Forage Yield and Quality of Warm- and Cool-season Grasses

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Abstract

High quality forage is needed in the northern Great Plains during the summer when major growth of cool-season grasses has ceased and quality of standing forage is low. The objective of this study was to compare forage yield, nutritional quality, and water use of 2 warm-season grasses {P-15584 little bluestem [*Schizachyrium scoparium* (Michx.) Nash] and 'Pierre' sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]} and 2 cool-season grasses {'Nordan' crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] and 'Mayak' Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski]} harvested from 1979 through 1982 at anthesis or when drought stopped further plant growth. Forage was harvested from established stands seeded in rows 53-cm apart growing on a silty range site (Typic Haploborolls) near Sidney, Mont. Plots were 8 by 23 m replicated 5 times in randomized complete blocks. Forage yield averaged 0.84, 0.98, 1.75, and 2.52 t/ha ($S_{\bar{x}} = 0.17$); in vitro organic matter digestibility averaged 56.4, 67.3, 62.0, and 62.3% ($S_{\bar{x}}$ 1.1), crude protein averaged 8.0, 10.3 8.6, and 12.8% ($S_{\bar{x}} = 0.4$); phosphorus averaged 0.14, 0.16, 0.15, and 0.16% ($S_{\bar{x}} = 0.01$) over a 4-year period for little bluestem, sideoats grama, crested wheatgrass, and Russian wildrye, respectively. Regression showed that in vitro organic matter digestibility and crude protein concentration were negatively correlated with forage yield. Forage yield and phosphorus concentration were positively correlated with evapotranspiration. The study showed that Russian wildrye would provide the highest quality forage during June and sideoats grama during July. Livestock need both cool- and warm-season forages to provide the highest forage quality.

High quality forage is needed for grazing animals in the northern Great Plains during the summer when major growth of cool-season grasses has ceased and quality of standing forage is low. Warm-season grasses might provide such high quality forage becuse they mature a month later than cool-season grasses (Newell and Moline 1978). Little bluestem [*Schizachyrium scoparium* (Michx.) Nash] and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] are 2 of the higher forage yielding warm-season grasses that survive in the northern Great Plains where mean January temperature is less than −10° C and annual precipitation is less than 380 mm.

There is little published research on forage yield and quality of warm-season grasses native to the northern Great Plains. Limited data have been published on the nutritional quality of little bluestem (Burzlaff 1971, Kamstra 1973, Newell and Moline 1978) and sideoats grama (Newell and Moline 1978) grown in the central Great Plains. Burzlaff (1971) found that in vitro dry matter digestibility (IVDMD) of little bluestem decreased from 68% in early June to 36% by early November. Kamstra (1973) found that the in vitro cellulose digestibility of little bluestem from June through September was about 10 percentage units lower than that of either western wheatgrass (*Agropyron smithii* Rydb.) or green needlegrass (*Stipa viridula* Trin). He also found that the crude protein of little bluestem during this period was about 1 percentage unit less than that of western wheatgrass but nearly the same as that of green needlegrass. Newell and Moline (1978) found that the average weighted IVDMD of initial growth and regrowth of 6 warm-season grasses (May through September) was only 54.7% while that of 6 cool-season grasses (May through June) was 57.7%. They reported that sideoats grama and indiangrass [*Sorghastrum nutans*(L.) Nash] were more digestible than big bluestem (*Andropogon gerardii* Vitm.), sand bluestem (*A. hallii* Hack.), little bluestem, or switchgrass *(Panicum virgatum* L.).

The objective of this study, was to compare forage yield, nutritional quality, and water use of 2 warm-season grasses (little bluestem and sideoats grama) and 2 cool-season grasses {crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult] and Russian wildrye [*Psathyrostachys juncea* (Fisch.) Nevski]} harvested during a 4-year period at anthesis or when drought stopped further plant growth.

Materials and Methods

The study site was 7 km southeast of Sidney, Mont., at an elevation of 610 m on a silty range site. The soil is a Shambo loam (Typic Haploborolls fine-loamy, mixed). Analysis of the 0- to 7.5-cm depth of soil showed that pH of a saturated paste was 8.0 and conductivity was 0.5 mmhos/cm; organic matter, 3.9%; sodium bicarbonate-extractable phosphorus, 11 ppm; ammonium acetate-extractable potassium, 440 ppm; and exchangeable calcium, magnesium, sodium, were 14, 3, and 0.5 meq/100 g, respectively. Average annual precipitation at the site was 346 mm, seasonal distribution is shown in Table 1. January and July long-term mean temperatures were −13 and 20° C, respectively, and the average frost-free period was 122 days.

