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INFLUENCE OF HARVEST AND NITROGEN FERTILIZER ON FOUR WARM-SEASON GRASSES

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Abstract. Two cultivars each of four warm-season grass species under three N fertilizer treatments and three harvesting regimes were studied to determine the effect of nitrogen fertilizer and harvest date on forage yield. Research was conducted in eastern Nebraska on an alluvial soil. The eight grasses studied were 'Blaze' and 'PM-K-129' little bluestem [*Schizachyrium scoparium* (Michx.) Nash], 'Cave-in-Rock' and 'Pathfinder' switchgrass (*Panicum virgatum* L.), 'Holt' and 'Oto' indiangrass [*Sorghastrum nutans* (L.) Nash], and 'Kaw' and 'Pawnee' big bluestem (*Andropogon gerardii* var. *gerardii* Vitman). Dates of harvest were mid-July, mid-August, and early October. Regrowth from plots harvested in mid-July and mid-August was harvested in early October. Yields, analyzed by orthogonal comparisons, tested quadratic and linear effects of harvest date and N treatments. Total yields of all cultivars, except 'Cave-in-Rock', showed quadratic effects. Mid-August yields were greater than the averaged yields of mid-July and early October harvests. Yields of 'Blaze', 'Pathfinder', and 'Holt' exhibited no significant differences between mid-July and early October harvests. Nitrogen was applied at the rates of 0, 100, and 200 kg/ha. These high rates of nitrogen were applied to determine yield potential of the grasses. A large increase in dry matter production occurred following the addition of 100 kg/ha of N fertilizer. For most cultivars, a slight yield increase occurred as N was increased from 100 to 200 kg/ha. Yields obtained in this research indicate a high yield potential for these warm-season grasses.

Key Words. little bluestem, *Schizachyrium scoparium*, big bluestem, *Andropogon gerardii*, indiangrass, *Sorghastrum nutans*, switchgrass, *Panicum virgatum*, nitrogen fertilizer, harvest dates, Nebraska

INTRODUCTION

Eastern Nebraska was once occupied by tallgrass prairie, which was dominated by perennial warm-season grasses (Stubbendieck 1988). Big bluestem (*Andropogon gerardii* var. *gerardii* Vitman), indiangrass [*Sorghastrum nutans* (L.) Nash], switchgrass (*Panicum virgatum* L.), and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] were the primary species (Weaver 1954). Most of eastern Nebraska is under cultivation today, and little native prairie remains. Due to improper management, much of this uncultivated land is now dominated by introduced cool-season grasses, such as Kentucky bluegrass (*Poa pratensis* L.).

Warm-season grasses have often been overlooked as a potential forage source in the tallgrass prairie region because they are typically found on sites that have little opportunity for high yields due to low fertility and low levels of management. Relatively little research has been done to find the maximum potential yields of warm-season grasses growing on a favorable site. The objective of this study was to determine the yield response and potential of several warm-season grass cultivars as affected by harvest date and nitrogen fertilizer.

Increased forage production following application of nitrogen (N) fertilizer has been shown in numerous studies (Johnson *et al.* 1948, Rogler and Lorenz 1957, Moser and Anderson 1965, Reardon and Huss 1965, Lorenz and Rogler 1967, Cosper *et al.* 1967, Rehm *et al.* 1972, Perry and Baltensperger 1979). Factors affecting plant response to fertilization were soil type, soil fertility, soil temperature, and the amount of precipitation. Length of grazing period and date and rate of application can alter effectiveness of nitrogen fertilizer (Goetz 1969).

Vogel and Bjugstad (1968) reported that clipping of little bluestem, big bluestem, and indiangrass during the mature seed stage or later increased yield and stimulated spring tillering, as compared to clipping during the summer which reduced yields. Clipping between floral initiation and anthesis caused the greatest reduction in yields of the warm-season grasses. On bluestem range in North Dakota, maximum yields were obtained with harvest dates between 15 July and 1 August. Plots harvested on 1 June declined in yield over the eight-year experiment (Lorenz and Rogler 1973). Significant yield reductions occurred when forage was removed twice, rather than once, during the growing season.

Near Manhattan, Kansas, a four-year study was conducted on irrigated and fertilized big bluestem growing on uplands (Owensby *et al.* 1970). Plots clipped during both July and August resulted in increased herbage production, as compared to plots clipped only at the end of the growing season. Clipping during the growing season conserved moisture and increased water use efficiency. Conversely, yields were decreased with two or three clippings during a five-year study of pure stands of big bluestem and switchgrass near Lincoln, Nebraska (Newell and Keim 1947). Yields from these plots were 1,270 kg/ha for big bluestem and 550 kg/ha for switchgrass. With a single clipping at the end of August, big bluestem and switchgrass produced 1,500 and 1,020 kg/ha, respectively.

