or cut for hay through 1992. The residue was burned in March 1993. In subsequent years, the aftermath was mowed in March to a height of about 6 cm and dropped in place.

The experimental area was fenced into 8 pastures, each 1.34 ha in size. The long axis of the pastures, averaging 210 m, was generally perpendicular to the terraces and crossed an average of 7 terraces. A randomized complete block design was used with 4 blocks each containing 2 pastures. Pasture treatments were no fertilizer N or 35 kg N ha^{-1} $year^{-1}$ applied as ammonium nitrate. Fertilizer was applied in April from 1993 to 1996 with a drop spreader. Treatments were repeated on the same pastures in successive years.

Grazing was initiated when grass was 15 to 20 cm tall. Grazing was terminated when forage mass in the unfertilized pastures was visually estimated to be 50% of the forage mass in unfertilized exclosures. Average starting and ending dates were 7 June and 4 August for a 58-day grazing period.

Grazing management consisted of set stocking with 2 yearling steers per unfertilized pasture and 4 steers per N-fertilized pasture. The cross-bred steers were produced by Hereford or Angus cows and Simmental, Limousin, or Brahman bulls. Steers were blocked into treatment groups on the basis of body weight. Initial steer weights averaged 255 kg. To calculate stocking rate, steer weights were converted to animal units using the formula: AU=(initial body weight)$^{0.75}$/500$^{0.75}$ (Forage and Grazing Terminology Committee 1991). The stocking rate over years averaged 52 and 104 animal-unit-days (AUD) ha^{-1} for unfertilized and fertilized pastures, respectively. A moderate stocking rate for steers grazing rangeland in this region is 49 AUD ha^{-1} over a 10-month grazing season, resulting in steer gain of 45 to 50 kg ha^{-1} (Shoop and McIlvain 1971).

Steers were weighed prior to the start of grazing and again when removed from the pastures. Steers were held for 18 hours without feed or water before each weighing. The steers grazed dormant native pastures of similar species composition to the experimental pastures from January until June and were implanted with Synovex[1] in May. Steers had unlimited access to block salt and were not supplemented during the study period. There was no animal mortality during the course of the study.[2]

Forage mass at the start of the annual grazing trials was determined by hand clipping all vegetation in ten, 0.5 m^2 quadrats to a 7-cm stubble height within each pasture, drying to a constant weight at 57° C and weighing. At the 6 June 1995 sampling, cool-season annual grasses were clipped separately from warm-season grasses. At the end of the grazing period, total forage mass representing residual vegetation in each pasture was determined by using a sickle bar mower to harvest five, 1.3 × 4.0 m plots at a 7-cm height. The total clipped vegetation was weighed in the field. A sub-sample was also weighed in the field and oven dried for calculation of dry matter. Ungrazed forage mass, assumed to be peak forage mass, was determined on the same date in five, 2.4 × 4.9 m exclosures within each pasture. The same harvest methods were used to sample exclosures. The exclosures were moved to new locations each year. Forage sampling areas were midway between terraces.

The forage sub-samples were ground to pass a 1-mm screen and analyzed for N (kjeldahl procedure; Bremner and Breitenbeck 1983) and in vitro dry matter digestibility (IVDMD; Tilley and Terry 1963, as modified by White et al. 1981). Nitrogen concentration was multiplied by 6.25 to estimate crude protein.

Species composition and ground cover in the pastures were determined by point sampling. In August 1993, points were systematically sampled along 200-m pace transects. Fifty points were distributed along 4 transects for a total of 200 points per pasture. The plant species intersected at ground level was recorded for each point. If no plant base was intersected, the nearest plant to the point was recorded. Point data were summed for each species and divided by the total number of points to calculate relative species composition. In October 1996, 100 points were systematically sampled along the 200-m pace transects for a total of 400 points per pasture. At each point, we recorded whether the point intersected a plant base, litter, or bare ground. If a plant base was intersected, we recorded the plant species. Point data were summed for each category and divided by the total number of points to calculate relative cover for vegetation, litter, and bare ground. Plant species data were summed individually and divided by the total number of plant hits to calculate relative species composition.

