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Response of an Irrigated Cool- and Warm-Season Grass Mixture to Nitrogen and Harvest Scheme

JOSEPH L. PETERSEN AND LOWELL E. MOSER

Abstract

Maintaining a mixture of cool- and warm-season grasses under intensive management for season-long production is difficult, due to species shifts, especially to a dominance of cool-season grasses when heavy amounts of nitrogen (N) fertilizer are used. The objective of this study was to determine if high forage yields could be produced season long while maintaining a desirable balance of warm- and cool-season grasses.

The study was conducted near Mead, Nebraska on a Sharpsburg silty clay loam (Typic Argiudoll). An irrigated mixture of 3 warm-season grasses and 1 cool-season grass, big bluestem (*Andropogon gerardii* Vitman), switchgrass (*Panicum virgatum* L.), and indian-grass [*Sorghastrum nutans* (L.) Nash] and smooth brome (*Bromus inermis* Leyss.) was fertilized at low (150 kg/ha), medium (250 kg/ha) and high (350 kg/ha) rates of N in split applications. Three harvest schemes were designed to either produce high quality forage or to maximize yield.

Herbage yields showed a quadratic response with N level. A late May/mid July harvest scheme for the first and second cuttings did not produce as much forage as late May/late August or early June/late August harvest schemes. Population of smooth brome and other cool-season grasses declined with the higher N rates. Populations of warm-season grasses were not greatly affected by N level. Density of smooth brome increased under all harvest scheme treatments and the highest increase for other cool-season grasses was with a May 24/July 13 harvest scheme. Warm-season grasses maintained a steady density over the 3 years. Forage was produced from early May until late summer with an irrigated cool- and warm-season mixture. Fall production of smooth brome was minimal, although stand was generally maintained. Nitrate N accumulated in the soil under the medium and high N treatments.

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Cool- or warm-season grass pastures generally have a relatively short period of active production in the central Plains states. In eastern Nebraska, perennial cool-season grasses initiate growth in April, mature early to mid-June, and produce regrowth in September and October. Growth of warm-season grasses begins about mid-May and they reach maturity in late August. Since warm-season grasses are dormant until late May, there is little soil water depletion in the early spring. In order to distribute high quality forage throughout the grazing season a producer needs both cool- and warm-season grasses.

Seeding a mixture of cool- and warm-season grasses generally has not been recommended. Warnes et al. (1971), suggested that the inclusion of cool-season grasses in a mixture of warm-season grasses would decrease maximum production. Ruminant animals are selective grazers, and in a grass mixture they have a free choice of plants, making it difficult to obtain full use of each species in the proper season (Conard and Youngman 1965). Nitrogen (N) supplied in early spring generally favors cool-season species which utilize the early season soil moisture and lessen the competitive ability of warm-season grasses (Owensby et al. 1970, Warnes et al. 1971, Rehm et al. 1976). Therefore, cool-season species will soon dominate. If water can be supplied to warm-season grasses in the summer, vegetative composition shifts might be minimized, while maintaining high yields of the grasses.

Nitrogen fertilizer has increased the yield of both smooth brome (*Bromus inermis* Leyss.) (Colville et al. 1963; Paulsen and Smith 1968) and warm-season prairie grasses (Rehm et al. 1972, Hall et al. 1982). Harvesting grasses at early morphological stages generally results in lower yields than when harvested at later stages. Total dry matter yields of smooth brome increased when cutting was delayed until early anthesis and declined when clipped during stem elongation (Kniewel et al. 1971, Kunelius et al. 1974). In a study conducted in the Missouri Ozarks, harvesting of 3 warm-season grasses at the seed-ripened stage or later increased yields. Foliage removal when flowering stalks were starting to form (late July) decreased yields and stand persistence (Vogel and Bjugstad 1968).

The objective of this research was to determine if herbage production for a mixture of cool- and warm-season grasses would be possible for the entire growing season if supplied with nitrogen and water and harvested appropriately. A related objective was to determine if warm-season grasses would maintain their density in the presence of a cool-season grass under high levels of nitrogen when water was not limiting.