Table 1. Precipitation received at the study site near Sidney, Mont. from 1979 through 1982.

Crop year	Oct.-Dec.	Jan.-Mar.	Apr.	May	June	July-Sep.	Total crop year
				mm			
1978-79	49	44	25	36	43	104	301
1979-80	15	29	8	5	51	117	225
1980-81	69	9	28	17	61	135	319
1981-82	42	75	8	61	71	132	389
Long-term Avg.	42	31	30	51	72	120	346

Little bluestem (P-15584), 'Pierre' sideoats grama, 'Nordan' crested wheatgrass, and 'Lodorm' green needlegrass were seeded 23 May 1975 at 80 pure live seeds per meter of row. Plots were 8 by 23 m and consisted of 15 rows spaced 53 cm apart. Plots were arranged in randomized complete blocks with 5 replications. The 2 cool-season grasses did not germinate because of the residual effect of the application of 1.1 kg active ingredient (ai)/ha of atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) the previous year (30 Apr. 1974). Lodorm green needlegrass and Nordan crested wheatgrass were reseeded on 25 May 1976 at 115 pure live seeds per meter of row the same as previously done. Green needlegrass did not germinate so those plots were reseeded with 'Mayak' Russian wildrye on 30 Aug. 1976 at 80 pure live seeds per meter of row. Atrazine was applied at 1.1 kg ai/ha to the plots of warm-season grasses on 22 Sept. 1978 to control annual bromegrasses (*Bromus tectorum* L. and *B. japonicus* Thunb. ex Murr.). Bromacil (5-bromo-3sec-butyl-6-methyluracil) was applied at 1.8 kg ai/ha on 23 Apr. 1981 on warm-season grass plots to control annual bromegrasses and green foxtail [*Setaria viridis* (L.) Beauv.]. Data for the study were not collected until 1979 to avoid high forage yields the first 2 years after establishment as reported by White (1985). Forage was harvested at a 5-cm stubble height from

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10 m of one row each year from 1979 through 1982 as each species reached anthesis or when drought stopped further plant growth. Forage from the remainder of the plot was harvested and removed a few days later. Plant material was dried at 70° C and ground to pass a 1-mm screen before analysis.

In vitro organic matter digestibility (IVOMD) was determined by a modification of the Tilley and Terry two-stage method as previously described by White et al. (1981). Nitrogen concentration (conc). determined by the macro-Kjeldahl method was multiplied by 6.25 to estimate crude protein. Phosphorus conc. was determined by wet digesting forage samples with perchloric-sulfuric acid on a block digestor. The digest was analyzed with an autoanalyzer by the vanadate-molybdate method for phosphorus conc.

Daily precipitation was measured at the site from April through October in a standard 20-cm diameter rain gauge. Precipitation data from November through March were obtained from an official weather station located 7 km away on similar topography. Soil water content by 30-cm increments from 0- to 120-cm depth was determined with a neutron probe every 2 weeks from late April through early August each year from 1979 through 1982 via access tubes located in each plot. Soil water in the 120- to 270-cm depth was also measured at the same time in one plot within each replication to determine if there was measurable drift in neutron probe readings during the study. Soil water data showed no evidence of drift in the readings nor water percolation below a depth of 120 cm. Evapotranspiration (ET) was defined as the net soil water loss in the 0- to 120-cm profile plus precipitation received from late April through harvest each year. There was no evidence of surface runoff during the study.

The effect of species and year on forage yield, IVOMD, crude protein, and phosphorus conc. in the forage plus soil water used and ET were determined with an analysis of variance using a split plot in space design. Since the species-by-year interaction was significant, a 2-way analysis of variance was also conducted separately for each set of data each year. If there was a significant ($P \geqq 0.05$) *F*-value, then the least significant difference ($P=0.05$) was calculated to determine differences between species means.