The experiment was analyzed as a randomized complete block design with repeated measures. The main treatment was N fertilizer application and the repeated factor was year. Pastures were the experimental unit for all analyses. Response variables were forage mass, forage quality, livestock gain per head, and livestock gain per ha. For forage mass and nutritive value, dates within year were analyzed separately. Species composition and ground cover were analyzed as a randomized complete block design with years analyzed separately because methods were changed over years. The protected LSD was used to assess differences among treatment means ($\alpha = 0.05$).

Results and Discussion

Annual precipitation was generally favorable over the study period (Table 1). Only 1994 was below the 85-year average. Precipitation from April through July ranged from 91 to 171% of

Table 1. Annual and seasonal precipitation (mm) at Woodward, Okla., 1993–1996.

Year	Period	
	Annual[1]	April–July
	(mm)	
1993	640	264
1994	445	269
1995	825	498
1996	906	459
85-year average	601	292

[1]Calculated from Oct. through Sept.

[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

[2]All animal care procedures followed USDA-ARS Directive 130.4 and met regulations of the Animal Welfare Act of 1966 and subsequent amendments.

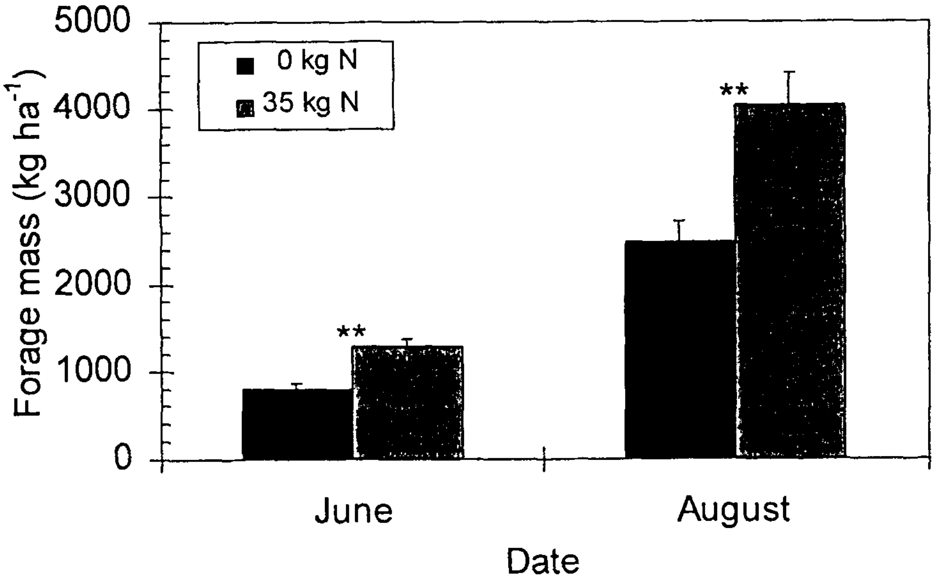

Fig. 1. Forage mass of an ungrazed native grass mixture in early June and early August as affected by N treatment, 1993-96. ** Indicates difference between means ($P < 0.01$).

average. Seasonal precipitation in 1996 was poorly distributed with 174 mm for April-June and 258 mm in July. This followed a record dry period from October 1995 through March 1996 when precipitation was 36% of average.

Forage Mass

Forage mass in June was increased by 60% with N fertilization (Fig. 1; $P < 0.01$) and resulted in a fertilizer N use efficiency of 14 kg forage produced per kg N applied. Ungrazed forage mass in August was increased 63% with fertilization (Fig. 1; $P < 0.01$) and resulted in a fertilizer N use efficiency of 45 kg forage per kg of N applied. This N fertilizer use efficiency at peak forage mass is much higher than the 12 to 27 kg forage per kg N reported from other reseeded pastures (Launchbaugh 1962, Rehm et al. 1972, Rehm 1984).

