Old World bluestem responses to nitrogen fertilization

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Abstract

Old World bluestem *(Bothriochloa ischaemum* L.) is being extensively seeded on marginal farmland in the Southern Plains. This field study was conducted in western Oklahoma to develop guidelines for efficient N fertilization of this perennial, warm-season grass established on soil depleted in plant-available N by 80 to 90 years of cultivation and erosion. Ammonium nitrate at 0, 35, 70, and 105 kg N $ha^{-1}yr^{-1}$ was broadcast on Old World bluestem stands for 5 years on Woodward sandy loam (Typic Ustocrept) and for 3 years on Pratt loamy sand (Psammentic Haplustalf). Forage production averaged 800 kg $ha^{-1}yr^{-1}$ without N fertilization. An average of 30 kg of forage was produced per kg N applied at rates of 35 and 70 kg N $ha^{-1}yr^{-1}$. The 105 kg N $ha^{-1}yr^{-1}$ treatment produced substantially more forage than the 70 kg N $ha^{-1}yr^{-1}$ treatment only in years with above-average precipitation or favorable precipitation distribution. Partial die-out of Old World bluestem occurred one year; N fertilization increased die-out on Pratt loamy sand. Application of 70 kg N ha^{-1} in April was more effective in forage production and fertilizer N use in some years than split applications of 35 kg N ha^{-1} in April and June. Accumulation of N in forage over 5 years, plus residual N in stem bases, roots, and the surface 0.1 m of the Woodward sandy loam was 1,040 and 1,350 kg N ha^{-1} for the 0 N and 70 kg N $ha^{-1}yr^{-1}$ treatments, respectively. The difference of these values, 310 kg N ha^{-1}, suggests that most of the 350 kg N ha^{-1} applied over 5 years was accounted for; however, the standard error of difference between the means was large (50 kg N ha^{-1}).

Key Words: marginal farmland, Southern Plains, *Bothriochloa ischaemum,* nitrogen balance, soil water

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The major 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 the relative ease of establishment, high forage and beef production potential, and a greatly increased seed supply of this species (Dewald et al. 1985). Old World bluestem is also being seeded 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 90 years of cultivation and erosion. Nitrogen fertilization criteria for Old World bluestem has largely been adapted from experience with weeping lovegrass (*Eragrostis curvula* [Schrader]Nees), where the suggested management is to broadcast 35 kg N ha^{-1} in early spring, followed by 35 kg N ha^{-1} in early June if soil water is adequate (McIlvain and Shoop 1970, Dahl and Cotter 1984). Both Old World bluestem and weeping lovegrass are introduced warm-season species which respond well to N fertilization and adequate plant-available P. However, weeping lovegrass has more exacting management requirements to sustain palatability and is about 2 weeks earlier in its spring growth cycle than Old World bluestem.

The study objective was to develop guidelines for efficient use of N fertilizer in forage production and N recovery by Old World bluestem established on marginal farmland in the Southern Plains. A secondary objective was to calculate a N balance for the N fertilizer added over a 5-yr period.

Materials and Methods

This study was conducted on Woodward sandy loam (coarse-silty, mixed, thermic Typic Ustocrept) on the USDA-ARS Southern Plains Range Research Station in Woodward, Okla. The soil, cultivated an estimated 80 to 90 years prior to the study, was low in organic matter (9.8 g kg^{-1}), total N (0.52 g kg^{-1}), and NO_3-N (1.4 mg