Materials and Methods

The study was conducted on an established mixture of warm- and cool-season perennial grasses at the University of Nebraska Field Laboratory near Mead, Neb., approximately 52 km north-east of Lincoln, Neb. The annual precipitation averages 76 cm with approximately 75% falling during the growing season. The grasses, seeded in 1967 on a Sharpsburg silty clay loam (Typic Argiudoll) included 3 warm-season grasses: big bluestem (*Andropogon gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash], switchgrass (*Panicum virgatum* L.), and 1 cool-season grass: smooth brome. Three N rates combined with 3 harvest schemes (3 × 3 factorial) were replicated 4 times in a randomized complete block design. Individual plots were 2.75 × 6.10 m (16.8 m²).

Prior to spring growth in 1978, old growth was removed, leaving a stubble approximately 7.6 cm high. Sixty-seven kg/ha phosphorus (P₂O₅) was applied to all plots on April 1, 1978. Broadcast N as ammonium nitrate (NH₄NO₃) and harvest scheme treatments were applied in 1978 and 1979 (Table 1). Grass was irrigated during both

Table 1. Nitrogen rates and harvest scheme treatments applied in 1978 and 1979.

Date of application	Nitrogen rate (kg/ha)		
	Low	Medium	High
April 1	50	100	150
June 10	50	75	100
Sept. 1	50	75	100
Total N	150	250	350

Harvest scheme	Dates of Harvest		
	First cut	Second cut	Third cut
1	May 24	July 13	November 7
2	May 31	August 28	November 7
3	June 6	August 28	November 7

growing seasons with a sprinkler irrigation system. Irrigation scheduling was based on soil moisture observations and precipitation records at the Mead Field Laboratory. The total amount of water (precipitation and irrigation water) received by the plots was 102 and 123 cm for 1978 and 1979, respectively. Annual and broadleaf weeds were controlled by the application of DCPA dimethyl tetrachloroterephthalate) at 11.2 kg/ha and 2,4-D [(2,4-dichlorophenoxy)acetic acid] at 1.2 kg/ha both years.

Soil samples were taken at the end of the 1978 and 1979 growing seasons to a depth of 90 cm. Soil nitrate N determinations were made at 30-cm increments to a depth of 90 cm and estimated for a 180-cm profile as follows: (0.118) (sampling depth cm) (N ppm) (1.12)/0.7 = kg/ha (Knudson, personal communications 1980).

To determine forage dry matter yields, a 0.81 × 5.2-meter strip was harvested in the center of each plot at a 7.6 cm height (Table 1). A subsample was taken, weighed immediately, and dried to a constant weight in a 75°C forced air oven to determine moisture content.

Botanical density was determined during the third week of June in 1978, 1979, and 1980. The vegetation analysis was conducted after there was 8 to 25 cm regrowth following the completion of the spring harvest when the cool-season grasses had matured and the warm-season grasses had initiated vegetative growth. Estimates of density were obtained by modifying methods described by Anderson (1942). A line with 6 evenly spaced rings attached was stretched

at 5 randomly selected positions across each plot. A 1-m rod marked with 1-cm increments was inserted into the vegetation under each ring. Stem base occurrence in a 1-cm wide area was determined along the rods.

A multivariate procedure was used for a mean vector statistical analysis of the botanical density. Mean vectors were determined for 5 groups of vegetation: smooth brome, other cool-season perennial grasses, warm-season perennial grasses, perennial and annual forbs, and annual grasses. A Wilks' Lambda Criterion Test was used to evaluate the change in density over time (Morrison 1976). Total dry matter yields were averaged over 1978 and 1979 because there was no treatment by year interaction. Orthogonal comparisons were performed to evaluate yields as affected by harvest scheme ($p < .05$) and the nature of the response curve of N treatments (Steel and Torrie 1980). With 3 levels of nitrogen, the response must be either linear or quadratic (nonlinear).

Results and Discussion

Forage production was about 1,000 kg/ha greater ($p < .01$) in 1978 than in 1979 when averaged over all treatments. Lorenz and Rogler (1967) reported there was more initial vigor the first year of fertilizer application than in succeeding years. In addition, intensive harvest management in 1978 may have lowered the yields of grasses in 1979.

