

# Stockpiling Potential of Perennial Forage Species Adapted to the Canadian Western Prairie Parkland

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## ABSTRACT

Stockpiling perennial forages for fall and winter grazing is not generally practiced on the Prairie Parkland of Canada. The objective was to determine forage species with most potential for stockpiling in this short-season region. The research was conducted for 3 yr at Lacombe, AB. Plots of adapted forage grasses and alfalfa (*Medicago sativa* L.) were clipped in early July. Regrowth forage mass was determined in mid-September, mid-October, and the following April. Forage quality measurements included in vitro digestible organic matter (IVDOM), crude protein, water-soluble carbohydrates (WSC), and acid (ADF) and neutral (NDF) detergent fiber. Overwinter yield losses were lower with grasses (3–35%) than alfalfa (43%). Meadow bromegrass (*Bromus riparius* Rhem.) had stable stockpiled yields over both dry (5130 kg ha<sup>-1</sup>) and wet (5450 kg ha<sup>-1</sup>) years and retained nutritive value well into winter and spring. Timothy (*Phleum pratense* L.) provided greatest stockpiled yields in years of above-average rainfall (9700 kg ha<sup>-1</sup>), but protein levels (<70 g kg<sup>-1</sup>) may be lower than desired in some years. Kentucky bluegrass (*Poa pratensis* L.) and creeping red fescue (*Festuca rubra* L.) had relatively low stockpiled yields (3160–5020 kg ha<sup>-1</sup>). However, quackgrass [*Elytrigia repens* (L.) Nevski] yielded well under good rainfall conditions (6180 kg ha<sup>-1</sup>), and dry matter loss (16%) was below average. Spring NDF (644 g kg<sup>-1</sup>) and IVDOM (495 g kg<sup>-1</sup>) concentrations of creeping red fescue were lowest and highest among species, respectively. Creeping red fescue and meadow bromegrass have the best chance of meeting cow nutritive requirements during winter and spring.

WINTER FEEDING of beef cattle is expensive because supplemental feed is required for 150 to 200 d on the Canadian Prairies (Mathison, 1993; Entz et al., 2002). Therefore, producers are seeking economical winter feeding alternatives. Stockpiling perennial forage species may be a practical and economical technique to extend the grazing season. Savings can be made through reduced harvesting, hauling and feeding conserved forage, and less manure removal if cattle remain on stockpiled pasture than if fed conventionally (Johnson and Wand, 1999; Riesterer et al., 2000). Winter grazing on native range is performed on the southern prairies (Willms et al., 1993), and grazing dryland grasses such as Altai wildrye (*Elymus angustus* Trin.) is possible although difficult in deep snow (Lawrence and Heinrichs, 1974). Also, innovative producers in the parkland of the prairies have fall-, winter-, and spring-grazed a variety of forage species, including creeping red fescue, Kentucky bluegrass, quackgrass, and mixed alfalfa–grass stands. However, little research to support this interest in stock-

piling has been conducted north of the midwest USA as the majority of Canadian beef cow–calf producers rely on conserved winter feed.

Species selection, accumulation (rest) period, and soil nutrient management impact the success of stockpiled forage systems (Matches and Burns, 1995). Where tall fescue (*Festuca arundinacea* Schreb.) is adapted, it is the species of choice because of timely regrowth under fall climatic conditions and resistance to weathering after growth ceases. Legumes are usually not as suitable as grasses for stockpiling as nutritive value declines rapidly as leaves are lost due to frost or maturity (Matches and Burns, 1995). Where tall fescue is not adapted (e.g., western parkland), other species need to be evaluated and compared for stockpiling potential.

Losses occur to both yield and nutritive value during stockpiling. Yield loss is due to factors including translocation of nutrients out of senescing leaves, respiration processes that impact yield as growth rates decline, and leaf-drop and decay (Ocumpaugh and Matches, 1977; Matches and Burns, 1995). Rain and snowmelt after frost leach cell solubles from leaves, reducing nutritive value as well as yield (Archer and Decker, 1977; Ocumpaugh and Matches, 1977; Matches and Burns, 1995; Burns and Chamblee, 2000b).

