Forage Yield and Quality of Dryland Grasses and Legumes

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Abstract

A 7-year study was conducted on forage yield, digestibility, and crude protein of 7 species of grass, 3 cultivars of alfalfa, and cicer milkvetch at Sidney, Mont., from 1975 through 1981. Forage quality was inversely proportional with forage yield. Crude protein concentration of legumes and grasses decreased 0.8 and 1.25 percentage units, respectively, while dry matter digestibility decreased 1.5 to 2.3 percentage units per every 1,000 kg/ha increase in forage yield. Meadow bromegrass and reed canarygrass produced the least forage from the second through seventh years of the study. Neither forage yield nor quality differed among the 3 creeping-rooted alfalfas: 'Rambler', 'Drylander', and 'Orenberg'. Russian wildrye, Altai wildrye, and green needlegrass produced the most forage during the 1980 drought, and the alfalfas, pubescent wheatgrass, and meadow bromegrass produced the least. Cicer milkvetch and reed canarygrass died during the 1980 drought. Forage digestibility of the alfalfas was 5 to 6 percentage units higher than that of the grasses, and the alfalfas also produced more digestible forage per unit of land. The crude protein concentration of alfalfas was almost twice that in grasses, and alfalfa produced almost twice as much crude protein per unit of land (kg/ha).

In the evaluation of forage species and cultivars for livestock production, forage quality, as well as quantity, should be considered. If forages are used for maintenance of mature cows, maximum forage yield of each species is most important if digestibility is 50% or greater. However, if forages are used for growth of heifers or steers, or for additional energy for cows just before or after they calve, then high forage quality may be more important than forage yield.

Reports of 2 studies in the northern Great Plains contained data on both forage yield and dry matter digestibility (DMD) of major dryland forage species, but for only 1 or 2 years after establishment (Lawrence 1978, White and Wight 1981). Kilcher and Heinrichs (1974) and Kilcher (1980) showed that forages under semiarid conditions must be evaluated over a period of at least 5 years, excluding the first year after establishment, to determine their relative ranking.

Our objective was to determine forage yield, DMD, digestible-forage yield, crude protein (CP) concentration, and CP yield of 7 grass species, 3 cultivars of alfalfa, and cicer milkvetch over a 7-year period (1975-1981) when grasses were harvested at anthesis and legumes at 10% bloom.

Materials and Methods

The study site was on a glaciated plain 4 km northwest of Sidney, Mont., on a sandy range site (fine-loamy, mixed Typic Argiborolls) that normally receives 346 mm of precipitation yearly. The native vegetation (blue grama-threadleaf sedge-needleandthread *(Bouteloua gracilis-Carex filifolia-Stipa comata)* faciation of the mixed prairie) was removed with a rototiller, and the site was summer-fallowed for 2 years before seeding. The following legumes and grasses were seeded in a 12-m rows spaced 50 cm apart during late May and early June of 1974:

Legumes	
'Rambler', 'Drylander', and 'Orenberg' alfalfa	*Medicago sativa* subsp. *varia* (Martyn) Arc.
'Lutana' cicer milkvetch	*Astragalus cicer* L.
Grasses	
'Nordan' crested wheatgrass	*Agropyron desertorum* (Fisch. ex Link) Schult.
'Luna' pubescent wheatgrass	*Agropyron intermedium* var. *trichophorum* (Link) Halac.
'Regar' meadow bromegrass	*Bromus biebersteinii* Roem. & Schult.
'Prairieland' Altai wildrye	*Elymus angustus* Trin.
'Mayak' Russian wildrye	*Psathyrostachys junceus* (Fisch.) Nevski (Dewey and Hsiao 1983)
'Sidney sel.' reed canarygrass	*Phlaris arundinacea* L.
'Lodorm' green needlegrass	*Stipa viridula* Trin.

The 6- × 12-m plots were replicated 4 times in a completely randomized design. Specific details of the study site were previously described by White and Wight (1981). They reported on seasonal forage yield and DMD of the above-identified species sampled 7 and 11 times at progressive growth stages in 1975 and 1976, respectively, the first and second years after establishment. This paper will report on the forage yield and quality at anthesis or at 10% bloom of those same species from 1975 through 1981.