A five-year clipping study was conducted in northcentral Oklahoma on pure stands of indiangrass, big bluestem, little bluestem, and switchgrass (Dwyer *et al.* 1963). Four clipping treatments were applied with clipping heights of 5 and 10 cm. The annual clipping treatment dates were: 1) July; 2) June and September; 3) June, July, August, and September; and 4) January. Greatest forage yields for all species occurred under the annual July clipping, followed by the June and September clipping treatment.

METHODS

The study area was on the Desoto National Wildlife Refuge, located about 32 km north of Omaha in Washington County, Nebraska. The soil was a course-silty, mixed (calcareous), mesic Mollic Udifluvent (DaMoude 1980). This nearly level, imperfectly drained, alluvial soil was formed in sediments recently deposited by the Missouri River. The soil series was Haynie. Texture of the top soil varied from a silt loam to a silty clay loam. The subsoil was stratified sand and silt. The pH of the top soil was 7.9, and the organic matter was 1.5%. The water table was a depth of approximately 2.5 m.

Long-term, average annual precipitation at the DeSoto National Wildlife Refuge is 770 mm. Precipitation for the two years of the study was 790 and 750 mm. An average of 66% of the precipitation is recorded during the active growth period (May 1-October 1) of the warm-season grasses.

The Soil Conservation Service (SCS) seeded a group of 18 x 160 m plots to various warm-season grasses seven years prior to the start of this experiment. Unpublished SCS data indicated that rather high forage yields were harvested from most plots. Plots were grazed at low stocking levels by wildlife prior to this study. Plots had not been fertilized. Based on yield potential and widespread usage, two cultivars within each of four species were selected for this experiment: 'PM-K-129' and 'Blaze' little bluestem, 'Pathfinder' and 'Cave-in-Rock' switchgrass, 'Holt' and 'Oto' indiangrass, and 'Pawnee' and 'Kaw' big bluestem.

The design of this experiment was a split plot with four replications within each cultivar. Harvest dates were the main plots and rates of N fertilizer were the subplots. Dimensions of the main plot were 9 x 18 m. Three fertilizer treatments were applied, which divided the main plots into 3 x 6 m subplots.

Plots were burned in April of each year of the study to remove the accumulated plant material. Plots were sprayed in early June with 2,4-D (2,4-dichlorophenoxyacetic acid) amine at the rate of 0.35 liter/ha to control broadleaf weeds.

Subplots were fertilized with ammonium nitrate (NH_4NO_3) at rates of 0 (N_0), 100 (N_{100}), and 200 (N_{200}) kg/ha on 20 May of each year of the experiment. Harvest dates were 15 July, 15 August, and 10 October. Regrowth following the first two harvests was harvested 10 October. Only total yields are addressed in this paper.

Plots were harvested with a flail-type harvester which cut a 0.9 x 3.0 m strip out of the center of the subplots at a height of approximately 10 cm. The forage was collected, and a wet field weight was obtained. From this sample, a subsample of approximately 500 gm was selected and weighed. This subsample was placed into a forced air oven at 65 C until a constant weight was reached. Dry matter was determined, and hay yields (12% moisture) were calculated.

A separate statistical analysis was conducted for each grass variety. Two years of data were combined for analysis because of the absence of year interactions. This also created more degrees of freedom which decreased the mean square error term. An analysis of variance (ANOVA) and F tests were computed for each variable. Responses to nitrogen and harvest dates were analyzed for each variable using orthogonal comparisons. Contrasts were not adjusted for unequal spacing of harvest dates.

Orthogonal comparisons tested linear and quadratic effects of N and harvest date on total yield. The orthogonal comparison used to test linear effects of N compared N_0 to N_{200}. The orthogonal comparisons used to test quadratic effects compared the N_{100} treatment with the yield averages from the N_0 and N_{200} treatments. Quadratic effects were considered significant when the yield of N_{100} was significantly different ($P > 0.05$) than the averaged yields of N_0 and N_{200}. The N treatments were averaged over harvest date.

The effect of harvest date on hay yield was evaluated using orthogonal comparisons. Total yields compared 15 August harvests plus regrowth with averaged yields of 15 July harvests plus regrowth and 10 October harvests. Harvest dates were averaged over N treatments.