Harvest scheme (HS) affected yields more than did N treatments. Total dry matter yields for HS1 were lower ($p < .05$) than the average of HS2 and HS3. HS3 plots also yielded more dry matter than HS2 plots (Fig. 1). The primary component for the first

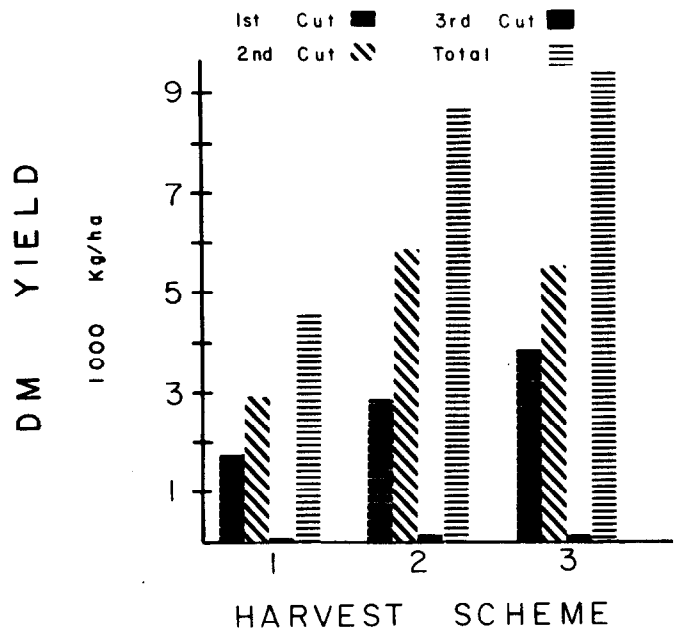


Fig. 1. Dry matter (DM) yields of forage grasses averaged over 1978 and 1979, as affected by harvest scheme. Yields for each of the 3 harvest dates and a total are shown. Harvest scheme 1 (cut May 24, July 13, Nov. 7), harvest scheme 2 (cut May 31, Aug. 28, and Nov. 7), and harvest scheme 3 (cut June 6, Aug. 28, and Nov. 7). Orthogonal contrasts for total yields show that HS1 is different than an average of HS2 and HS3. Total yield for HS2 was less than for HS3.

cutting was smooth brome. The first cut for HS2, (about May 31, 1 week later than HS1), yielded about 1,100 kg/ha more than HS1. When the first cutting was delayed until June (HS3), first harvest yields were 2,100 and 1,000 kg/ha greater than those of HS1 and 2, respectively (Fig. 1). Warm-season grasses largely comprised the second cutting, taken July 13, for HS1 and August 28, for HS2 and HS3. The 6-week delay in harvest for HS2 and HS3 compared to

HS1 increased yields more than 2,000 kg/ha for the warm-season component. Regrowth for HS1, between July 13 and August 28, was not large enough to measure in 1978 and was estimated to be about 300 kg/ha in 1979.

Yields for a third and final harvest in early November were low for all treatments both years (Fig. 1,2). Smooth brome was present