Stepwise (addition) multiple regression was used to determine whether forage yield by replication was significantly correlated with precipitation from October through December, January through March, April, May, June, and crop year (October of previous year through September of current year), plus precipitation, soil water used, and ET from late April through harvest. Stepwise regression was also used to determine whether precipitation from late April through harvest, soil water used, ET, forage yield, stand age, and harvest date were significantly correlated with crude protein and phosphorus conc. All differences mentioned in this paper are significant at the ($P \geqq 0.05$) probability level unless otherwise stated.

Results and Discussion

Forage Yield

The average forage yield of the 4 species was 2.43, 0.32, 0.89, and 2.44 t/ha [standard error of mean ($S_{\bar{x}}$) = 0.17] in 1979, 1980, 1981, and 1982, respectively. In 1979, precipitation during April, May, and June was below normal (Table 1) but adequate soil water (Table 2) allowed near normal forage yield. Drought conditions prevailed during 1980 and 1981. May precipitation during 1980 and 1981 was only 10% and 33% of normal with little stored soil water available. In 1982, little soil water was available but May precipitation was 20% above normal and allowed for near normal forage production.

The average forage yield of little bluestem, sideoats grama, crested wheatgrass, and Russian wildrye over the 4-year period was 0.84, 0.98, 1.75, and 2.52 t/ha ($S_{\bar{x}}$ = 0.17), respectively. Little bluestem and sideoats grama did not differ ($P>0.05$) in forage production during any of the 4 years (Fig. 1a). The two warm-season grasses produced only 30 to 60% as much forage as crested wheatgrass depending upon the year.

Crested wheatgrass produced 60, 50, 90, and 70% as much forage as Russian wildrye during the first through the fourth year of the study, respectively (Fig. 1a). Perhaps Russian wildrye out yielded crested wheatgrass because of the additional soil nitrogen that was mineralized during the year's delay in Russian wildrye stand establishment. There was no difference in soil water used by the 2 cool-season species during any of the 4 years (Table 2). Leyshon et al. (1981) reported that Russian wildrye produced more forage than crested wheatgrass when planted in rows wider than 50 cm. However, White and Wight (1984) found that Russian wildrye and crested wheatgrass were nearly equal in forage yield over a 7-year period when planted on a sandy range site in 50-cm rows.

Table 2. Harvest date, precipitation, soil water used, evapotranspiration (ET) from late April through harvest by warm- and cool-season grasses grown near Sidney, Mont.

Species	Year	Har. date	Precip.	Soil water	ET
		month/day	----------	mm	----------
Little bluestem	1979	7/31	155	65	220
	1980	8/7	74	11	85
	1981	7/24	141	21	162
	1982	8/10	200	26	226
Sideoats grama	1979	7/18	99	61	160
	1980	8/7	74	12	86
	1981	7/17	114	19	133
	1982	7/19	150	17	167
Crested wheatgrass	1979	6/29	81	67	148
	1980	6/2	10	6	16
	1981	6/29	101	8	109
	1982	6/29	132	34	166
Russian wildrye	1979	6/19	56	72	128
	1980	6/2	10	6	16
	1981	6/2	65	2	67
	1982	6/21	117	26	143
F-Prob. Species			—	0.84	<0.01
F-Prob. Years			—	<0.01	<0.01
F-Prob. S by Y			—	0.04	<0.01
$S_{\bar{x}}$ (S by Y)			—	4.6	4.6

Table 3. Correlation coefficients of forage yield from five replications of warm- and cool-season grasses grown near Sidney, Mont. from 1979 through 1982 with precipitation received during selected periods, soil water used, and evapotranspiration from late April through harvest.

	Species			
Forage yield vs.	Little bluestem	Sideoats grama	Crested wheatgrass	Russian wildrye
Precipitation				
Oct.–Dec.	0.22	0.18	0.41	0.24
Jan.–Mar.	0.63**	0.87**	0.67**	0.63**
Apr.	0.14	–0.23	0.18	0.12
May	0.74**	0.97**	0.88**	0.75**
June	–0.10	0.50*	0.16	–0.01
July–Sep.	–0.38	0.15	–0.12	–0.28
Crop year[1]	0.52*	0.86**	0.76**	0.57**
Apr.–Har.[2]	0.69**	0.84**	0.76**	0.58**
Soil water used	0.65**	0.23	0.83**	0.81**
Evapotranspiration	0.80**	0.84**	0.94**	0.89**

*,**Significant at the 0.05 and 0.01 levels, respectively.