RESULTS AND DISCUSSION

Little Bluestem

Little bluestem fertilized with nitrogen exhibited a significant quadratic effect for total yield (Table 1). 'Blaze' and 'PM-K-129' N_{100} yields were greater than the averaged yields of N_0 and N_{200}. Nitrogen was apparently not a limiting factor for grass production at the N_{200} treatment level.

Nitrogen generally increases leaf area which will increase evapotransportation. This could result in limiting growth due to moisture stress. However, on this study site, moisture limitation is probably not a major factor. Water table depth is approximately 2.5 m. The soil is not classified as a subirrigated site by the SCS because the major portion of the grass root system will not have free access to water. However, the lower portion of the grass roots will reach the water table. Consequently, the genetic potential for N response may occur near 100 kg/ha.

Harvest dates tested by orthogonal comparisons exhibited a significant quadratic effect for total yield (Table 1). Highest total yield for 'Blaze' occurred on 15 August. The maturity of 'Blaze' was probably the main reason for the total yield on 10 October being less than on 15 August. By October, 'Blaze' was dormant.

Table 1. Yield (tonnes/ha) of 'Blaze' and 'PMK-129' little bluestem with three harvest regimes and three levels of nitrogen fertilizer.

Harvest regime or fertilizer rate	*Little bluestem* 'Blaze'	'PMK-129'
	---------- tonnes/ha ----------	
Harvest Regimes:		
7/15 and 10/10	6.89	6.50
8/15 and 10/10	10.89	10.15
10/10	8.87	10.19
Nitrogen Rate:		
0 kg/ha	6.55	7.21
100 kg/ha	10.23	10.00
200 kg/ha	9.88	9.62
Treatment Contrasts	Pr > F	
Quadratic effect of harvest regime	0.02	0.04
Quadratic effect of nitrogen regime	0.02	0.03

Dry matter production had ceased, and leaves were senescing. Thus, total dry matter yield was reduced.

Due to the later maturity of 'PM-K-129' than that of 'Blaze', only a small amount of leaf loss had occurred. Therefore, total yield did not decrease by the 10 October harvest date.

Little bluestem total yields on 15 July produced the least amount of dry matter. Lowered yields may be partly due to low carbohydrate reserves. Little bluestem was rapidly growing, so energy was being used for dry matter production. Carbohydrate reserves were used to initiate growth and perhaps to maintain rapid production. After clipping, plants may have been slow to recover from defoliation due to low availability of carbohydrates and/or few remaining nonelongated tillers.

Switchgrass

Switchgrass fertilized with nitrogen exhibited a significant quadratic effect for total yield (Table 2). Switchgrass N_{100} yields were greater than the averaged yields of N_0 and N_{200}. Nitrogen was apparently not the first limiting factor for grass production at the N_{200} treatment. As with the little bluestem cultivars, it appears that the genetic potential for N response for 'Cave-in-Rock' and 'Pathfinder' under the conditions of this experiment occurred near 100 kg/ha.

Harvest dates, tested by orthogonal comparisons, exhibited a significant quadratic effect for total yield of 'Pathfinder' switchgrass (Table 2). Yields of 'Pathfinder' on 15 August were greater than the average yields of the other two harvest dates. Total yield on 10 October was slightly lower than on 15 July. Harvest dates for 'Cave-in-Rock' exhibited a linear effect for yield.

Indiangrass

'Holt' indiangrass fertilized with nitrogen exhibited a significant quadratic effect for total yield (Table 3). The N_{100} yields were greater than the averaged yields of N_0 and N_{200}. 'Oto' indiangrass fertilized with nitrogen exhibited a significant linear increase for total yield (Table 3).

Both indiangrass cultivars exhibited a large yield increase with the high rate of N. McKendrich *et al.* (1975) reported indiangrass to have biennial tillers. The tillers remained active in the fall. Perhaps this longer growth period allowed indiangrass to respond to the high levels of N.

Table 2. Yield (tonnes/ha) of 'Cave-in-Rock' and 'Pathfinder' switchgrass with three harvest regimes and three levels of nitrogen fertilizer.