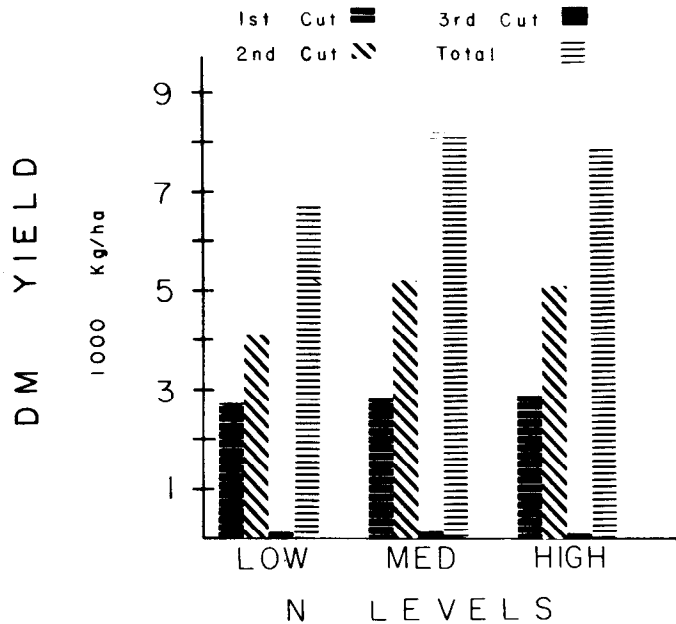


Fig. 2. Dry matter (DM) yields of forage grasses averaged over 1978 and 1979, as affected by low (150 kg/ha), medium (250 kg/ha), and high (350 kg/ha) levels of nitrogen. Each N treatment shows yields for 3 harvests and a total yield. Orthogonal contrasts on total yield indicate a quadratic relationship with N level.

during the autumn but it did not respond to additional N, moisture, and cool temperatures. However, the herbage was a darker green color with higher N rates. The intense competition of the N-stimulated warm-season grasses during the summer may have caused the smooth brome to utilize reserve carbohydrates during summer dormancy in order to survive. Consequently, the vigor of the smooth brome was low in the autumn. Evidently, sufficient carbohydrate reserves were stored in the fall to initiate spring growth of smooth brome in 1979 and 1980.

Orthogonal contrasts between the N levels revealed a quadratic relationship for total yield (Fig. 2). Dry matter yields apparently peaked with about 250 kg/ha N. Application of N in excess of 250 kg/ha did not increase yields further. The N by year interaction was not significant for the first cutting of the season. High yields were obtained all N rates the first year of application, probably because the plots had not received intensive management previously. The heavy rates of N and competition from vigorous warm-season grasses in 1978 may have caused a decline of carbohydrate reserves in the smooth brome (White 1973).

Yields, of the predominantly warm-season grasses at the second cutting, increased about 1,000 kg/ha from the low to the higher N rates in 1978 and 1979. Since shoot apices were not removed from the warm-season species in the first cutting, plants were able to respond to nitrogen and water. For all N rates summer harvests which contained predominately warm-season grasses were higher yielding than the spring or fall harvests which contained predominately smooth brome.

Species Density

The vegetation was grouped into 5 categories to be evaluated with a vector analysis using a Wilks' Lambda Criterion Test. The categories were smooth brome, other cool-season perennial grasses,

warm-seasonal perennial grasses, annual and perennial forbs, and annual grasses. Because weeds respond well to additional N and water (Huffine and Elder 1960), plots were sprayed with DCPA and 2,4-D in 1978 and 1979 to control annual grass and broadleaf weeds, respectively. As a result, forbs were reduced from 1978-80, and the analysis of variance was not significant for annual grasses (data not shown). Wilks' Lambda Criterion Test indicated that the year by harvest scheme interaction was significant ($p < .05$) for smooth brome, other cool-season grasses, and warm-season grasses. This demonstrated that the response of density to harvest scheme differed among years (Fig. 3). The response of N treat-

