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Growth Responses of Perennial Cool-Season Grasses Grazed Intermittently

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Abstract

Eight introduced and two native perennial cool-season grass varieties were grown for comparison in the highly variable climate of western Kansas. Grasses were seeded in a randomized complete block design with four replications on two different range sites. Grasses were grazed in 2000-2002 when vegetation height reached approximately 12 inches. All but one of the varieties produced greater dry matter yield than the native western wheatgrasses during the first year. However, tall wheatgrass and the native western wheatgrass varieties were among the highest yielding and had the greatest tiller numbers during 2002, a drought year. Most varieties produced 1.5 to 4.0 times more forage in 2001, a wet year, than in 2000 or 2002. With stress from grazing and lack of precipitation, cool-season grasses had greater yield response if greater numbers of tillers were present. Establishing and maintaining high tiller densities in stressful environments is a key contributor to productive grazed perennial cool-season grass stands in the western Great Plains.

Introduction

Perennial cool-season grasses are desirable for extending the grazing season in the central Great Plains where warm-season grasses are dominant. Growth of perennial cool-season grasses usually occurs from April to June and from late August through October in the Great Plains (14). Most introduced forage selections in the USA have been based on production under mechanical harvesting with very little emphasis on response to grazing (10). However, defoliation from clipping may have different effects than grazing on the vegetative component. In grass swards either grazed by sheep or clipped at the same time, grazing reduced yield compared to clipping (1). Grazing animal-sward interactions are especially important in stressful environments.

Evidence of this was seen in western Kansas with two native warm-season grass species. When not grazed, stands consisted of 90% bluestems (*Andropogoneae* sp.) for 20 years, but under moderate grazing stands had less than 13% bluestem (12). The benchmarks for successful establishment and persistence are sustained plant density (2) and harvested yield over time. This project was initiated to evaluate production and stand responses of native and introduced cool-season grass varieties selected for adaptation to the Great Plains while undergoing the stresses of grazing and the variable climate of west-central Kansas.

Research Protocol

Ten perennial cool-season grasses were seeded at two locations (upland and lowland) in a randomized complete block design with four replications near Hays, KS. The upland location was a Harney silt loam soil (fine, smectitic, mesic Typic Argiustoll), and the lowland location was a Roxbury silt loam soil (fine-silty, mixed, mesic Cumulic Haplustoll). Locations were 3 miles apart. Daily precipitation was collected manually at each location from April through September each year.

Grasses included ‘Lincoln’ smooth bromegrass (*Bromus inermis* Leyss.), ‘Bozoisky’ Russian wildrye (*Psathyrostachys juncea* (Fisch.) Nevski), ‘Luna’ and ‘Manska’ pubescent wheatgrass (*Thinopyrum intermedium* ssp. *barbulatum* (Shur) Barkw. & D.R. Dewey), ‘Alkar’ and ‘Jose’ tall wheatgrass (*T. ponticum* (Podp.) Barkw. & D.R. Dewey), ‘Slate’ and ‘Oahe’ intermediate wheatgrass (*T. intermedium* (Host) Barkw. & D.R. Dewey), and the only native grasses in the study, ‘Barton’ and ‘Flintlock’ western wheatgrass (*Pascopyrum smithii* (Rydb.) Love). Plots were 30 × 12 ft (9.9 × 3.9 m) in size with 1-ft row spacings, and were seeded at 30 pure live seeds per square foot (330/m^2) in a firm and clean tilled seed bed. Seeding occurred on 10 April 2000 at the upland site and 28 April 2000 at the lowland site with a plot hoe drill equipped with press wheels and modified with a spinning cone device for even seed distribution among rows. Plots received N at 40 lb/acre in the form of ammonium nitrate prior to seeding and additional N at 40 lb/acre in early April in 2001 and 2002. Plots also were sprayed with 1 qt of 2,4-D per acre (2,4-Dichlorophenoxyacetic acid) following the first harvest in 2000 and 2001 to reduce broadleaf weed competition.