Because losses tend to increase dramatically after hard frost and snow in the northern (Riesterer et al., 2000), midwest (Ocumpaugh and Matches, 1977) and southeast USA (Burns and Chamblee, 2000b), it is recommended to graze before these heavy losses occur. Producers in the western parkland have attempted to stockpile a variety of forage species as pure stands and mixtures, with accumulation periods beginning in early July after harvesting hay or completing one cycle of grazing. Grazing of stockpiled forage may occur any time after conventional pastures cease to be productive (September) until the following spring. The objective of this research was to compare perennial forage species generally adapted to the western parkland of the prairies for stockpiling potential under a single accumulation period beginning in early July. Our hypotheses were that while all species may be stockpiled (Johnson and Wand, 1999), timing for grazing is critical to optimize use of specific species and that while grasses are generally superior to alfalfa for stockpiling, alfalfa may be useful within limits, if utilized soon after frost.

## MATERIALS AND METHODS

The study was initiated in the spring of 1997 at Lacombe, AB, Canada (52°28' N, 113°45' W; 847 m). Three main plots, each containing 10 perennial forage treatments in 3- by 6-m

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**Abbreviations:** ADF, acid detergent fiber; IVDOM, in vitro digestible organic matter; NDF, neutral detergent fiber; WSC, water-soluble carbohydrates.

subplots, were established on fallowed ground in three replicates on an Orthic Black Chernozemic Ponoka clay loam soil (Udic Borolls). Harvest date treatments (whole or main plots) were randomized within each replicate and forage species treatments randomized within each harvest date. Harvest dates were on 15, 15, and 12 September and 20, 12, and 13 October in 1998, 1999, and 2000, respectively, and 19, 25, and 19 April in 1999, 2000, and 2001, respectively. Before seeding, fertilizer was broadcast to supply 15, 27, 13, and 11 kg ha<sup>-1</sup> of N, P, K, and S, respectively. In subsequent years, all plots received broadcast applications of 50, 26, and 50 kg ha<sup>-1</sup> of N, P, and K, respectively, in April after cutting of the third harvest block and an additional 50 kg N ha<sup>-1</sup> following first cut in July.

Each plot consisted of 12 rows, 25 cm apart, planted with a double-disk drill at the recommended rate (pure live seed equivalent) for each species (Aasen et al., 1994). Species treatments included 'Algonquin' alfalfa, 'Kirk' crested wheatgrass (*Agropyron cristatum* L.), 'Troy' Kentucky bluegrass, 'Manchar' smooth brome grass (*Bromus inermis* Leyss.), 'Paddock' meadow brome grass, 'Kay' orchardgrass (*Dactylis glomerata* L.), 'Champ' timothy, common quackgrass, 'Boreal' creeping red fescue, and an Algonquin alfalfa–Paddock meadow brome grass mixture. The alfalfa–meadow brome grass mixture was planted at full seeding rates in alternate rows. A local ecotype of quackgrass was planted using rhizomes, 10 to 20 cm in length, at a density of 4 rhizomes m<sup>-2</sup>.

Experimental samples and data were collected during the 1998, 1999, and 2000 and the following April after snowmelt. All forage was removed from the plots initially with a Carter flail harvester (Carter Manufacturing Co. Inc., Brookston, IN) set at a height of 7.5 cm on 8, 9, and 5 July in 1998, 1999, and 2000, respectively. One more harvest of stockpiled forage (regrowth) following the July cut was taken in mid-September, mid-October, and mid-April of the following year. The September harvest occurred before frost, with an approximately 9-wk accumulation period. The October harvest occurred after a hard frost, before snowfall. The April harvest occurred after snowmelt. Four rows 5.3 m long (5.3 m<sup>-2</sup>) were cut from each species subplot. All of the forage from each subplot was collected and weighed fresh. A subsample of approximately 500 g was dried at 50°C for 72 h for dry matter determination. Then it was ground, first through a shear mill (Wiley Model 4, Arthur H. Thomas Co., Philadelphia, PA) equipped with a 2-mm screen and then through a cyclone mill (Model MS, UD Corp., Boulder, CO) using a 1.0-mm screen, before determination of forage quality. Total N concentration of samples was measured using the Dumas combustion method (Etheridge et al., 1998) with a Leco C and N determinator (Model CN 2000, Leco Corp., St. Joseph, MI). Crude protein was estimated by multiplying N concentration by 6.25. In vitro