[1] Crop year = October of previous year through September of current year.

[2] Precipitation from late April through harvest.

There was a species-by-year interaction ($P<0.01$) between the amount of soil water used and ET by warm- and cool-season grasses (Table 2). Warm-season grasses used more soil water ($P=0.01$) than the cool-season grasses in 1981 but not in the other

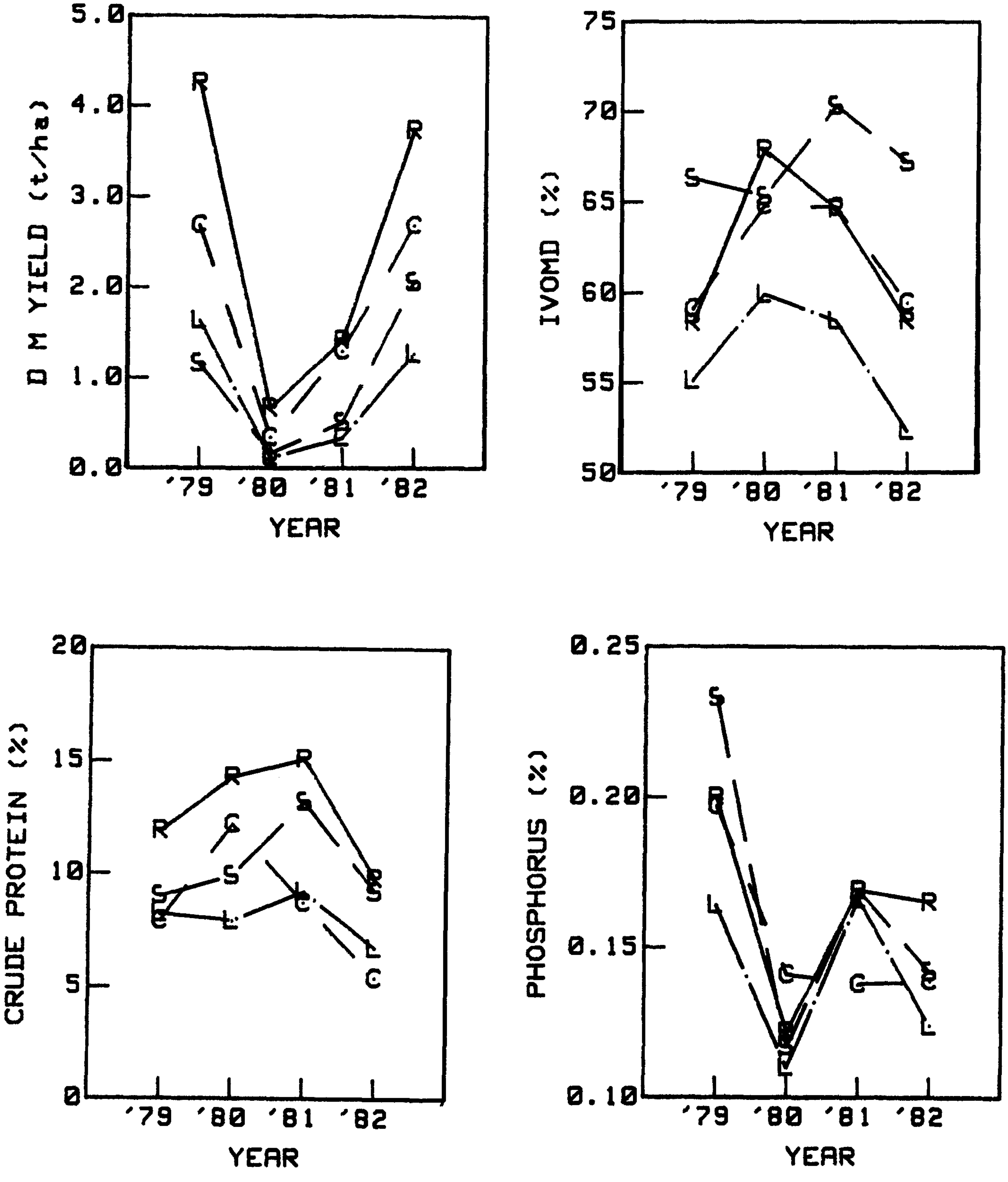

Fig. 1. *Forage yield (DM), in vitro organic matter digestibility (IVOMD), crude protein, and phosphorus conc. in Russian wildrye (R), crested wheatgrass (C), sideoats grama (S), and little bluestem (L) when grown near Sidney, Mont. from 1979 through 1982.*

years. Soil water used and ET of warm- and cool-season grasses was confounded because of the difference in time when the grasses were harvested, especially during drought conditions. Warm-season species generally had more precipitation available to them during late April through harvest than cool-season species because they required a longer time to reach anthesis (Table 2).