There were no treatment by year interactions for ungrazed forage production. The lack of interaction is surprising given the variation in seasonal precipitation. Such responses confirm that native grasses are well adapted to climatic extremes and response to N over these extremes is consistent.

Our stocking rates were designed to use about one-half of the forage on the unfertilized pastures and to leave comparable amounts of forage on both treatments at the end of the grazing period. Averaged over years, this objective was met with 1,240 and 1,230 kg ha^{-1} of residual forage in the unfertilized and fertilized pastures, respectively. However, there was a treatment by year interaction for forage mass in the pastures at the end of the grazing period (Fig. 2; $P < 0.01$). Forage mass did not differ between treatments in 1993 or 1994. In 1995, forage mass was higher in unfertilized pastures. In 1996, forage mass was higher in fertilized pastures.

Forage utilization was consistently higher in fertilized pastures for 1993–1995 (Fig. 2; $P < 0.05$) since residual forage levels in fertilized pastures were equal to or greater than those in unfertilized pastures and total forage production was higher in fertilized pastures. In 1996, forage utilization was about 75% in both treatments. This reflects the lack of precipitation in the early portion of the 1996 growing season. Utilization levels increased over years in both treatments. The average utilization level of 70% in the N-fertilized pastures is considerably higher than the 50% utilization recommended for unfertilized native rangelands in this region.

Forage Nutritive Value

Percentage crude protein was consistently higher in the N-fertilized forage in early June when grazing was initiated (Fig. 3; $P < 0.05$). Crude protein concentration in the forage was still higher in the N-fertilized pastures at the end of the grazing trial although the difference was smaller than in June ($P < 0.05$). Crude protein concentration was not different in the exclosures. Previous studies have shown that similar increases in crude protein concentration of forage are common with N fertilization (Rehm et al. 1972; Pettit and Deering 1974; Samuel et al. 1980; Rehm 1984). A diminishing impact of fertilization as plant phenology advances was also reported by Burzlaff et al. (1968) and Houston and Van Der Sluijs (1975). There was no fertilizer by year interaction for crude protein for any date-grazing combination.

Nitrogen fertilizer had small and inconsistent effects on IVDMD of forage. Nitrogen fertilizer increased IVDMD in June ($P < 0.05$; Fig. 3). Averaged over years, the IVDMD of forage in June was 60.0% and 62.9% in unfertilized and fertilized pastures, respectively. In August, IVDMD did not differ between treatments for grazed pastures (Fig. 3). In the exclosures, IVDMD was slightly higher in the unfertilized pastures than in the fertilized pastures in August (Fig. 3; $P < 0.05$). There were no treatment by year interactions for IVDMD for any sampling date. Fertilization with N also had no impact on IVDMD of reseeded native grasses in Nebraska (Rehm et al. 1972; Rehm 1984).

Plant Species Composition and Ground Cover

Relative composition of the major plant species was similar among treatment pastures in 1993 when the study was initiated (Table 2). The only changes in individual species composition between N treatments over the study period were increases in

Table 2. Relative composition (%) of plant species based on basal cover as affected by N fertilizer treatment.

Component	1993 Fertilizer treatment None	1993 Fertilizer treatment 35 kg N ha^{-1}	SE	1996 Fertilizer treatment None	1996 Fertilizer treatment 35 kg N ha^{-1}	SE
	---------(%)---------			---------(%)---------		
Blue grama	49.5	49.6	1.2	38.6*	47.5	1.5
Sideoats grama	24.5	24.5	1.8	39.6	29.7	2.6
Little bluestem	9.9	9.7	0.6	7.9	3.7	2.0
Sand bluestem	3.9	4.2	0.5	1.4	0.1	0.5
Indiangrass	—	—	—	2.3	1.0	0.3
Switchgrass	7.0	6.1	1.8	4.2	1.4	0.7
Sand dropseed[2]	—	—	—	1.8	4.9	0.8
Windmillgrass	—	—	—	3.3*	9.6	0.8
Other grasses	5.3	5.8	1.4	1.0	2.1	0.5