Five tillers per plot were randomly selected, marked, and assigned a developmental leaf stage (3) to document the number of live retained green leaves per tiller. The newest leaf without a collar was measured to the nearest 1/25th of an inch from leaf tip to the collar of the previous leaf (5). Tiller stage and leaf measurements were made at 3 to 8 day intervals depending on the climate and growth rates. Stage number at each interval within 2 weeks prior to harvest was averaged to attain a harvest mean, and a season value was calculated across harvests for statistical analysis. Leaf growth was calculated as the difference in leaf lengths between two measurement periods. Total leaf growth during the 2 weeks before each harvest was divided by the number of days to calculate an average growth rate per day. Leaf measurements were not taken prior to one harvest in late May of 2001 at the lowland site because excessive rainfall made it impossible to collect data. Before being grazed, when any grass reached a 12-inch height or approached boot stage, tillers in two 1-ft^2 frames from each plot were counted and clipped near ground level, leaving approximately ½ inch of stubble. Plots were then grazed to a 2-inch height within 3 days by 550- to 850-lb steers. The upland site was grazed twice in 2000, and three times in both 2001 and 2002. The lowland site was grazed twice in 2000, four times in 2001, and three times in 2002. Grazing events were separated by at least 35 days. Clipped forage was dried in a forced-air oven at 120°F for 48 hours and then weighed to determine dry matter yield.

Data were collected in 2000-2002, and were analyzed by location because of non-homogeneous error variances reported from a Bartlett’s test, and the number of defoliations and leaf measurements varied between locations. General linear models of SAS (13) were used to analyze leaf number, leaf growth, tiller number, and forage yield, with significance based upon $P < 0.05$. Leaf number, leaf growth, and tiller number were also used in a stepwise multiple linear regression procedure of SAS (13) to account for variation in yield. Tiller and yield values were log transformed for regressions because relationships between tiller density and yield often become more linear with log transformation (7).

Weather

Precipitation during 2000 was near normal early in the growing season (Fig. 1A). However, both sites had 3 to 4 inches below normal precipitation for the entire growing season and moisture was lacking for autumn growth. In 2001, both sites received over 6 inches more rainfall than the long-term April to September average (Fig. 1B). Moisture conditions in 2001 were ideal for grass growth, but conditions in 2002 were poor. In 2002, rainfall at both sites was 3 to 5 inches below average (Fig. 1C), with May through July having the greatest deficit.

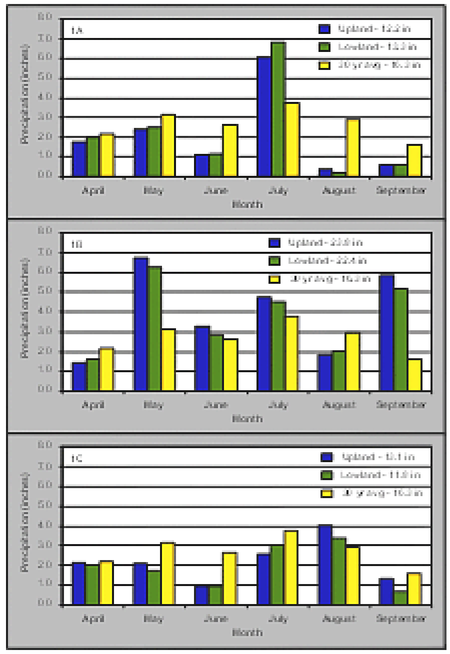

Fig. 1. Monthly and total precipitation at an upland and lowland site near Hays, Kansas, for the growing season of April through September in (A) 2000, (B) 2001, and (C) 2002.