Forage yield of all species, except sideoats grama, had a higher correlation with ET than with soil water used or precipitation during any month or period of months (Table 3). The lower correlation of sideoats grama forage yield with ET occurred because forage yield per millimeter of soil water used in 1982 was much higher than in the other years. Forage yield of all species was highly

Table 4. Regression equations showing the factors significantly related with forage yield, in vitro organic matter digestibility, crude protein, and phosphorus conc. of warm and cool-season grasses near Sidney, Mont.

Forage yield (t/ha)		
LB	$Y = -0.791 + 9.4\ \mathrm{ET}$,	$r = 0.81$
SO	$Y = -1.598 + 18.9\ \mathrm{ET}$,	$r = 0.84$
CW	$Y = -0.061 + 16.5\ \mathrm{ET}$,	$r = 0.94$
RWR	$Y = -0.083 + 29.3\ \mathrm{ET}$,	$r = 0.89$
In Vitro Organic Matter Digestibility (%)		
LB	$Y = 59.5 - 3.65$ Forage yield,	$r = 0.62$
SO	$Y = 67.3 - .007$ Forage yield,	$r = -0.02$
CW	$Y = 66.6 - 2.26$ Forage yield,	$r = -0.73$
RWR	$Y = 67.8 - 2.18$ Forage yield,	$r = -0.80$
Crude Protein (%)		
LB	$Y = 35.7 - 0.129$ Har. date,	$r = 0.73$
SO	$Y = 43.3 - 2.2$ Forage yield $- 0.151$ Har. date,	$r = 0.67$
CW	$Y = 12.2 - 2.1$ Forage yield,	$r = 0.80$
RWR	$Y = 77.1 - 1.2$ Forage yield $- 0.416$ Har. date,	$r = 0.84$
Phosphorus (%)		
LB	$Y = 0.810 + 0.00019\ \mathrm{ET} - 0.0033$ Har. date,	$r = 0.86$
SB	$Y = 1.092 - 0.0298$ Yr. $- 0.0042$ Har. date,	$r = 0.95$
CW	$Y = 0.179 + 0.00027\ \mathrm{ET} - 0.022$ Yr.	$r = 0.77$
RWR	$Y = 0.132 + 0.00035\ \mathrm{ET}$	$r = 0.58$

Forage yield = t/ha, ET = mm from late April through harvest.
Har. date is days from first of January, Yr. is year of study (1,2,3,4)

correlated with May precipitation and poorly correlated with April and June precipitation. White (1986) reported that forage yield of western wheatgrass had a higher correlation with ET from late April through June than with precipitation during any other 3 consecutive months or soil water used. White (1985) in 6 studies in the northern Great Plains also found that forage yield of Russian wildrye and crested wheatgrass was more highly correlated with precipitation during April and May than with precipitation during any other period.

Of the warm-season grasses, sideoats grama produced about twice as much forage per millimeter of ET as little bluestem (Table 4). An exception occurred during the 1980 drought. Sideoats grama produced more forage per millimeter of ET than little bluestem because sideoats grama reached anthesis about 14 days earlier (except during the drought) (Table 2). Warm-season grasses produced about half as much forage per millimeter of ET as the cool-season grasses (Table 4). Of the cool-season grasses, Russian wildrye produced more forage per millimeter of ET than crested wheatgrass because Russian wildrye reached anthesis about 15 days earlier than crested wheatgrass (except during the 1980 drought) and therefore less ET loss had occurred.