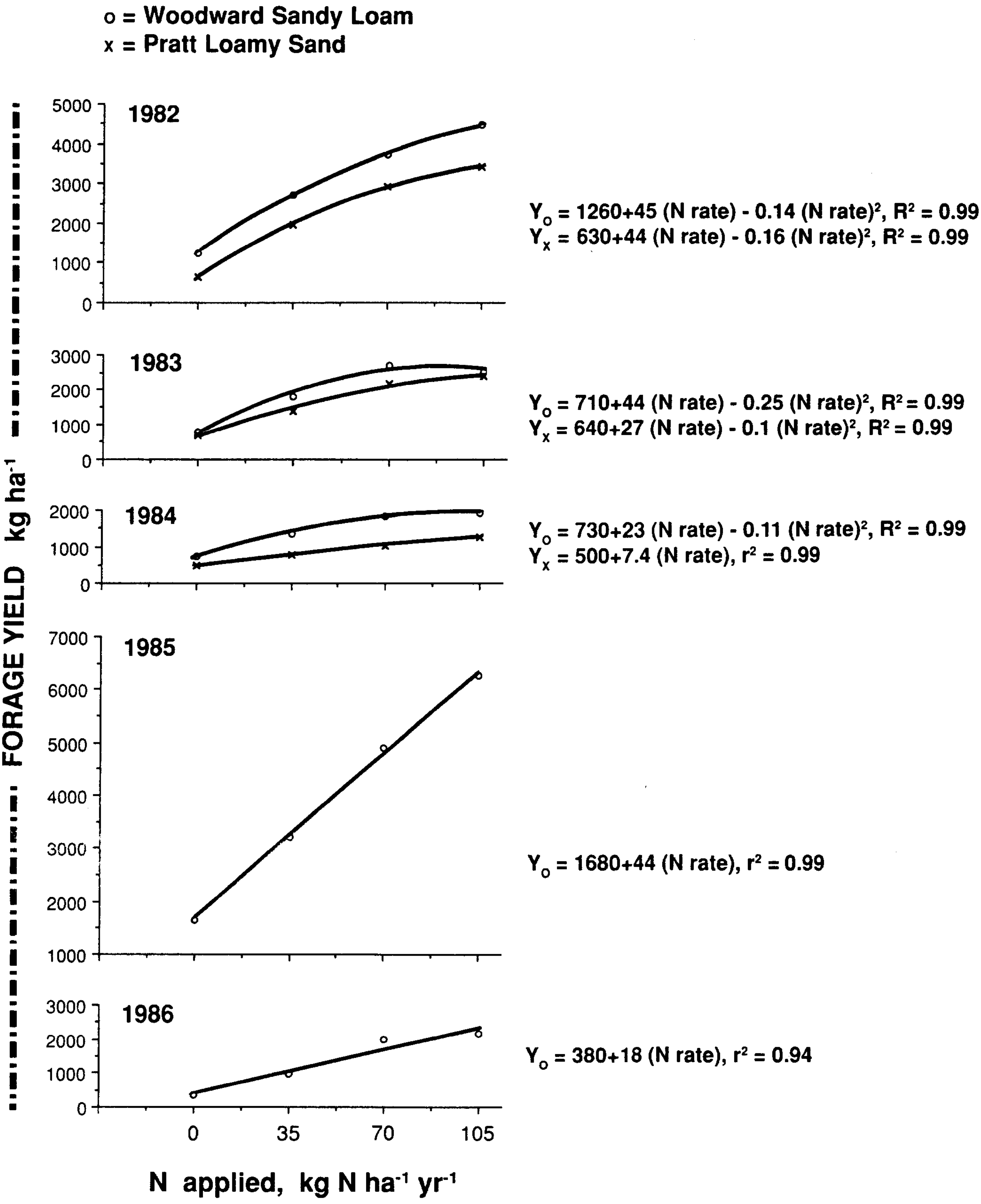

Fig. 1. Forage yields of Old World bluestem over 5 growing seasons as affected by N fertilization rates.

kg^{-1}), in the surface 0.15 m. The soil was calcareous containing 1.7 g $CaCO_3$ kg^{-1} in the surface 0.15 m (pH 7.4) and increasing to 86 g $CaCO_3$ kg^{-1} at 0.6 m (pH 8.2). Plant available P tested low (7 mg P/kg soil by $NaHCO_3$ extraction) and potassium (240 mg K/kg soil by NH_4-acetate extraction) tested adequate.

Forage production is also reported for 1982–1984 from a parallel study on Pratt loamy sand (sandy, mixed, thermic, Psammetic Haplustalf). This soil, also farmed an estimated 80 to 90 years, was very low in organic matter (4.9 g kg^{-1}), total N (0.28 g kg^{-1}), and NO_3-N (0.4 mg kg^{-1}) in the surface 0.15 m. This soil was non-calcareous, pH was 6.7, plant available P tested low (3 mg P/kg soil), and K (80 mg K/kg soil) tested marginal. Die-out of Old World bluestem was severe on this soil in the spring of 1985, and as a result data collection was not continued beyond 1984.