Forage Yield

Several varieties with the greatest yields in 2000 or 2001 were different than the varieties with the greatest yield at the end of 2002. Seven varieties had the greatest forage yield on the upland location the first season, totaling 1430 to 2110 lb/acre from two harvests (Table 1). Three of these grasses, Slate, Manska, and Jose, also had the greatest yield in 2001 when three cuttings were taken. During the drought of 2002, Alkar, Barton, and Flintlock produced the greatest yield, totaling 4160 to 4930 lb/acre from three harvests. With greater rainfall in 2001 and drought in 2002, all varieties except for Alkar and Flintlock produced up to two times more forage in 2001 than in 2002. At the lowland site, Manska, Alkar, Slate, and Oahe were the top producers in 2000 (Table 2). Jose and Oahe produced abundant forage during 2001. Abundant rainfall in 2001 enabled all varieties at the lowland location to produce 2 to 4 times more forage than in 2000, and 1.5 to 2.5 times more forage than in 2002. Barton produced the greatest forage yield in 2002, followed by Jose, Alkar, and Flintlock, totaling 5820 to 7620 lb/acre from three harvests during the drier season.

Table 1. Total-season forage yield and average tiller density from each harvest of 10 perennial cool-season grasses grazed intermittently on an upland site in western Kansas in 2000, 2001, and 2002.

Grass variety	**Yield tiller density** (lb/acre)			**Tiller density** (tillers per ft^2)		
	2000	**2001**	**2002**	**2000**	**2001**	**2002**
Alkar	1430	4600	4930	74	79	107
Barton	1080	5190	4160	58	95	116
Bozoisky	470	3370	2360	40	93	89
Flintlock	830	4250	4490	53	71	109
Jose	1970	6040	3980	114	116	124
Lincoln	1660	4270	2270	63	86	80
Luna	1470	4260	3250	67	72	84
Manska	1990	5830	2940	83	87	82
Oahe	1840	5250	3220	80	82	78
Slate	2110	6440	3430	89	85	84
$LSD_{0.05}$ †	830			18		

† LSD is for year × variety interaction within rows or columns.

Table 2. Total-season forage yield and average tiller density from each harvest of 10 perennial cool-season grasses grazed intermittently on a lowland site in western Kansas in 2000, 2001, and 2002.

Grass variety	**Yield** (lb/acre)			**Tiller density** (tillers per ft^2)		
	2000	**2001**	**2002**	**2000**	**2001**	**2002**
Alkar	3630	10170	5820	135	152	137
Barton	2650	10840	7620	120	153	195
Bozoisky	2050	8190	3920	118	159	131
Flintlock	1850	8580	6410	84	125	186
Jose	3160	12020	6550	164	184	190
Lincoln	2860	9120	3780	86	106	120
Luna	2930	11140	5210	107	117	127
Manska	4210	10080	4630	131	119	129
Oahe	3600	12220	4660	138	136	129
Slate	3470	10820	4960	129	125	128
$LSD_{0.05}$ †	1030			20		

† LSD is for year × variety interaction within rows or columns.

Tiller Density and Yield

Tiller density, leaf number, and leaf elongation were used in stepwise multiple linear regression to account for variation in forage yield at each location. Tiller density alone accounted for the most variation in yield differences at each location (Table 3). Varieties with the greatest tiller densities also tended to have the greatest yields in the dry years of 2000 and 2002, resulting in significant positive relationships ($P < 0.0001$).

Table 3. Regression statistics of the relationship between seasonal yield, tiller density, leaf growth, and leaf number of 10 perennial cool-season grasses grown at two sites near Hays, KS, and grazed intermittently in 2000, 2001, and 2002.

Location	n	Equation†	Y intercept	Partial r^2	Root MSE	Model prob > F
Upland						
2000	40	log(YLD) = 1.38*log(TD) +	0.25	0.80	0.11	0.0001
		0.08*(LN)		0.03		
2001	40	log(YLD) = 0.91*log(TD) +	1.61	0.32	0.07	0.0001
		0.91*(LG)		0.22		
2002	40	log(YLD) = 0.96*log(TD) +	1.56	0.52	0.07	0.0001
		1.12*(LG) +		0.11		
		-0.05*(LN)		0.03		
Lowland						
2000	40	log(YLD) = 0.89*log(TD) +	1.42	0.45	0.09	0.0001
		0.31*(LG)		0.14		
2001	40	log(YLD) = 0.23*log(TD)	3.52	0.06	0.07	0.11
2002	40	log(YLD) = 0.94*log(TD) +	1.61	0.63	0.06	0.0001
		0.35*(LG)		0.03		

† YLD = yield; TD = tiller density; LN = leaf number; LG = leaf growth.