*Indicates difference within a year and row ($P < 0.05$).
[2]*Sporobolus cryptandrus* (Torr.) Gray

blue grama and windmillgrass (*Chloris verticillata* Nutt.) with N fertilization. When sand bluestem, indiangrass, and switchgrass were pooled into a single category of tallgrasses, this group declined with fertilization (7.9% versus 2.5%, $P < 0.05$). We can not completely separate the effects of fertilization and grazing on species composition changes. While forage mass increased 60% with fertilization, stocking rates were increased 100% on the fertilized pastures. Forage utilization rates were also higher on fertilized pastures. In previous studies, blue grama increased in response to both N fertilizer (Berg 1995) and heavy stocking rate (Launchbaugh 1957). Windmillgrass is generally considered to be a weedy grass and increases with heavy stocking rates while the tallgrasses decrease (Sims and Dwyer 1965). On the other hand, increases in weedy grasses have also been reported after N fertilization (Pettit and Deering 1974, Rehm 1984).

Total cover of live vegetation was higher in N-fertilized pastures in 1996 (Table 3). This coincides with the shift to sod-forming grasses indicated by the species composition results. Litter

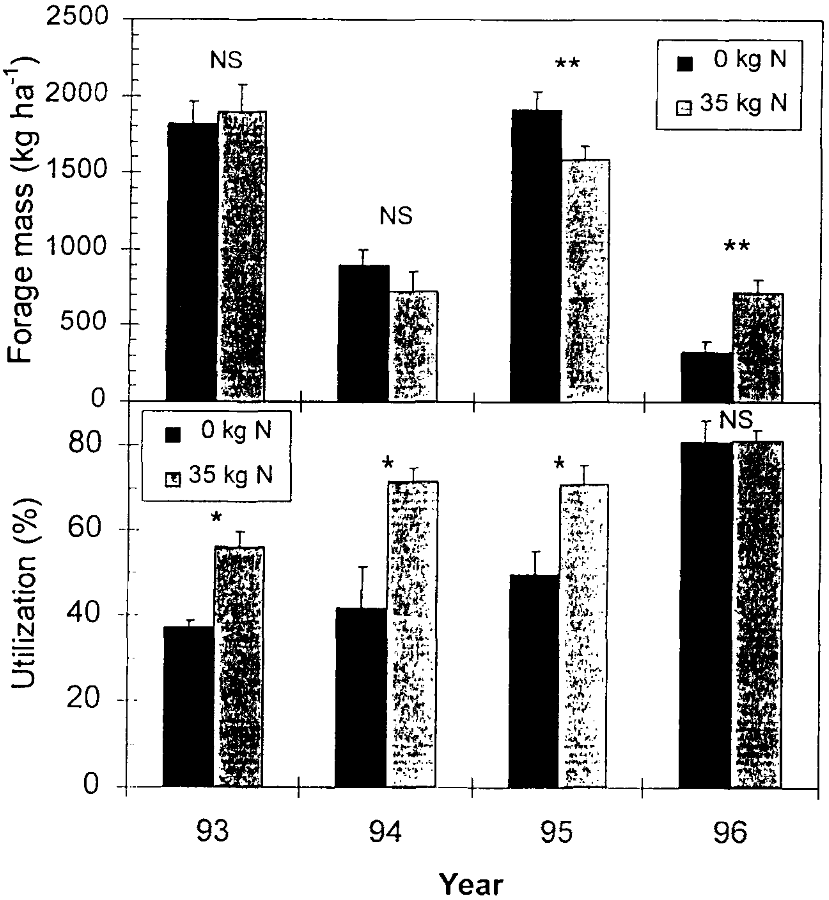

Fig. 2 Forage mass and percent utilization of a native grass mixture in grazed pastures in early August as affected by N treatment and year. Within year, * and ** indicates difference at $P < 0.05$ and $P < 0.01$, respectively.