Triple superphosphate at the rate of 50 kg P ha^{-1} was broadcast and disked into both soils prior to seeding, and because of the low fertility of the Pratt loamy sand a mixed fertilizer at the rate of 50 kg N, 30 kg P, and 40 kg K ha^{-1} was broadcast on this soil. Another 50 kg P ha^{-1} was broadcast on the study sites at the beginning of the fourth growing season.

Individual plots were 2.7 (9 rows 0.3 m apart) by 6.1 m replicated 4 times in a randomized block design. Old World bluestem 'WW-Spar' was seeded in June 1981 at the rate of 2-kg pure live seed ha^{-1}. A good grass stand was established by sprinkle irrigating in June and July 1981. The plots were not harvested in 1981. Residue was burned in February 1982.

Ammonium nitrate was broadcast each year in early April from 1982 through 1986. The N rates were 0, 35, 70, 70 split, and 105 kg N ha^{-1}yr^{-1}. Split N rate plots received the second application the day after the initial harvest each year which was on 1 June, 20 June, 14 June, 31 May, and 9 June in 1982 through 1986, respectively. Throughout the study the 70 kg N ha^{-1} split N application treatment (70 split) received 35 kg N ha^{-1} in April and 35 kg N ha^{-1} after the initial harvest. The 105 kg N ha^{-1}yr^{-1} treatment received split applications in 1982 and 1983 and one April application in 1984, 1985, and 1986. Treatments were repeated on the same plots each year.

Forage was harvested 2 to 3 times during the growing season at a height of 10 cm with a rotary mower from 1982 through 1986. Aftermath, mowed at a height of 7 cm late in the dormant season, was dropped in place after the 1982 growing season and harvested after the 1983 through 1985 seasons. Four inside rows 4.5 m long (5.4 m^2) were harvested from each plot, weighed, subsampled, and the subsample dried at 60° C. Subsamples were ground to pass a 1-mm screen and N determined (Bremner and Breitenbeck 1983). In vitro dry matter digestibility (Tilley and Terry 1963) was determined on forage produced on the 70 kg N ha^{-1}yr^{-1} treatment. Forage from the remainder of the plot was mowed and removed from the study site. Grass was in the boot stage at the first and second harvests each year and usually headed in later-season harvests.

The final forage harvest on the Woodward sandy loam was made on 11 Aug. 1986. The following day, ground cover by living and dead plant material was measured by 3 random placements of a 1-m stick within each plot perpendicular to rows, and recording the presence or absence of plant material under each cm mark. The control (0 N) and 70 kg N ha^{-1}yr^{-1} (applied in April) treatments were then sampled for residual N in plant parts and soil. To facilitate sampling the site was sprinkle irrigated. Stubble, litter, and stem bases cut off at the soil surface were collected from four 0.3 ×0.3-m quadrats centered on inside rows of each plot. Root samples were collected to 10 cm depths by using a fabricated soil sampler which extracted a rectangular prism 2.8 × 15 × 10 cm; 4 samples across 2 rows were taken in each plot. The stubble and stem base samples and 0 to 10-cm root samples were washed by placing in water and then collecting the floating plant material which was rinsed over a screen with 1-mm openings. A hydraulic soil sampler was used to sample ten 4.2-cm diameter cores at increments of 0.1 to 0.4, 0.4 to 0.8, and 0.8 to 1.2-m on each plot. Roots in the cores were separated from the soil by flotation (Smucker et al. 1982). Roots were dried at 60° C, weighed, ground, and N determined (Bremner and Breitenbeck 1983).

For soil analysis, another set of samples from 0 to 1.2 m were taken as outlined above for roots. An additional five 4.2-cm diameter soil cores were taken from 1.2 to 2.8 m on each plot. Soil samples were air dried and then crushed and sieved through a 2-mm screen. Total N was determined by a microkjeldahl procedure (Bremner and Breitenbeck 1983). Ammonium in 2 M KCl extracts was determined by the indophenol blue method (Dorich

Table 1. Nitrogen concentrations in successive harvests of Old World bluestem during 1982 as affected by nitrogen fertilization rates.