Harvest regime or fertilizer rate	*Switchgrass* 'Cave-in-Rock'	'Pathfinder'
	------------ tonnes/ha	------------
Harvest Regimes:		
7/15 and 10/10	11.10	10.93
8/15 and 10/10	11.78	13.95
10/10	9.11	10.19
Nitrogen Rate:		
0 kg/ha	8.91	8.80
100 kg/ha	12.25	13.82
200 kg/ha	10.82	12.45
Treatment Contrasts	Pr > F	
Quadratic effect of harvest regime	0.13	0.04
Quadratic effect of nitrogen regime	0.02	0.05

Table 3. Yield (tonnes/ha) of 'Holt' and 'Oto' indiangrass with three harvest regimes and three levels of nitrogen fertilizer.

Harvest regime or fertilizer rate	*Indiangrass* 'Holt'	'Oto'
	---------- tonnes/ha	----------
Harvest Regimes:		
7/15 and 10/10	6.60	7.26
8/15 and 10/10	9.33	10.60
10/10	7.94	10.16
Nitrogen Rate:		
0 kg/ha	3.50	3.78
100 kg/ha	9.20	10.22
200 kg/ha	11.17	14.02
Treatment Contrasts	Pr > F	
Quadratic effect of harvest regime	0.03	0.05
Quadratic effect of nitrogen regime	0.05	0.11

Harvest dates tested by orthogonal comparisons exhibited a significant quadratic effect for total yield (Table 3). Yields on 15 August were greater than the averaged yields on the other two harvest dates. Yields on 10 October were less than those on 15 August probably because of the maturity stage of the plants by October. Dry matter was reduced due to leaf loss.

The least amount of dry matter was harvested on 15 July. Indiangrass has few basal nodes, and the growing point is elevated above the ground soon after growth starts (Rechenthin 1956). Therefore, many growing points were probably removed during the first harvest. Cutting below the growing point prevents leaf initiation and expansion except by the slower process of tillering (Dahl and Hyder 1977). Regrowth may have been slowed by the tillering process, reducing dry matter yields of the regrowth. Lower 15 July yields may have been partly due to low carbohydrate reserves. Carbohydrate reserves were used to initiate growth and, perhaps, to maintain rapid production. After clipping, plants may have taken longer than normal to recover from defoliation due to low available carbohydrates.

Big Bluestem

Big bluestem fertilized with N exhibited a significant quadratic effect for total yield (Table 4). Big bluestem N_{100} yields were greater than the averaged yields of N_0 and N_{200}. Nitrogen was apparently not a limiting factor for grass production at the N_{200} treatment.

Table 4. Yield (tonnes/ha) of 'Kaw' and 'Pawnee' big bluestem with three harvest regimes and three levels of nitrogen fertilizer.

Harvest regime or fertilizer rate	*Big bluestem* 'Kaw'	'Pawnee'
	---------- tonnes/ha	----------
Harvest Regimes:		
7/15 and 10/10	8.14	9.38
8/15 and 10/10	13.06	12.49
10/10	10.13	7.84
Nitrogen Rate:		
0 kg/ha	6.45	6.26
100 kg/ha	11.57	11.37
200 kg/ha	13.31	12.08
Treatment Contrasts	Pr > F	
Quadratic effect of harvest regime	0.01	0.02
Quadratic effect of nitrogen regime	0.05	0.05

Harvest date orthogonal comparisons exhibited a significant quadratic effect for total yields of big bluestem (Table 4). The 15 August yields were greater than the average yields on 15 July and 10 October. Highest yields occurred with the 15 August harvest. The 10 October harvest severely reduced yields of 'Pawnee'. By October, big bluestem was dormant. Dry matter production had ceased. Since leaves were senescing, a reduction in total dry matter yield resulted.

Branson (1953) observed big bluestem to be somewhat more resistant than switchgrass to grazing. The growing points remained below the ground level until late July. Also, about two-thirds of big bluestems' shoots are vegetative rather than fertile (Branson 1953). July 15 yields were less than yields on August 15. Owensby *et al.* (1971) reported reduced carbohydrate percentages in rhizomes and stem bases in mid-July in big bluestem due to rapid vegetative growth. Reduction in carbohydrates from rapid growth plus harvesting at that time may have slowed recovery, reducing regrowth yields. Maximum carbohydrate accumulation occurred during mid-August to early September in big bluestem (Owensby *et al.* 1971). Carbohydrate levels were probably high at the 15 August harvest.

CONCLUSIONS

Yields of native, warm-season prairie grasses growing under favorable conditions, including added nitrogen, were exceptionally high. Some yields were similar to dry matter yields reported for corn (*Zea mays* L.) silage (Goodrich and Meiske 1985). Further research on yield potential and research on forage quality are warranted. High producing perennial species may be more economical and practical than use of annual species for production of dry matter for livestock.

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