Forage from a 10-m row was harvested to a 5-cm stubble height at anthesis in all years except 1980. A drought in 1980 would have prevented all species from reaching anthesis, and they were harvested on 2 June. Plant material was prepared for subsequent analysis by drying at 70°C and grinding to pass through a 1-mm screen. In vitro DMD was determined by a modification of the Tilley and Terry two-stage method and data were converted to estimated in vivo DMD as described by White and Wight (1981). The 1977 forage samples were inadvertently discarded before in vitro DMD was determined. Nitrogen in the 1975 through 1977 forage samples was determined according to the procedure described by Schuman et al. (1973) after the forage was digested on a block digestor, and nitrogen in the 1978 through 1981 forage samples was determined by the macro-Kjeldahl method. Nitrogen concentration was multipled by 6.25 to estimate CP. Daily precipitation was measured at the site from April through October in a standard 20-cm diameter rain gage. Precipitation data from November through March were obtained from the official weather station 4 km away.

Maximum and minimum daily air shelter temperatures were also measured at the official weather station. Daily mean temperatures above 3, 5, 7, 9, and 11°C threshold were accumulated from the first of February each year until anthesis of each species to calculated degree days required. In order to determine which threshold temperature most accurately predicted anthesis, degree days were normalized by a method previously reported by White (1979). The average degree days found for each species over the 5 or 6 years was used to determine which calendar date it would have predicted anthesis. The differences between predicted and actual anthesis

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dates with 51 observations was analyzed to determine which threshold temperature produced the lowest standard deviation in days.

A combined species-by-year analysis of variance was performed on forage yield, DMD, digestible-forage yield, CP concentration, and CP yield for the last 6 years of the study. Those analyses indicated a highly significant interaction among years and species; therefore, one-way analysis of variance was performed on data for each year and accumulated yield from 1976 through 1981. The cluster analysis method of Scott and Knott (1974) was used each year to separate treatment means into nonsignificant ($P = 0.05$) groups to illustrate differences among groups of species. All mean differences discussed in this paper are significant ($P<0.05$) unless otherwise stated.

Results and Discussion

Precipitation

Precipitation during October through May 1974-75, 1975-76, 1977-78, and 1978-79 was 8, 31, 51, and 8% above the 30-year average, respectively, and during that period in 1976-77, 1979-80, and 1980-81 was 40, 60, and 18% below the 30-year average, respectively. Precipitation during the critical months (April-May) was 40, 23, and 79% above the 30-year average during 1975, 1976, and 1978 and 62, 7, 81, and 41% below the 30-year average during 1977, 1979, 1980, and 1981, respectively, with a serious drought in 1980.

Anthesis or 10% Bloom

Russian wildrye, and meadow bromegrass were among the first species to reach anthesis; and crested wheatgrass, Altai wildrye, and pubescent wheatgrass were the last (Table 1). The date each species reached anthesis or 10% bloom varied by year and species and had a standard deviation of ±9.2 days from each species mean data. Threshold temperatures of 3, 5, 7, 9, and 11° C predicted anthesis within a standard deviation of ±4.5, 3.9, 3.4, 3.2, and 3.4 days, respectively, for all species except alfalfas in 1981. Apparently, lack of rain until late May delayed the alfalfas from reaching 10% bloom by 14 days beyond the predicted date. It is not known why the best threshold temperature for these 11 species is 6 degrees higher than that found by White (1979) for 53 species at this same location.

Forage Yield

Alfalfas and pubescent wheatgrass produced their maximum forage yield in 1975, the first year establishment (Table 1). Other investigators have also found that pubescent wheatgrass (Whitman et al. 1961, Dubbs 1966) and alfalfa (Whitman et al. 1962) produced their maximum forage yield the first year after seeding. Altai wildrye, green needlegrass, Russian wildrye, crested wheatgrass, and meadow bromegrass produced their maximum forage yield in 1976, the second year after establishment.

Available N released from 2 years of summer fallowing prior to seeding may account for part of the increased forage production the first 2 or 3 years. Black and Wight (1979) reported that roots in this same native range site before it was plowed and seeded contained 181 kg N/ha and the soil 9 kg N/ha as NO_3-N. Assuming that it would require 3 to 4 years for the roots to decay releasing their N, then 2 years of summer fallowing plus the establishment year would have released 135 to 180 kg N/ha which would have been available to the plants in 1975 and 1976.