Harvest date	N applied, kg/ha 0	35	70	70 split	105	CV
	g N/kg forage					
1 June	14 c+	17 b	20 a	17 b	19 a	4
21 June	11 b	11 b	13 b	17 a	19 a	8
20 July	8 c	10 b	11 ab	11 ab	12 a	6

+means within a harvest date followed by a common letter are not significantly different at $P = 0.05$ level.

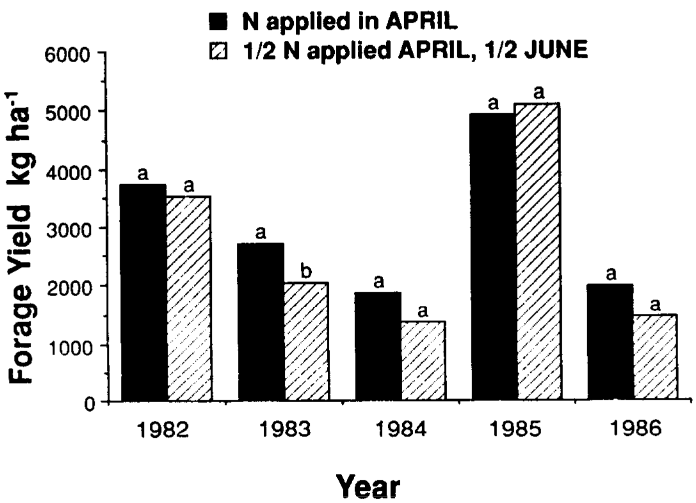

Fig. 2. Forage yields of Old World bluestem as affected by 70 kg N ha^{-1}yr^{-1} applied in April or split April and June application. Yields within a year designated with a common letter are not significantly (P>0.05) different.

Table 2. Nitrogen harvested each year and apparent N fertilizer recovery in Old World bluestem forage over 5 harvest seasons as affected by N fertilization rates on Woodward sandy loam.

Year	N applied kg ha^{-1}yr^{-1} 0	35	70	70 split	105	P>F	CV
	kg N ha^{-1}						
1982	15	35	55	50	75		7
1983	5	20	35	25	30		18
1984	5	15	25	15	30		17
1985	10	25	45	45	65		17
1986	5	10	25	20	25		10
Apparent fertilizer N recovery in forage over 5 years (%)							
		35	40	33	35	0.59	20