Tiller density may be an indicator of expected forage production under precipitation and grazing stress. In 2001 with above average precipitation, tiller density had little influence on forage yield and had lower coefficients of determination than in 2000 or 2002 (Table 3). Nelson and Zarrough (11) reported that tall fescue increased tiller numbers to a finite density with increased nitrogen fertilizer, and increases in sward yield at the greatest densities resulted from greater individual tiller weight with the increased fertilization. The results presented here suggest that a similar response occurs with greater precipitation in grazed swards. Increased sward yield with more rainfall resulted from increased individual tiller weights, but under moisture and grazing stress, tiller density had a greater impact on forage yield. Seven of the ten varieties at both locations did not change tiller density from 2000 to 2001, or from 2001 to 2002, yet all produced much greater yields in 2001, a wet year.

In a greenhouse study of Russian wildrye and intermediate wheatgrass, defoliation intensity had a greater effect on yield and tiller number than moisture level (4). However, greater yields of Russian wildrye and intermediate wheatgrass at greater moisture levels were considered to be a result of larger tillers rather than greater tiller number (4). Kemp and Culvenor (6) also concluded that more and larger tillers were a crucial component in cool-season grasses surviving stressful environments.

Jose had greater tiller density than other grasses at both locations during 2000 and 2001 (Table 1 and 2). Jose, Barton, Flintlock, and Alkar had equal tiller density, all greater than 100 tillers per square foot, at the upland location during 2002 (Table 1). At the lowland location in 2002, Jose, Barton, and Flintlock had the greatest tiller density of 186 to 195 tillers per square foot (Table 2). No other grasses were able to maintain a stand density above 140 tillers per square foot at the lowland location in 2002. At both sites, Barton and Flintlock had two of the lowest densities in 2000, but by 2002 had the greatest densities. Surprisingly, Bozoisky at the lowland site was the only grass with reduced tiller density in the dry season of 2002 compared to the moist season of 2001. In the Texas Rolling Plains, tiller survival of wheatgrass species was dependent on drought severity, defoliation intensity, and defoliation frequency, with no consistent pattern across species (8).

Mitchell et al. (9) found that 2- and 3-year-old stands of Slate and Lincoln had greater tiller density than in the present study. The combination of more narrow row spacings and much greater N fertilizer rates in a climate more suitable for cool-season growth likely contributed to the greater tiller densities than in the present study.

Stand age had a minimal effect on tiller density, but had a small effect on yield. Of the varieties that had equal stand density in the two similar precipitation years of 2000 and 2002, all but Lincoln at the upland site and Manska at the lowland site had greater yield in 2002 than in 2000. The greatest influence of stand age was likely from growth starting earlier in the spring in 2001 and 2002 for all varieties from the already established stands, which allowed for more harvests. Barton at both locations and Flintlock at the lowland location were the only varieties with increased tiller density each year.

Leaf Number, Leaf Growth, and Yield

Leaf number had almost no relationship to forage yield (Table 3). At both locations in all years, Lincoln had more retained leaves per tiller than any other grass the 2 weeks prior to each harvest, except for Barton in 2001 and Flintlock in 2002 at the upland site (Table 4 and 5). Few other differences occurred in leaf number except for a general decline for most grasses at both sites after the first year. Leaf growth prior to harvest did have a slight relationship with forage yield, with the greatest influence at the upland site in 2001 and 2002, and the lowland site in 2000 (Table 3). Five of the varieties had greater leaf growth than Barton, Flintlock, and Jose at the lowland site in 2000 (Table 5). At the upland site, Lincoln and Bozoisky had slower leaf growth in 2001 than in 2000, but at the lowland site all introduced grasses had slower leaf growth in the second than in the first year. In 2001 and 2002 at both sites, leaf growth was similar among varieties within a year, and between years within any variety (Table 4 and 5). Different leaf widths among species may have resulted in the weak relationship between leaf growth and yield, because grasses with similar leaf widths have had stronger relationships (5).