digestible organic matter concentration was measured using a 48-h digestion period in a buffered rumen fluid followed by direct acidification for a 24-h pepsin digestion (Marten and Barnes, 1980). Neutral detergent fiber and ADF were determined as described by Van Soest and Robertson (1980). Water-soluble carbohydrate concentration was determined after Thomas (1977) using the phenol-sulfuric method for colorimetric assessment of reducing sugars, using fructose as the standard.

### Statistical Analysis

Only data of stockpiled forage at the three harvest dates were considered in this study as they were the materials of interest. Data were subjected to analysis of variance as a split plot in space and time for perennial crops (Steel and Torrie, 1980) using the SAS GLM procedure (SAS Inst., 1989). Years were treated as a repeated subunit. Harvest times were the main plot, and forage species treatments were the subplots (Table 1). The three-way interaction (year × harvest date × species) was used as the error term to test the significance of the two-way interactions. When significant *F* tests ( $P < 0.05$ ) occurred, mean separation was achieved using least significant differences calculated from appropriate error terms as described by Gomez and Gomez (1984). Significance of effects is presented in Table 1. Throughout the Results and Discussion, significance is defined by a probability level used of  $P \leq 0.05$  unless otherwise specified.

### Climate

The accumulation period for stockpiled forage was from July to early September. During this period, rainfall totaled 153, 257, and 243 mm for 1998, 1999, and 2000 compared with a long-term average of 186 mm (Table 2). Precipitation during October, November, and December was about 65% of normal during 1999 and 2000 and above normal in 1998. Precipitation was average during 1999 and 2000 but only 31% of average from 1 January to 31 March 2001. Mean temperature did not limit forage production during the accumulation period in any of the 3 yr. Mean temperatures were rarely below the long-term average and were above average during November and December of 1999. Monthly mean temperature during January of 2001 was 9.8°C above normal (Table 2). Thus, there were periods (October through December 1999 and October 2000 through March 2001) when stockpiled forage was not covered by snow because of lack of precipitation or relatively warm weather, or both. First dates of a frost of -5°C were 29 October, 28 September, and 23 September in 1998, 1999, and 2000, respectively; first dates of a temperature of -10°C were 9

**Table 1. Significance of year, harvest, and species effects and interactions on dry matter yield and forage quality of regrowth of 10 forage grasses, legumes, and mixtures harvested mid-September, mid-October, and mid-April over 3 yr.**

Effect	Variable†					
	Dry matter yield	IVDOM	Protein	WSC	NDF	ADF
Species	***	***	***	***	***	***
Harvest	**	***	**	***	***	***
Species × harvest	*	*	ns‡	*	***	***
Year	**	**	***	*	**	ns
Year × species	***	ns	*	ns	*	**
Year × harvest	ns	**	**	**	**	**
Year × species × harvest	ns	ns	ns	ns	ns	ns

\* Significant effect at 0.05 level of probability.

\*\* Significant effect at 0.01 level of probability.

\*\*\* Significant effect at 0.001 level of probability.

† IVDOM, in vitro digestible organic matter; Protein, crude protein; WSC, water-soluble carbohydrates; NDF, neutral detergent fiber; ADF, acid detergent fiber.

‡ ns, not significant ( $P > 0.05$ ).