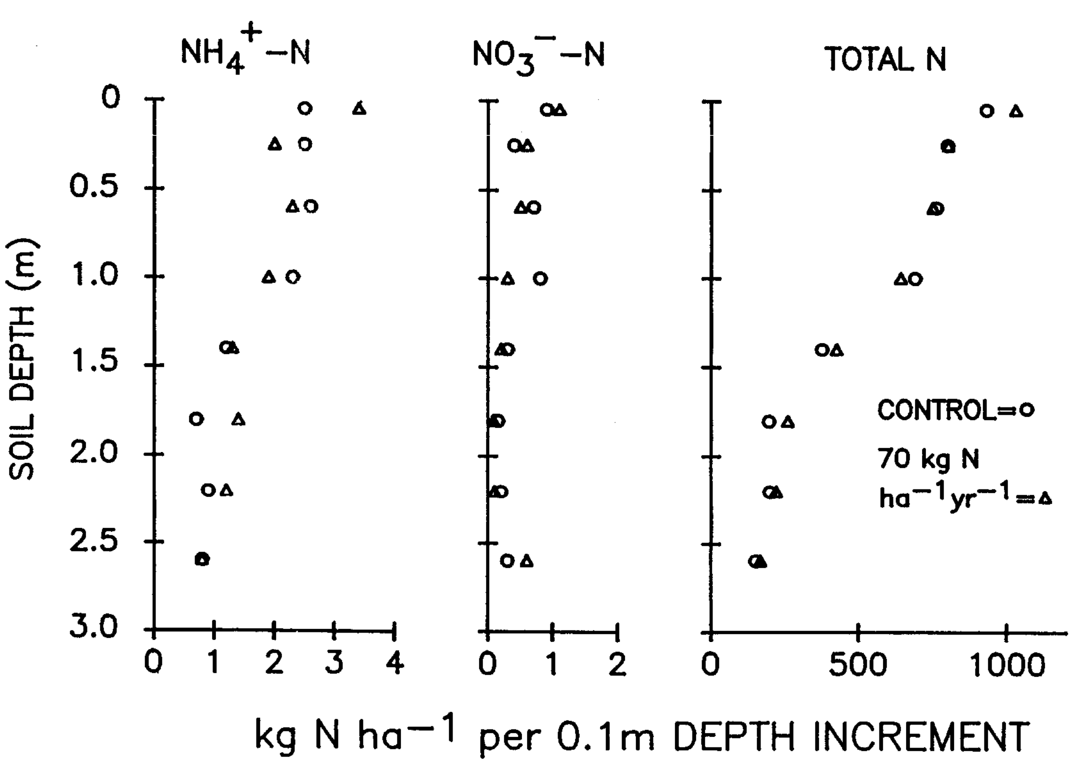

Fig. 3. Ammonium, nitrate, and total N in Woodward sandy loam supporting Old World bluestem after 5 years of nitrogen fertilization.

and Nelson 1983). Nitrate was extracted with water and determined by the chromotropic acid method (Soltanpour and Workman 1981).

Soil bulk density at 0 to 10 cm and 10 to 20 cm depths was determined by the excavation procedure (400 to 700 cm^3 excavated and displacement by sand) on soil between rows of grass at 2 locations on each plot. Bulk density at the 0 to 10 cm depth was not significantly different (P>F = 0.25) between the control ($\bar{x}$ = 1.59 g cm^{-3}) and the 70 kg N ha^{-1} ($\bar{x}$ = 1.55 g cm^{-3}) treatments; nor for the 10 to 20 cm increment (P>F = 0.80, control $\bar{x}$ = 1.59 g cm^{-3}, 70 kg N ha^{-1} $\bar{x}$ = 1.59 g cm^{-3}). Total soil N was calculated by the following method: (1) 0 to 10 cm depth, the N concentration in the soil was multiplied by the mean bulk density for that depth on that plot; (2) 10 to 40 cm depth, N concentration was multiplied by the mean bulk density determined on the 10 to 20 cm increment on that plot; (3) increments from 0.4 to 2.8 m, N concentration was multiplied by an estimated bulk density of 1.59 g cm^{-3}.

Soil water was determined by the neutron scattering technique to a depth of 2.8 m by 20-cm increments. Measurements were made on 5 to 8 dates per year. Data used in this paper are from 3 selected dates: (1) Maximum water content measured in March or April; (2) water content in June, usually measured the day after the first harvest; (3) minimum water content measured in August or September. Early season soil water depletion was calculated as the difference in soil water between the March or April measurements and those in June. Full season soil water depletion was calculated as the difference between the March or April measurements and those in August or July.

Precipitation recorded within 1-km of the study sites has a 72-yr mean of 596 mm yr^{-1} with 70% received in April through September. Precipitation was 644, 567, 545, and 943 mm in 1982 through 1985, respectively; and 256 mm was received in 1986 through 11 August (70% of the normal to 11 August) when the study was terminated. Exceptional events during the study were 290 mm rain in May 1982 (72 yr May mean, 97 mm), 6 mm rain in July and August 1983 (72-yr July + August mean, 125 mm), 4 mm rain in July 1984, and 943 mm precipitation in 1985. The highest air temperature during the study was 42° C and the low was –22° C

A 2-way analysis of variance was conducted for forage yields o each soil for each year and treatment effects partitioned into linea quadratic, cubic, and residual components. Data on ground cove N in plant parts and soil, and soil water were subjected to analys of variance and Tukey's test (P=0.05) used to compare treatme means. To calculate the standard error of difference betwee means for the summation of N in forage, stem bases, roots, an 0–10 cm soil from the control and 70 kg N ha^{-1}yr^{-1} treatments th total variance was calculated by the method suggested by Legg an Meisinger (1982).

Results and Discussion

Old World bluestem forage production on the marginal farm land averaged 800 kg ha^{-1}yr^{-1} without N fertilization (Fig. 1). Thi is about half of the herbage production expected from native rang in the area (Shoop and McIlvain 1971, Berg and Sims 1984).