The alfalfas, wheatgrass, and cicer milkvetch produced the highest forage yield of any species in 1975, and the wildryes produced the lowest (Table 1). The low forage yield by Russian and Altai wildryes was due to the low production of floral (reproductive) tillers during 1975, whereas the wheatgrasses produced nearly 100% floral tillers. Meadow bromegrass and reed canarygrass produced the lowest forage yield during the study.

The 1980 growing season provided an opportunity to observe the forage species under drought conditions. Green needlegrass, Russian wildrye, and Altai wildrye produced more forage than other species in 1980, but the quantity was still only 23 to 25% of the average that was produced in the previous 3 years. Meadow bromegrass, crested wheatgrass, and pubescent wheatgrass produced only 21, 11, and 5%, respectively, of the average that was produced in the previous 3 years. Because of the drought, alfalfas, cicer milkvetch, and reed canarygrass produced no forage by early June 1980, and the latter two died. Russian wildrye and crested wheatgrass produced the most forage after the 1980 drought.

During the last 6 years, the average forage yield for wildryes, green needlegrass, alfalfas, wheatgrasses, and cicer milkvetch were nearly equal, but meadow brome and reed canarygrass produced significantly less than the other forages. The average forage yield of

Table 1. Average anthesis date, degree days (threshold 9° C), and forage yield of grasses and legumes when harvested at anthesis or at 10% bloom each year for 7 years near Sidney, Montana.

Species/cultivars	Anthesis: Julian date	Anthesis: Degree days	Forage yield: 1975	1976	1977	1978	1979	1980	1981	Avg. 1976-81
			—— Mg/ha ——							
Legumes										
Drylander alfalfa	165	290	3.4a†	3.0a	1.0b	3.2a	1.2c	0.0c	0.9b	1.6a
Orenberg alfalfa	165	290	3.3a	2.9a	1.6a	2.6b	1.2c	0.0c	0.9b	1.5a
Rambler alfalfa	165	290	4.1a	2.9a	1.0b	3.0a	1.0c	0.0c	0.7b	1.4a
Cicer milkvetch	169	350	2.6a	2.0b	1.0b	3.1a	1.9a	0.0c	0.0c	1.3a
Grasses										
Altai wildrye	174	400	0.4b	3.8a	1.2b	2.6b	1.4b	0.4a	0.8b	1.7a
Russian wildrye	160	270	0.2b	3.4a	1.5a	2.1c	0.9c	0.4a	1.4a	1.6a
Crested wheatgrass	173	400	2.8a	3.3a	1.8a	2.1c	1.1c	0.2b	1.2a	1.6a
Green needlegrass	163	300	1.2b	3.1a	0.8b	3.1a	0.9c	0.4a	0.9b	1.5a
Pubescent wheatgrass	180	470	3.5a	3.0a	1.6a	2.6b	1.0c	0.1c	0.6b	1.5a
Meadow bromegrass	160	260	1.2b	2.2b	0.9b	2.0c	0.7d	0.2b	0.9b	1.2b
Reed canarygrass	164	290	1.1b	1.6b	1.1b	1.9c	0.5d	0.0c	0.0c	0.9c
Average	—	—	2.2	2.8	1.2	2.6	1.1	0.2	0.8	1.4
F test	—	—	**	**	*	**	**	**	**	**
SE	9.2‡	3.2‡	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1

†Treatment means followed by the same letter within a column are not significantly ($P = 0.05$) different from each other (Scott and Knott, 1974).
‡Standard deviation in days.
*,**Significant ($P<0.05$), or highly significant ($P<0.01$) differences among species that year.

Table 2. Estimated in vivo DMD of grasses and legumes harvested at anthesis or at 10% bloom for 6 years near Sidney, Montana.