**Table 2. Monthly precipitation and mean monthly temperatures during 1998, 1999, 2000, and 2001, and long-term average precipitation and monthly average temperatures at Lacombe.**

Month	Monthly precipitation					Monthly mean temperature				
	1998	1999	2000	2001	Avg.†	1998	1999	2000	2001	Avg.
	mm					°C				
January	6.4	31.8	21.4	2.1	19.1	-17.6	-13.0	-13.2	-4.0	-13.8
February	0.0	8.5	8.9	7.4	17.0	-4.3	-7.1	-9.6	-11.6	-10.5
March	30.3	19.1	20.8	8.0	19.1	-2.9	-4.9	-2.5	-1.0	-1.4
April	19.8	31.7	17.0	2.5	26.2	6.1	4.9	3.4	4.2	3.7
May	57.2	51.2	50.2	47.0	50.2	13.1	8.6	8.7	10.5	9.9
June	121.6	60.8	101.2	103.9	82.3	13.2	12.5	12.8	12.9	13.6
July	61.2	184.4	148.2	58.2	79.8	18.0	13.9	16.3	15.9	16.1
August	76.2	69.6	66.8	0.0	65.0	17.4	15.4	14.4	16.4	14.9
September	15.6	4.0	28.4	0.0	41.8	11.7	9.9	9.5	11.8	11.9
October	83.2	16.4	7.4	8.3	20.2	5.7	4.6	4.2	3.3	4.5
November	19.6	12.5	18.3	15.9	17.0	-4.8	-2.0	-4.6	-1.8	-4.5
December	25.4	7.1	9.5	2.4	17.0	-11.4	-3.2	-12.9	-11.6	-10.8
Total	516.5	497.1	498.1	253.1	454.7					

† Average of 93 yr at Lacombe.

November, 27 October, and 4 October in 1998, 1999, and 2000, respectively.

## RESULTS AND DISCUSSION

### Significance of Effects

The year  $\times$  harvest date  $\times$  species interaction was never significant (Table 1). The species  $\times$  harvest date effect was significant ( $P < 0.05$ ) for all variables except protein, and since these effects were of most interest, the data are presented. Year  $\times$  harvest date effects were usually significant and are presented graphically (Fig. 1) to indicate year-to-year variability of the harvest date effect. Except for forage mass and ADF, the year  $\times$  species effect was either nonsignificant or of low significance ( $0.04 < P < 0.05$ ). Year-to-year variation tended to be small and inconsistent, and since trends related to known year-to-year differences (climate) were not discernable, data are not shown for this effect.

### Stockpiled Forage Mass

All species except crested wheatgrass maximized forage mass by mid-September and did not gain or lose dry matter significantly by mid-October (Table 3). Crested wheatgrass forage dry matter yield was maximized at the mid-October harvest. There was little change in rank among species for September and October harvests. By mid-October, timothy, crested wheatgrass, smooth brome grass, and meadow brome grass-alfalfa formed a top group for forage mass. Kentucky bluegrass, alfalfa, and creeping red fescue were lowest, and others were intermediate, with individuals similar to members of both groups. The spring forage mass was a product of accumulated fall forage mass and overwinter loss of dry matter. All species except timothy and Kentucky bluegrass lost significant amounts of dry matter between October and April. By April, timothy remained significantly higher for forage mass than the other species, alfalfa was lowest, and others were intermediate. Overwinter loss of forage mass ranged from 43% for alfalfa to 3 and 7% for timothy and Kentucky bluegrass, respectively. The average was 25%. Losses of this magnitude for cool-season grasses are in agreement with Riesterer

et al. (2000) in Wisconsin, who found mean losses of 22 and 31% of standing forage organic matter at two different locations. Yield losses are primarily due to leaf loss (Ocumpaugh and Matches, 1977; Burns and Chamblee, 2000b). Winter losses of biomass with cool-season grasses were greater from December to March than October to December in Wisconsin (Riesterer et al., 2000). Riesterer et al. (2000) found losses due to lodging and freezing occurred under deep snow. This did not occur in the current study, as snow depths were never excessive. For the period November to March inclusive, rainfall equivalent of snowfall was 104, 71, and 45 mm for years beginning in 1998, 1999, and 2000, respectively, compared with an average of 89 mm (Table 2).