Nitrogen fertilization substantially increased forage productio (Fig. 1). Yield responses were nearly linear to N fertilization rate of 35 and 70 kg N/ha (Fig. 1). The response continued with the 10 kg N ha^{-1} rate in years with more favorable precipitation pattern

Table 3. Nitrogen accumulation in harvested forage plus N in stem bases roots, and surface 10 cm of Woodward sandy loam supporting Ol World bluestem over 6 growing seasons as affected by 70 kg N ha^{-1}yr^{-1} applied the last 5 seasons.

	N Applied kg ha^{-1}yr^{-1}			
	0	70	P>F	CV
	------ kg N ha^{-1} ------			
Forage	40	180	0.001	4
Stem bases	20	60	0.01	25
Roots	50	80	0.001	6
Soil, 0–10 cm	930	1030	0.14	7
Summation	1040	1350		

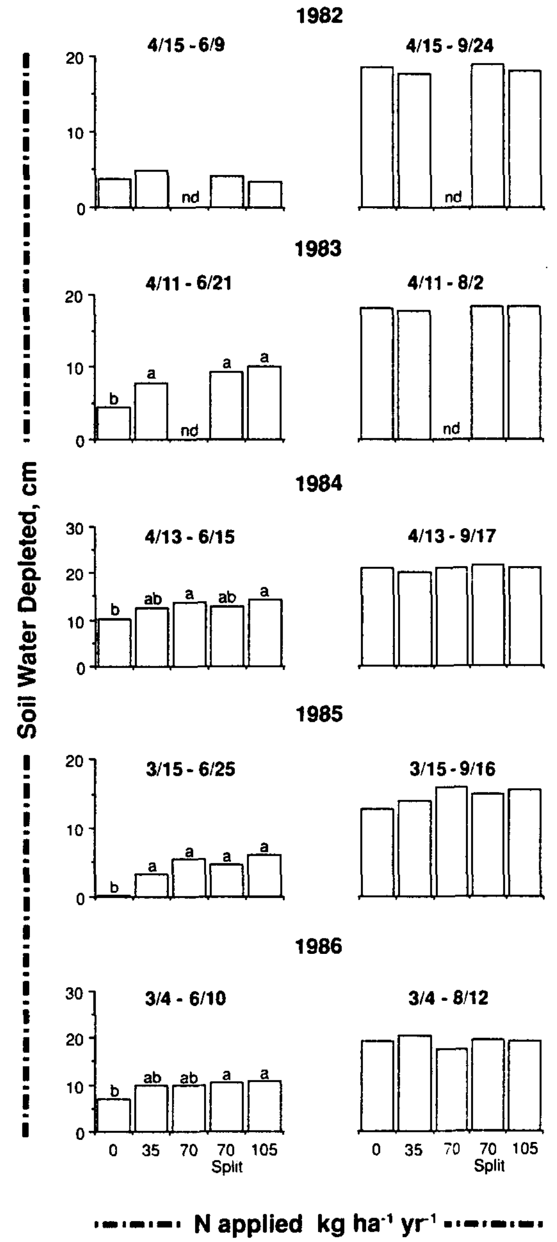

Fig. 4. Soil water depletion in Old World bluestem stands over early-season and full-season intervals as affected by N rates. Values within a time period within a year not accompanied by letters or accompanied by the same letter are not significantly different (P>0.05). Value not determined = nd.

(1982) or with above-normal total precipitation (1985). In years with summer drouths (1983, 1984) or with below-normal precipitation (1986) there was limited or no increase in forage yield from the additional N in the 105 kg N/ha treatment over the 70 kg N ha^{-1} treatment.

Over the 5 harvest seasons, 30 kg of forage was produced per kg of N applied to the Woodward sandy loam at the 35 and 70 kg N ha^{-1} rates. This yield efficiency for forage produced per unit N applied, although highly dependent upon harvesting regime, is within the range reported for other grasses in other regions (Mays 1974).