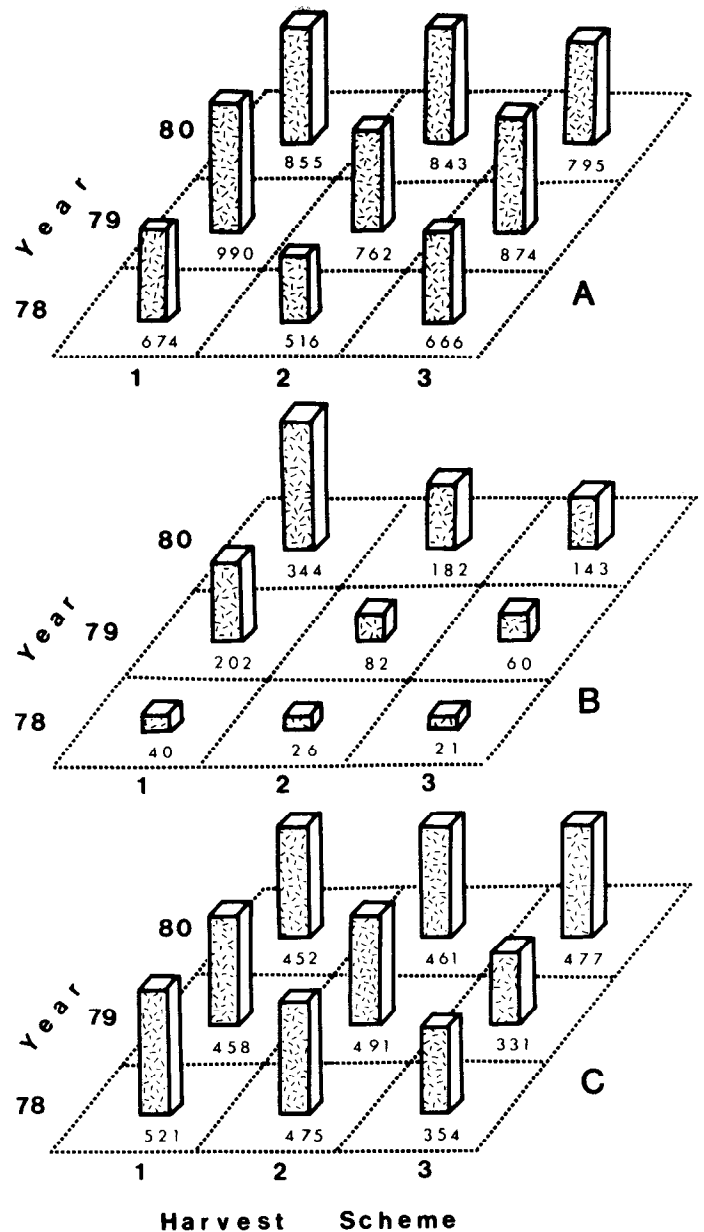


Fig. 3. Density of smooth brome (A), cool-season grasses other than smooth brome (B), and warm-season grasses (C) in no. of shoots/m², over 3 years, as affected by harvest scheme 1 (cut May 24, July 13, No. 7), harvest scheme 2 (cut May 31, Aug. 28, Nov. 7), and harvest scheme 3 (cut June 6, Aug. 28, Nov. 7).

ments was similar each year and has been evaluated within each vegetation group on the 3-year average since there was no interaction with year (Fig. 4).

Density of smooth brome and other cool-season grasses increased from 1978 to 1980, under all harvest scheme treatments (Figs. 3A

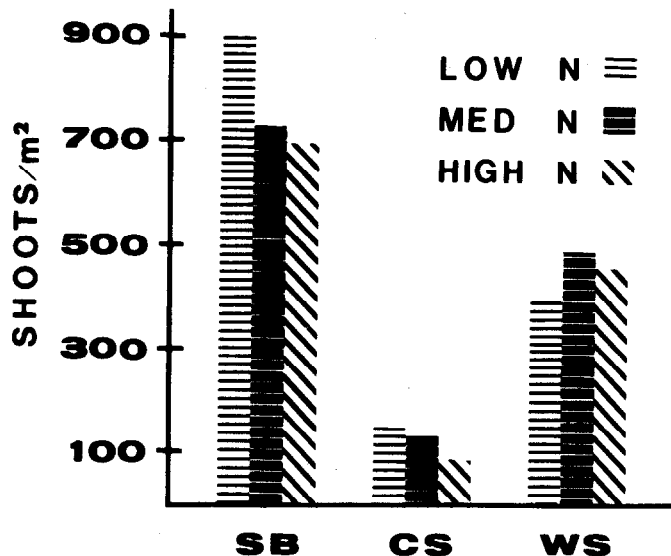


Fig. 4. Average number of shoots/m² in mid-June for 1978-1980 for low (150 kg/ha), medium (250 kg/ha), and high (350 kg/ha) nitrogen levels for the plant groups: smooth brome (SB), perennial cool-season grasses other than smooth brome (CS), and perennial warm-season grasses (WS). Orthogonal contrasts indicated that there is a significant ($p < .05$) linear response of SB to N level and there are no detectable trends ($p < .05$) CS or WS.

and 3B). Tiller growth may have been promoted by N, irrigation, and the removal of several years of accumulated mulch, prior to initiation of the study. Increases for smooth brome were greatest from 1978 to 1979 and evidently plateaued as only HS2 had a slight increase in 1980. Kentucky bluegrass (*Poa pratensis* L.) was the main component of the cool-season species group. The population increased more than 8-fold under HS1 for the 3 years and a 7-fold increase occurred for HS2 and 3. The shoot apices for some warm-season grasses were possibly clipped with the July 13 harvest under HS1, reducing the competitive ability of those plants much earlier than with HS2 or 3, which were clipped in late August.