Year impacted forage mass for harvest and species independently. In 1999 and 2000, timothy ranked highly because it was able to take advantage of above-average rainfall and had low losses during winter (Table 4). Orchardgrass, quackgrass, creeping red fescue, and crested wheatgrass all responded positively to more precipitation, resulting in significantly greater forage masses during the final 2 yr. Except for quackgrass and timothy, these species had average to above-average losses over winter (Table 3). Meadow brome grass and smooth brome grass were stable for forage mass over years, ranking higher in 1998 than in the other years (Table 4). Smooth brome grass had above-average, and meadow brome grass average, percentage yield loss (Table 3). Alfalfa (high loss), Kentucky bluegrass (generally low yield), and creeping red fescue (generally low yield and high loss) were among the lowest species for forage mass, averaged over harvests (Table 4).

The year  $\times$  harvest date interaction was not significant for dry matter yield (Table 1), but years were different. Accumulated forage mass, averaged over species during September and October for 1999 and 2000, was approximately 133% of 1998 (Fig. 1a). The year-to-year differences in mean forage mass among harvests reflected rainfall during the accumulation period, which was 140 and 130% of average in 1999 and 2000, respectively, and 82% of average in 1998. The percentage of forage mass loss between October and April was also

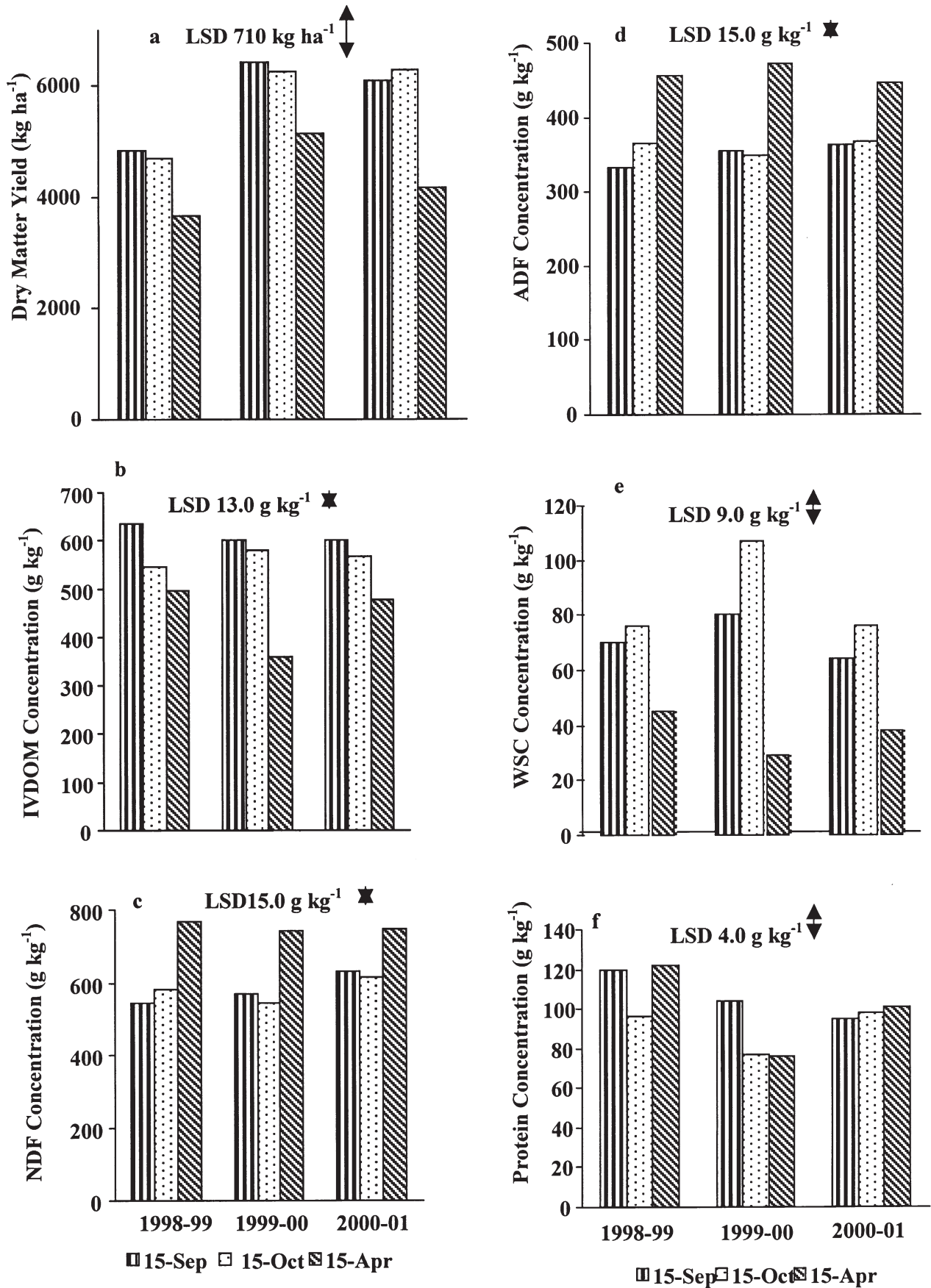


Fig. 1. (a) Mean dry matter yield, (b) in vitro digestible organic matter (IVDOM) concentration, (c) neutral detergent fiber (NDF) concentration, (d) acid detergent fiber (ADF) concentration, (e) water-soluble carbohydrate (WSC) concentration, and (f) crude protein concentration of 10 forage species stockpiled and harvested at three harvest dates dates between September and the following April for 3 yr. Bars indicate LSD (0.05) for comparison of harvest dates within years.

**Table 3. Dry matter yields of regrowth for forage species cut mid-September, mid-October, and mid-April averaged over 1998, 1999, and 2000.**

Species	Harvest date			LSD1†	Percentage change‡
	mid-Sept.	mid-Oct.	mid-Apr.		
	kg ha <sup>-1</sup>				%
Alfalfa	5560	5040	2890		43
Meadow brome/alfalfa	5990	5900	3710		37
Meadow bromegrass	5830	5780	4520		22