Die-out of Old World bluestem was prevalent in the spring of 1985 when an estimated 80% of the plants were dead on N-fertilized plots on the Pratt loamy sand. Fewer plants were dead, an estimated 40%, on the control plots on this soil. Plant loss on the finer textured soil, Woodward sandy loam, was about 30% with the loss being similar on N-fertilized and control plots. In the same spring, die-out in 30 to 40 year old stands of weeping lovegrass was extensive in western Oklahoma and adjacent areas in Texas. Some die-out of little bluestem (*Schizachyrium scoparium* [Michaux] Nash), a native, also occurred. The plant deaths were apparently associated with consecutive summer drouths (1983, 1984) and cold winters. Nitrogen fertilization was apparently a contributing factor to the Old World bluestem die-out on the Pratt loamy sand. Die-out of weeping lovegrass in northwestern Oklahoma was associated with higher rates (50 to 100 kg N/ha) of N fertilization (McIlvain and Schoop 1970).

The Old World bluestem stands in this study were initially thick—possibly too thick for optimum plant survival. Stand counts were not made but were estimated at 60 plants m^{-2} at the end of the first growing season. Stands on the Woodward sandy loam were still adequate after the die-out and responded vigorously to the above-normal precipitation in 1985 (Fig. 1). Nitrogen fertilized stands on the Pratt loamy sand were so thin after the die-out that the study was not continued on this soil.

Ground cover by living and dead plant material on the Woodward sandy loam on 12 Aug. 1986 after the terminal forage harvest was 50, 85, 98, 96, and 99% for the 0, 35, 70, 70 split, and 105 kg N ha^{-1} treatments, respectively. Ground cover on the 0 and 35 kg N ha^{-1} rate treatments was significantly (P<0.05) less than that on the higher N rate treatments.

Nitrogen concentration in forage was usually significantly greater with higher N rates, this effect decreased in later season harvests (Table 1). Digestibility also decreased in later season harvests. In vitro dry matter digestibility determined only on forage produced by the 70 kg N ha^{-1} rate was 67±1 (std dev), 66±1 and 62±1% for the 1 June, 21 June, and 20 July 1982 harvests, respectively. Digestibility for the first harvest each year averaged 66%. For the second harvest, always 3 weeks after the initial harvest, digestibility averaged 63%.

The quantity of N harvested annually in forage from the control (0 N) treatement (Table 2) was of the same magnitude as the average of 7 kg N ha^{-1} yr^{-1} received in precipitation (6 kg N ha^{-1}yr^{-1}) and dry fallout (1 kg N ha^{-1}yr^{-1}) (Sharpley et al. 1985). This suggests that the N received in precipitation is an important input to grass forage production on the old farmland.

Apparent fertilizer N recovery ranged from 33 to 40% when based on all forage harvested over 5 years (Table 2). No significant differences in apparent fertilizer N recovery among the N rates were found in the overall analysis (Table 2). However the CV was large, due primarily to variability within results from the 35 kg N ha^{-1} rate. Analysis of variance restricted to only the two 70 kg N ha^{-1} treatments showed significantly (P<0.05) greater N uptake in 1983, 1984, and 1986 from the single April application; and that apparent fertilizer N recovery over the 5-year period was also significantly (P<0.02) greater for this treatment. Split N applications in April and June to Old World bluestem on the Woodward soil offered no forage yield advantage over a single April application (Fig. 2).

Total N tended to be greater in the 0 to 0.1 m increment of soil fertilized with 70 kg N ha^{-1}yr^{-1} over 5 years than in the control (Fig. 3, Table 3). Ammonium and nitrate were low in both the control and 70 kg N ha^{-1}yr^{-1} treatments when sampled in mid August of the sixth growing season which was 4 months after the final N application (Fig. 3).

A balance sheet analysis of N in harvested forage over 5 seasons plus residual N in stem bases, roots, and surface 10 cm of soil shows a total of 1,040 kg N ha^{-1} for the control and 1,350 kg N ha^{-1} for the 70 kg N ha^{-1}yr^{-1} treatment (Table 3). The difference of these values, 310 kg N ha^{-1}, suggests an apparent recovery of 88% of the 350 kg ha^{-1} of fertilizer N applied over 5 years. However, this figure must be used with caution—the value of 310 kg N ha^{-1} has a standard error of difference between means of 50 kg N ha^{-1}— applying a 90% confidence interval gives a possible range of apparent recovery of 190 to 430 kg N ha^{-1}.