Warm-season grass density decreased slightly with HS1, remained fairly constant or increased with late cutting dates, which agrees with Conard and Arthaud (1957). Harvest scheme 2 and 3 allowed nearly full development of the warm-season species, which produced severe competition with the dormant cool-season grasses.

There was a significant ($p < .05$) linear decline in smooth brome as nitrogen level increased (Fig. 4). No significant trend in density was detected with the other cool-season grasses. Likewise no significant ($p < .05$) linear or quadratic trend was detected for the warm-season grasses (Fig. 4). Smooth brome makes little summer growth, preventing a high buildup of the carbohydrate supply. Excess N may have depleted the carbohydrate reserves before they could be replenished. McKee et al. (1967) suggested that at high N rates, stands of spring grown grass were thinned if clipped after flowering. The drastic change in microclimate at time of cutting may have killed some brome shoots.

Soil Nitrate Nitrogen

Orthogonal contrasts indicated a linear relationship between the estimated soil nitrate for a 180-cm soil profile and N fertilizer level in 1978 and 1979. The highest residual nitrate level was contained in the first 30-cm increment for all N rates and declined with depth (Table 2). The decline was linear in 1978 but by the end of 1979, the 30-60 and 60-90 cm depths had accumulated almost as much soil nitrate as the top 30 cm. Residual nitrate for the estimated 180 cm depth increased slightly between 1978 and 1979 for the low N rate. However, soil nitrate increased 25 and 21 kg/ha, respectively, under the medium and high N rates. The leaching of excess nitrate to the lower depths was probably hastened by irrigation. The high

Table 2. Soil nitrate nitrogen (kg/ha) present in November of 1978 and 1979, under low (150 kg/ha), medium (250 kg/ha), and high (350 kg/ha) nitrogen fertilization rates averaged over harvest schemes. Confidence intervals are indicated at ($p < .05$).

Year	Soil depth (cm)	Nitrate nitrogen (kg/ha)		
		Low N	Medium N	High N
1978	0-30	8 ± 1.9	12 ± 6.9	28 ± 19.3
	30-60	4 ± 3.0	9 ± 4.8	12 ± 8.0
	60-90	3 ± 0.3	4 ± 1.0	6 ± 2.7
	180 cm estimate	21 ± 3.3	31 ± 17.3	66 ± 41.5
1979	0-30	6 ± 0.8	17 ± 10.9	23 ± 8.9
	30-60	6 ± 1.7	15 ± 8.8	21 ± 4.6
	60-90	5 ± 2.6	12 ± 3.2	18 ± 6.7
	180 cm estimate	25 ± 3.3	56 ± 39.2	87 ± 27.0

residual soil nitrates at the medium and high N fertilizer rates were not surprising. These N fertilizer treatments included a September 1 application of 75 and 100 kg/ha N, respectively. Since little forage was produced in the fall and soil samples were taken in November, the applied N accumulated in the profile.

Conclusion

With the application of medium to high levels of N, a hay harvesting scheme, and irrigation, a mixture of warm- and cool-season grasses was maintained over a 3-year period. Although spring and summer production could be maintained with mixed warm- and cool-season grasses, fall growth of smooth brome was rather weak. This was probably due to severe competition during the summer in this hay harvesting situation. However, the following spring smooth brome had regained its vigor. Pasture studies are needed to determine whether putting a warm-season grass component in a cool-season grass mixture would increase livestock production or simplify grazing management compared to maintaining separate cool- and warm-season pastures under irrigated conditions. In situations where N fertilization causes a shift from warm-season to cool-season species, soil moisture plays an important role. In this study where soil moisture was maintained during the summer through irrigation, the warm-season grasses were not overtaken by cool-season grasses. Repeated applications of N at 250 and 350 kg/ha may be excessive, since residual nitrogen accumulated in the soil in the second year under both of these treatments.

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