Species/cultivars	1975	1976	1977	1978	1979	1980	1981	Avg. 1976–81
	DMD							
	— % —							
Legumes								
Rambler alfalfa	62b†	66a	NA	66a	66b	—	72a	68‡
Drylander alfalfa	64a	65a	NA	66a	66b	—	70b	67
Cicer milkvetch	63a	65a	NA	66a	69a	—	—	67
Orenberg alfalfa	62b	64b	NA	65b	67b	—	68c	66
Grasses								
Reed canarygrass	64a	63b	NA	66a	67b	—	—	65
Meadow bromegrass	61b	59c	NA	65b	66b	62b	65d	63
Altai wildrye	64a	60c	NA	60c	64c	65a	63e	62
Russian wildrye	65a	57d	NA	61c	65c	63b	57i	61
Crested wheatgrass	55d	56e	NA	60c	61e	64a	61g	60
Green needlegrass	58c	57d	NA	58d	63d	59c	62f	60
Pubescent wheatgrass	54d	57d	NA	59d	61e	63b	59h	60
Average	61	61	NA	63	65	63	64	
F test	**	**		**	**	**	**	
SE	0.6	0.5		0.4	0.6	0.7	0.4	

†Treatment means followed by the same letter within a column are not significantly ($P = 0.05$) different from each other (Scott and Knott, 1974).
‡Average of only 4 yrs.
**Highly significant ($P<0.01$) differences among species that year.
NA - Data not available.

the 3 alfalfas during the last 6 years did not differ significantly.

Other studies have shown that Russian wildrye produced only 50 to 60% as much forage as did crested wheatgrass when seeded in rows 15 to 30 cm apart (Clark and Heinrichs 1957; Stitt 1958; Whitman et al. 1961; Dubbs 1966, Dubbs 1975) or 46 cm apart (Seamands and Roehrkasse 1974). Leyshon et al. (1981) found that Russian wildrye produced 50, 80, and 110% as much forage, respectively, as crested wheatgrass when seeded in rows 30, 60, and 90 cm apart, respectively. However, our study indicated that Russian wildrye and crested wheatgrass produced nearly equal amounts of forage when seeded in rows 50 cm apart.

When seeded alone in rows 30 cm or less apart, alfalfa produced significantly more forage than either Fairway crested wheatgrass (Clark and Heinrichs 1957), standard crested wheatgrass (Whitman et al. 1962, Dubbs 1975), or Russian wildrye (Dubbs 1975). However, the reporting investigators used Ladak alfalfa, which is branch rooted, and all 3 of the alfalfas we used were the creeping-rooted type. Creeping-rooted types produce less forage than the branch-rooted types but persist longer under grazing (Heinrichs 1963).

Forage yields reported by others for green needlegrass have been erratic relative to crested wheatgrass yields. Green needlegrass produced more than (Clark and Heinrichs 1957), nearly the same as (Dubbs 1966), or significantly less than (Whitman et al. 1961, Stitt 1958) crested wheatgrass in studies conducted for 3 to 8 years.

Digestibility

The DMD of alfalfas and cicer milkvetch was highest and that of

Table 3. Crude protein (CP) concentration of grasses and legumes harvested at anthesis or at 10% bloom for 7 years near Sidney, Montana.

Species/cultivars	1975	1976	1977	1978	1979	1980	1981	Avg. 1976–81
	CP							
	— % —							
Legumes								
Rambler alfalfa	17a†	17a	19a	20a	18b	—	23a	19
Cicer milkvetch	18a	17a	20a	19b	21a	—	—	19‡
Orenberg alfalfa	17a	17a	20a	20a	18b	—	20b	19
Drylander alfalfa	18a	17a	19a	19b	18b	—	22a	19
Grasses								
Reed canarygrass	19a	16a	19a	10c	15c	—	—	15
Altai wildrye	16a	13b	15b	9c	10e	11b	12c	12
Russian wildrye	18a	11b	11c	8c	11d	10c	9d	10
Green needlegrass	17a	10c	13c	7d	12d	9c	11c	10
Meadow bromegrass	15a	10c	12c	7d	10e	8c	9d	9
Crested wheatgrass	10b	9c	8d	7d	8f	13a	8d	9
Pubescent wheatgrass	10b	7c	9d	7d	9f	11b	8d	8
Average	16	13	15	12	14	10	14	
F test	**	**	**	**	**	**	**	
SE	1.1	0.7	0.9	0.4	0.5	0.5	0.4	