Soil water depletion was usually greater by N fertilized Old World bluestem than unfertilized during early season growth; however, similar amounts of water were depleted from all treatments by late summer (Fig. 4). No differences were found in soil water depletion between treatments receiving N fertilizer. This indicates that soil water was not conserved by using lighter N rates or split N applications.

This clipping study characterized responses to N fertilization by Old World bluestem recently established on N-deficient soils. An attempt to simulate grazing was made by making 2 to 3 cuttings early in the growing season. The forage was removed. Under N fertilization and grazing, some of the forage N will be recycled and N in the system may increase faster than in this clipping study. Thus, fertilizer N response by pastures that have been N fertilized for 10 to 20 years may be less than found in this study.

Conclusions

Nitrogen was deficient for grass production on marginal farmland cultivated for 80 to 90 years in the Southern Plains. On such land, N fertilization was needed to realize the high forage production potential of Old World bluestem. These results also suggest that N relationships be explored in native grass stands established on highly erodible farmed soils under the USDA Conservation Reserve Program.

Seventy kg N $ha^{-1}yr^{-1}$ was an efficient N application rate to Old World bluestem in this 5-yr western Oklahoma study. The 105 kg N $ha^{-1}yr^{-1}$ rate resulted in substantially more forage production than the 70 kg N $ha^{-1}yr^{-1}$ rate only in years with greater than average precipitation or favorable precipitation distribution. A single application of 70 kg N ha^{-1} in April was as effective, or in some years more effective, in forage production and apparent recovery of fertilizer N in forage than split applications of 35 kg N ha^{-1} in April and June.

Partial die-out in thick stands of Old World bluestem occurred in 1 year of this study. Die-out was more severe in N fertilized stands than in unfertilized stands on a deep loamy sand soil but not on a sandy loam soil. The interaction between site adaptation, climatic conditions, and N fertilization of Old World bluestem is complex.

Literature Cited

Berg, W.A., and P.L. Sims. 1984. Herbage yields and water-use efficiency on a loamy site as affected by tillage, mulch, and seeding treatments. J. Range Manage. 37:180-184.

Bremner, J.M., and G.A. Breitenbeck. 1983. A simple method for determination of ammonium in semimicro-kjeldahl analysis of soils and plant materials using a block digester. Commun. Soil Sci. Plant Anal. 14:905-913.

Dahl, B.E., and P.F. Cotter. 1984. Management of weeping lovegrass in west Texas. Management Note 5, 1984. Dep. Range Wild. Manage., Texas Tech Univ., Lubbock.

Dewald, C.L., W.A. Berg, and P.L. Sims. 1985. New seed technology for old farmland. J. Soil Water Conserv. 40:277-279.

Dorich, R.A., and D.W. Nelson. 1983. Direct colormetric measurement of ammonium in potassium chloride extracts of soils. Soil Sci. Soc. Amer. J. 47:833-836.

Legg, J.O., and J.J. Meisinger. 1982. Soil nitrogen budgets. p. 503-566. *In:* F.J. Stevenson (ed). Nitrogen in agricultural soils. Amer. Soc. Agron., Madison, Wis.

Mays, D.A. (ed) 1974. Forage fertilization. Amer. Soc. of Agron. Madison, Wis.

McIlvain, E.H., and M.C. Shoop. 1970. Grazing weeping lovegrass. OSU Extension Facts 2558. Coop. Ext. Ser., Oklahoma State Univ., Stillwater.

Sharpley, A.N., S.J. Smith, R.G. Menzel, and R.L. Westerman. 1985. The chemical composition of rainfall in the Southern Plains and its impact on soil and water quality. Tech. Bull. T-162. Agr. Exp. Sta. Oklahoma State Univ., Stillwater.

Shoop, M.C., and E.H. McIlvain. 1971. Efficiency of combining improvement practices that increase steer gains. J. Range Manage. 24:113-116.

Smucker, A.J.M., S.L. McBurney, and A.K. Srivastava. 1982. Quantitative separation of roots from compacted soil profiles by the hydropneumatic elutriation system. Agron. J. 74:500-504.

Soltanpour, P.N., and S.M. Workman. 1981. Soil testing methods used at the Colorado State University Soil Testing Laboratory. Tech. Bull. 142, Colo. State Univ. Exp. Sta., Fort Collins.

Tilley, J.M.A., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.