Smooth bromegrass	6840	6100	4110		33
Orchardgrass	5630	5640	4380	750	22
Timothy	6530	7040	6840		3
Crested wheatgrass	5960	6790	4440		35
Kentucky bluegrass	4490	4340	4040		7
Creeping red fescue	4900	5060	3460		32
Quackgrass	5980	5730	4820		16
LSD2§	1220				

† LSD1 (*P* < 0.05) tests among means for harvest dates within species.

‡ Difference between October and April harvests.

§ LSD2 (*P* < 0.05) tests among means for species within harvest dates.

affected by year; the percentage change in forage mass was greater in 2000 than during the other years. The fall–winter period of 2000–2001 differed climatically from the other years in that a hard frost (–10°C) came early (4 October), average mean monthly temperature was more variable, and there was almost no snow cover.

In this study, management (i.e., long accumulation period) favored hay types over pasture types. The accumulation phase was at least 9 wk and was more typical of regrowth for a two-cut hay system than pasture. For example, species such as timothy, crested wheatgrass and smooth bromegrass had sufficient time, under favorable climatic conditions during 1999 and 2000, to express yield potential. The rapid regrowth typical of orchardgrass and meadow bromegrass, compared with smooth bromegrass (Baron et al., 2000), was not advantageous under the long accumulation period. This rest period is representative of accumulation periods used by producers who use stockpile systems in the region. The effect of accumulation or rest period on stockpiled forage mass among species is dealt with in another study (Baron et al., 2002).

Based on availability and utilization of forage throughout winter, Riesterer et al. (2000) concluded that tall fescue, an early maturing orchardgrass, and reed canary-

**Table 4. Dry matter yield of regrowth of forage species in 1998, 1999, and 2000 averaged over cutting dates, mid-September, mid-October, and mid-April.**

Species	Year			LSD1†
	1998	1999	2000	
	kg ha <sup>-1</sup>			
Alfalfa	4810	4210	4640	
Meadow brome/alfalfa	4880	5550	5180	
Meadow bromegrass	5130	5450	5540	
Smooth bromegrass	5600	5730	5730	
Orchardgrass	3730	5900	6010	
Timothy	4560	9700	6150	
Crested wheatgrass	3900	7050	6230	1080
Kentucky bluegrass	3160	4850	4860	
Creeping red fescue	3400	4780	5020	
Quackgrass	4540	6180	5810	
LSD2‡	410			

† LSD1 (*P* < 0.05) tests among means for years within species.