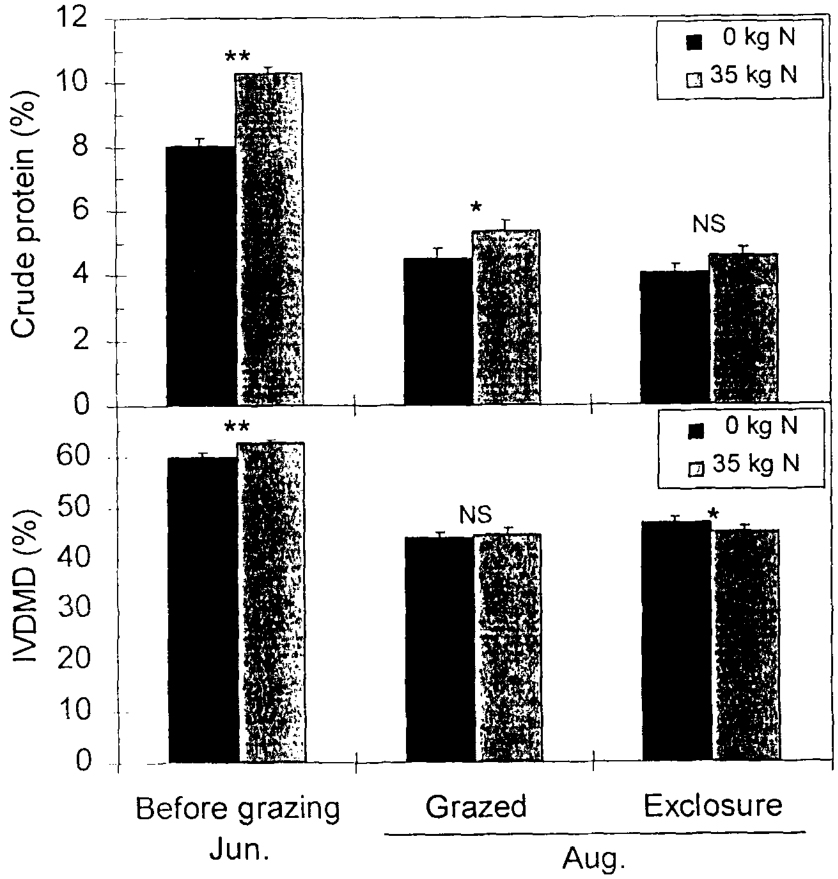

Fig. 3. Crude protein concentration and in vitro dry matter digestibility (IVDMD) of a native grass mixture as affected by N treatment and date, 1993-96. Within year, * and ** indicates difference at P < 0.05 and P < 0.01, respectively.

cover and bare ground were not affected by N fertilization in 1996. Ground cover was not measured in 1993 so results concerning ground cover components can not be strictly attributed to fertilizer treatment. However, the species composition data from 1993 suggest that the pastures were similar at the start of the study. Warnes and Newell (1969) and Rehm et al. (1972) reported reductions in bare ground on reseeded fields with the addition of 34–45 kg N ha^{-1} in small plot studies.

Downy brome (*Bromus tectorum* L.) contributed 24% of the forage mass on N-fertilized pastures when grazing began on 7 June 1995 as compared to 5% of the forage mass on unfertilized pastures. Downy brome, a cool-season annual, was mature when grazing began and little of the bromegrass was grazed. Cool-season annual grasses increased with N fertilization of native grass plantings in Kansas (Launchbaugh 1962). It should be expected that winter annual grasses will increase with spring application of N fertilizer in native warm-season grass pastures. Grazing these

Table 3. Ground cover (%) in 1996 as affected by N fertilizer treatment.