†Treatment means followed by the same letter within a column are not significantly ($P = 0.05$) different from each other (Scott and Knott, 1974).
‡Average of only 4 yrs.
**Highly significant ($P<0.01$) differences among species that year.

crested wheatgrass, green needlegrass, and pubescent wheatgrass was generally lowest (Table 2). The DMD of reed canarygrass forage was the highest among the grasses. No long-term data on DMD of major forage species harvested at anthesis in the northern Great Plains have been found in the literature. In a 2-year study, Lawrence and Knipfel (1981) found that the in vitro organic matter digestibility of Altai and Russian wildryes and of crested wheatgrass harvested in late June from irrigated land was in the same order as that found in this study.

The DMD of all species over the 6 years was inversely proportional with forage yield. As forage yield decreased by each 1,000 kg/ha, DMD increased by an average of 3, 2.3, 2.0, and 1.5-1.8 percentage units for crested wheatgrass, Russian wildrye, legumes, and all other species, respectively. The drought in 1980 reduced the DMD of only meadow bromegrass below what the proportional reduction in forage yield would have increased it, but had no additional effects on the DMD of the other species over that caused by reduced forage yields. In contrast, Wilson (1983) found that drought decreased DMD but reported that the literature showed that drought had both positive and negative effects on DMD.

From 1976–1981 (excluding 1977), Drylander alfalfa, Altai wildrye, and Rambler alfalfa produced the largest average digestible-forage yields 1100, 1090, and 1020 kg/ha, respectively. The average digestible-forage yield of Orenberg alfalfa was lower than that of the other alfalfas. Reed canarygrass and meadow bromegrass produced the lowest average digestible-forage yield (760 and 520 kg/ha respectively) during this period because they produced the lowest forage yields.

Crude Protein

The CP concentration in the legume forage was nearly double that in the grasses (Table 3). Reed canarygrass contained the highest average CP of the grasses; crested and pubescent wheatgrasses, the lowest. The CP was highest in 1975 for all species because the previous summer fallowing had made extra N available to the plants. Previous studies have shown that alfalfa contains significantly more CP than grasses (Dubbs 1975), and that Russian wildrye contains more CP than do wheatgrasses or green needlegrass (Whitman et al. 1961; Dubbs 1966).

Legumes had a common regression for CP versus forage yield for all years, but grasses required a separate regression line for the first 2 or 3 years because CP was about 5 units higher than during the next 4 years. The CP concentration of all legumes decreased about 0.8 percentage units with every 1,000 kg/ha increase in forage yield when averaged over all years. During the last 4 years, the CP concentration of all grasses, excluding reed canarygrass, decreased about 1.25 percentage units with every 1,000 kg/ha increase in forage yield.

The CP yield/ha for legumes was nearly double that for the grasses (280 versus 140 kg/ha) during the last 6 years, and the CP yield/ha for grasses was highest for Altai and Russian wildrye, 190 and 170 kg/ha, respectively. Green needlegrass, crested and pubescent wheatgrasses, reed canarygrass, and meadow bromegrass had the lowest average CP yield during the last 6 years of the study, 140, 130, 120, 120, and 110 kg/ha, respectively.

Conclusions

Forage quality was inversely proportional with forage yield. The DMD decreased between 1.5 and 2.3 percentage units for every 1,000 kg/ha increase in forage yield except for crested wheatgrass, where DMD decreased about 3.0 percentage units per 1,000 kg/ha increase in forage yield. Summer fallowing before seeding increased the CP concentration of the grasses about 5 percentage units during the first 2 or 3 years. The CP concentration of legumes and grasses decreased about 0.8 and 1.25 percentage units, respectively, for every 1,000 kg/ha increase in forage yield.

Cicer milkvetch and reed canarygrass did not appear to be adapted for long-term dryland forage production in the northern Great Plains because they did not survive the 1980 drought. Alfalfas should be used for forage production in the northern Great Plains because of their high DMD and CP; however, they produced less forage than green needlegrass and the two wildryes during a drought. Altai wildrye appeared to be one of the most desirable grasses for the characteristics measured, and meadow bromegrass the least desirable. Pubescent and crested wheatgrass were nearly identical in forage yield and quality during the study, except that crested wheatgrass produced more forage during the drought.

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