Table 4. Average leaf number per tiller and leaf growth for 2 weeks prior to each harvest of 10 perennial cool-season grasses grazed intermittently on an upland site in western Kansas in 2000, 2001, and 2002.

Grass variety	Leaf number (green leaves per tiller)			Leaf growth (inch/day)		
	2000	2001	2002	2000	2001	2002
Alkar	3.9	3.3	3.0	0.42	0.32	0.25
Barton	4.2	4.2	3.3	0.33	0.34	0.19
Bozoisky	4.1	2.7	2.6	0.59	0.22	0.16
Flintlock	4.1	3.9	3.4	0.36	0.34	0.23
Jose	4.0	3.3	2.9	0.39	0.30	0.21
Lincoln	5.4	4.5	3.7	0.58	0.36	0.20
Luna	3.8	3.3	3.0	0.48	0.37	0.26
Manska	4.1	3.3	2.8	0.41	0.36	0.21
Oahe	4.1	3.4	3.0	0.44	0.38	0.22
Slate	4.0	3.2	2.9	0.41	0.36	0.21
$LSD_{0.05}$ †	0.4			0.19		

† LSD is for year × variety interaction within rows or columns.

Table 5. Average leaf number per tiller and leaf growth for 2 weeks prior to each harvest of 10 perennial cool-season grasses grazed intermittently on a lowland site in western Kansas in 2000, 2001, and 2002.

Grass variety	Leaf number (green leaves per tiller)			Leaf growth (inch/day)		
	2000	2001	2002	2000	2001	2002
Alkar	4.3	3.2	2.8	0.67	0.36	0.30
Barton	4.5	3.3	3.1	0.39	0.32	0.21
Bozoisky	4.4	2.7	2.7	0.69	0.27	0.18
Flintlock	4.6	3.3	3.0	0.45	0.30	0.22
Jose	4.1	3.1	2.8	0.48	0.26	0.26
Lincoln	5.8	3.9	3.8	0.86	0.36	0.29
Luna	4.0	3.4	2.8	0.77	0.32	0.27
Manska	4.3	3.1	2.9	0.68	0.32	0.23
Oahe	4.4	3.1	2.8	0.63	0.28	0.21
Slate	4.4	3.2	2.9	0.65	0.30	0.21
$LSD_{0.05}$ †	0.4			0.17		

† LSD is for year × variety interaction within rows or columns.

Conclusion

Lincoln and Bozoisky produced among the poorest yields during 2001 and 2002. All other grasses produced acceptable forage during the drought year of 2002, but only Jose and Alkar produced as much forage as the natives Barton or Flintlock. These four perennial grasses increased or maintained tiller density and had the greatest production after 3 years of grazing, including a drought year. Although less productive than tall wheatgrass during the establishment year, by the third year it was not surprising that western wheatgrass would be among the most productive of these grasses for tiller survival and yield because it is native to the region. These improved varieties of tall wheatgrass and native western wheatgrass are sound options for producing greater tiller numbers and dry matter in grazed and non-irrigated perennial pastures. Tall wheatgrass is especially useful for production on highly saline and alkaline soils. Selection for varieties with greater tiller numbers, seeding at the greatest recommended rates, maintaining adequate soil nutrient status, and intermittent defoliation with rest periods to stimulate new tiller growth are management practices that may increase tiller numbers and would be beneficial in providing a productive stand of grazed perennial cool-season grass in the variable climate of the western Great Plains.

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