Component	Fertilizer treatment None	35 kg N ha^{-1}	SE
	----- (%) -----		
Live vegetation	46*	51	1.0
Litter	36	36	0.7
Bare ground	18	13	1.6

*Indicates difference within a year and row (P < 0.05).

winter annual grasses from early spring into the early May heading period may offer some control while also providing a high-quality forage until the warm-season grasses are ready for grazing. Spring burning is another option to control winter annuals in warm-season pastures (Gillen et al. 1987).

Kochia (*Kochia scoparia* (L.) Schrad.), a warm-season annual forb, was present in all pastures the first grazing season (1993) and was readily grazed. In 1995 after a moist fall and winter, marestail (*Conyza canadensis* (L.) Cronq.), an annual forb, was abundant in all pastures. We estimated individual marestail plants to be 2 to 3 times heavier in the N-fertilized pastures. There was limited grazing on the marestail. Annuals were virtually absent from the experimental pastures in 1996 following the severe winter-spring drought.

Livestock Performance

Averaged over years, average daily gain (ADG) was 0.96 and 1.02 kg head^{-1} day^{-1} for unfertilized and fertilized pastures, respectively. Average daily gain of steers was not different between treatments. Stocking rates were lower on the unfertilized pastures and average forage allowance was higher on the unfertilized pastures, 2,550 versus 1,580 kg AU^{-1}. The greater forage allowance in the unfertilized pastures probably allowed greater grazing selectivity and apparently negated the increase in forage crude protein with N fertilization. Donart et al. (1978) and Hart et al. (1995) reported no differences in gain per head between unfertilized and fertilized blue grama grasslands.

Because steer gain per head was equal but stocking rates were doubled on the fertilized pastures, steer gain per hectare increased significantly with N fertilization ($P < 0.01$) on these previously farmed soils. Steer gain averaged 83 and 176 kg ha^{-1} for unfertilized and fertilized pastures over the 4 study years. Fertilizer N use efficiency over the 4-year study averaged 2.7 kg steer gain per kg N applied. This ratio is considerably higher than those found for native blue grama grasslands. Donart et al. (1978) reported 0.6 kg steer gain per kg N applied in central New Mexico. In northeastern Colorado, fertilization produced 1.2 kg gain per kg N applied (Hart et al. 1995). Annual precipitation at these 2 sites, 396 and 312 mm, is considerably less than at our study location. The N use efficiency in our study is similar to, but slightly less than, the 3.4 kg steer gain per kg N applied on intensively grazed 'WW-Spar' Old World bluestem pastures in this region (Berg and Sims 1995). These Old World bluestems were also growing on soils that were previously cropped for long periods.

Based on current contract grazing rates, steer gain is valued at \$0.55 to 0.66 kg^{-1}. The cost of fertilizer N (urea) is \$0.55 kg^{-1} plus a \$0.29 kg^{-1} application cost. The N use efficiency of 2.7 kg steer gain per kg of N applied indicates a favorable economic return of \$0.65 to 0.94 per kg of N applied. Urea is a less expensive dry N source than ammonium nitrate, which was used in this study. However, N volatilization loss can be substantial with broadcast urea application on pastures. Delaying N application until late April on a warm-season grass planting in western Oklahoma resulted in similar forage production response from urea and ammonium nitrate (Berg 1993).

Intensive summer grazing of N-fertilized native grass plantings, as was done in this study, could be used in a sequence grazing system with earlier and later season grazing on rangeland or introduced grass pastures. Under intensive grazing it is important to allow sufficient forage growth before grazing begins. If grazing is started too soon, forage consumption will out-pace forage growth. Forage mass will then decline rather than remain constant or increase. This will result in reduced forage production and a shortened grazing period. We began grazing when approximately 1,000 kg ha^{-1} of forage had accumulated. This criterion was based on earlier studies with Old World bluestem (Berg and Sims 1995) and also seemed to work well on the native grass planting. Nitrogen fertilization of native warm-season grasses enhanced growth of winter annual grasses and annual forbs in some years. This must be recognized when considering N fertilization of warm-season grass plantings in the Southern Plains.

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