‡ LSD2 (*P* < 0.05) tests among means for species within years.

grass were best while quackgrass and smooth bromegrass were unacceptable for stockpiling potential under snowy conditions in Wisconsin. Timothy could be used before onset of snow.

### Nutritive Value

#### Species × Harvest Effect

There was a general decline in IVDOM concentration with successive harvests (Table 5). Averaged over species, the loss between September and October was 49 g kg<sup>-1</sup>, and from October to April, the loss was 128 g kg<sup>-1</sup>. At the September harvest, IVDOM concentration of meadow bromegrass was significantly higher than that of alfalfa, smooth bromegrass, and Kentucky bluegrass; others were intermediate. Between September and October, the decrease for IVDOM concentration ranged from 29 g kg<sup>-1</sup> for alfalfa to 69 g kg<sup>-1</sup> for meadow bromegrass. Meadow bromegrass, creeping red fescue, and crested wheatgrass were significantly higher than Kentucky bluegrass in October. Between October and April, losses of IVDOM ranged from 216 g kg<sup>-1</sup> for alfalfa to 74 g kg<sup>-1</sup> for meadow bromegrass. In April, meadow bromegrass and creeping red fescue had significantly higher IVDOM concentrations than all other species except crested wheatgrass. Alfalfa had the lowest IVDOM among species except smooth bromegrass, which in turn was lower than all other grasses except timothy and quackgrass.

Averaged over years, alfalfa had the lowest NDF concentration in September (Table 6); creeping red fescue had a lower concentration than meadow bromegrass, smooth bromegrass, orchardgrass, and Kentucky bluegrass but was similar to timothy and crested wheatgrass, while Kentucky bluegrass was highest. Between September and October, NDF concentration increased for alfalfa and smooth bromegrass; decreased for creeping red fescue, Kentucky bluegrass, and meadow bromegrass; and remained the same for other species. In October, smooth bromegrass had highest NDF concentration while creeping red fescue was lowest. By October, alfalfa was similar to grass species of intermediate rank, such as meadow bromegrass and crested wheatgrass, for NDF. By April, average NDF concentration had

**Table 5. In vitro organic matter digestibility of regrowth of forage species cut mid-September, mid-October, and mid-April averaged over 1998, 1999, and 2000.**

Treatment	Harvest date			LSD1†
	mid-Sept.	mid-Oct.	mid-Apr.	
	g kg <sup>-1</sup>			
Alfalfa	593	564	348	
Meadow brome/alfalfa	616	560	456	
Meadow bromegrass	648	579	505	
Smooth bromegrass	583	553	373	
Orchardgrass	612	572	427	
Timothy	610	558	409	16
Crested wheatgrass	628	583	475	
Kentucky bluegrass	591	528	440	
Creeping red fescue	629	597	495	
Quackgrass	608	551	405	
LSD2‡	50			

† LSD1 (*P* < 0.05) tests among harvest date means within species.

‡ LSD2 (*P* < 0.05) tests among species means within harvest dates.

**Table 6. Neutral (NDF) and acid (ADF) detergent fiber in regrowth of forage species cut mid-September, mid-October, and mid-April averaged over 1998, 1999, and 2000.**

Treatment	NDF			ADF		
	mid-Sept.	mid-Oct.	mid-Apr.	mid-Sept.	mid-Oct.	mid-Apr.
	$\text{g kg}^{-1}$					
Alfalfa	505	551	806	398	391	608
Meadow brome/alfalfa	575	586	735	370	408	482
Meadow bromegrass	598	572	722	362	359	452
Smooth bromegrass	589	627	778	362	382	492
Orchardgrass	599	590	729	362	358	444
Timothy	573	589	739	339	348	453
Crested wheatgrass	574	557	702	330	331	406
Kentucky bluegrass	644	611	716	358	357	422
Creeping red fescue	551	499	644	302	279	369
Quackgrass	572	588	721	321	354	447
LSD1†		17			17	
LSD2‡		34			35	

† LSD1 ( $P < 0.05$ ) tests among harvest date means within species.‡ LSD2 ( $P < 0.05$ ) tests among species means within harvest dates.

increased to 729 g kg<sup>-1</sup>, indicating very low quality feed-stuffs, but there were large differences among species. Alfalfa and smooth bromegrass were similar and highest; creeping red fescue had the lowest NDF value (644 g kg<sup>-1</sup>), which could support an intake of 1.8% of body weight (NRC, 1996). Others were intermediate and similar to each other, except crested wheatgrass was lower than timothy.