Digestibility

The IVOMD at harvest varied from 52 to 70% depending upon species and year (Fig. 1b). There was a species-by-year interaction ($P<0.01$) because IVOMD of sideoats grama and crested wheatgrass in 1980 were low relative to the IVOMD of the other species during the other years. The IVOMD of all species except sideoats grama varied inversely ($P<0.01$) with forage yield during the 4 years (Table 4). The decrease in IVOMD with increased forage yield was similar to that found for Russian wildrye and crested wheatgrass in a previous study (White and Wight 1984). It is difficult to compare the forage value of species when IVOMD and forage yield are both varying at the same time. The question is which species is the better: the one which produces the most forage but is less digestible or one which is more digestible but produces less forage. To simplify the problem, I have used regression analysis to determine IVOMD at a given level of forage production, thus comparing 1 variable at a time instead of 2 variables. Regression analysis showed that when IVOMD was compared at a forage yield of 2.0 t/ha, IVOMD was 52, 61, 63, and 67% for little bluestem, crested wheatgrass, Russian wildrye, and sideoats grama, respectively. Sideoats grama would provide high quality forage during the summer when cool-season grasses are dormant. Little bluestem forage quality was low at anthesis and would only meet animal maintenance requirements. Newell and Moline (1978) also reported low IVDMD for little bluestem during late July while that of sideoats grama was much higher.

Crude Protein

Crude protein at harvest varied from a high of 15% for Russian wildrye in 1981 to a low of 5% for crested wheatgrass in 1982 (Fig. 1c). There was a species-by-year interaction ($P<0.01$) because the crude protein conc. of crested wheatgrass was relatively higher in 1980 and lower the other years. Crude protein of Russian wildrye forage was the highest, while that of crested wheatgrass (except in 1980) and little bluestem were the lowest. Crude protein of crested wheatgrass and little bluestem near the anthesis would only be adequate for cattle maintenance, while the crude protein of Russian wildrye and sideoats grama would be adequate for yearling steers with expected gains of over 1 to 1.5 kg/ha day (National Research Council 1984).

Forage yield and harvest date were significantly correlated with the crude protein conc. of all grasses except crested wheatgrass and were selected by stepwise regression analysis before ET, soil water used, and precipitation received during either May or late April through harvest (Table 4).

When forage crude protein was compared at a given level of forage yield (2.0 t/ha) it was 7, 8, 9, and 13% for little bluestem, crested wheatgrass, sideoats grama, and Russian wildrye, respectively.

Phosphorus

Phosphorus conc. in the forage varied from a high of 0.23% to a low of 0.11% (Fig. 1d). Generally both the cool- and warm-season grasses failed to provide enough phosphorus to meet the maintenance requirements of mature cattle. Russian wildrye, crested wheatgrass, and sideoats grama (except the first year) and little bluestem forage all years contained less than 0.18% phosphorus level recommended by National Research Council (1984) for maintenance of mature cattle. There was a species-by-year interaction because the phosphorus conc. of crested wheatgrass was higher than that of the other species in 1980 and lower in 1981.

Phosphorus conc. was generally inversely related to crude protein. Phosphorus conc. was lowest during the 1980 drought and highest during the 1979 wet year when the most soil water was used. Phosphorus conc. of all grasses except sideoats grama increased 0.0002 to 0.0003 percentage units per millimeter increase of ET (Table 4). Phosphorus conc. of warm-season species was also significantly correlated with harvest date. Phosphorus conc. of sideoats grama and crested wheatgrass decreased 0.02 to 0.03 percentage units each year of the study. This decrease probably occurred because soil available phosphorus mineralized during stand establishment was gradually depleted.

Conclusions

Both cool- and warm-season forages are needed to provide high quality forage for livestock in the northern Great Plains. Cool-season forages will provide high quality forage through early summer but White and Wight (1981) showed that digestibility of cool-season grasses decreased an average of 0.25 percentage units per day until early August. By the time warm-season grasses reached anthesis some 15 to 30 days later, digestibility of cool-season grasses would have decreased about 4 to 8 percentage units (54 to 58%) and would only be adequate for 0.2 to 0.4 kg/day weight gain for yearling steers if they ate the whole plants (National Research Council 1984). Sideoats grama at this same time was 62.0% digestible and would provide about 0.7 kg/day weight gain. At anthesis, sideoats grama had adequate crude protein for yearling steers with expected gains of over 1 to 1.5 kg/day. All 4 grasses were deficient in phosphorus. Little bluestem at anthesis produced low forage yields and was lowest in forage quality and would only provide animal maintenance.

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