In September, creeping red fescue had the lowest ADF concentration (similar to crested wheatgrass and quackgrass) while alfalfa was highest (similar to meadow bromegrass–alfalfa) and others were intermediate (Table 6). In contrast to NDF, only creeping red fescue decreased between September and October for ADF concentration. Smooth bromegrass, meadow bromegrass–alfalfa, and quackgrass increased while the others stayed the same. In October, creeping red fescue had the lowest ADF concentration while alfalfa, smooth bromegrass, and the meadow bromegrass–alfalfa mixture were highest. All species increased for ADF between October and April. However, alfalfa increased at about twice the rate of the grasses. Smooth bromegrass continued to have the highest ADF concentration among the pure grass stands while creeping red fescue was lowest.

Burns and Chamblee (2000b) associated a decrease in fall NDF concentrations with increasing leaf carbohydrate concentrations (dilution). This would explain NDF and ADF patterns for species such as creeping red fescue from September to October. They also observed that green and dead leaves had relatively constant ADF and NDF levels over winter. In their study, NDF concentrations for dead and live leaves were approximately 700 and 500 g kg<sup>-1</sup>, respectively, and ADF concentrations of dead and live leaves were about 391 and 244 g kg<sup>-1</sup>, respectively. Therefore, concentrations of fiber among species and harvests reflect relative concentrations of leaf soluble and cell wall constituents as well as live and dead leaf material.

Crude protein concentration did not follow the same general decreasing trend with harvest (Table 7) as did IVDOM (Table 5). There was a decrease in crude protein concentration for all species between September and October. Between October and April, alfalfa and meadow bromegrass–alfalfa decreased, crested wheatgrass and Kentucky bluegrass stayed the same, and all other species increased in crude protein concentration. In September and October, alfalfa had higher crude protein concentrations than the grasses. In September, the meadow bromegrass–alfalfa mixture had a higher

**Table 7. Protein and water-soluble carbohydrates (WSC) of regrowth for forage species cut mid-September, mid-October, and mid-April averaged over 1998, 1999, and 2000.**

Treatment	Protein			WSC		
	Harvest date					
	mid-Sept.	mid-Oct.	mid-Apr.	mid-Sept.	mid-Oct.	mid-Apr.
	$\text{g kg}^{-1}$					
Alfalfa	149	122	107	55	81	27
Meadow brome/alfalfa	124	114	110	63	67	24
Meadow bromegrass	102	80	99	57	82	35
Smooth bromegrass	87	67	96	84	97	32
Orchardgrass	109	79	105	66	90	31
Timothy	80	71	98	81	80	41
Crested wheatgrass	106	75	74	81	115	50
Kentucky bluegrass	111	103	107	62	71	46
Creeping red fescue	106	82	100	80	118	48
Quackgrass	112	83	93	83	74	39
LSD1†		4			9	
LSD2‡		19			19	

† LSD1 ( $P < 0.05$ ) is between harvest date means within species.‡ LSD2 ( $P < 0.05$ ) is between species means within harvest dates.

crude protein concentration than meadow bromegrass, smooth bromegrass, and timothy, and in October, it was higher than all grasses except Kentucky bluegrass. Timothy had a lower crude protein concentration at the September harvest than all species except smooth bromegrass. Crested wheatgrass was among the species with lowest crude protein values at the October harvest and was lowest in April. The species with lowest crude protein concentrations had values close to 70 g kg<sup>-1</sup>, which does not meet requirements of growing cattle. This level is barely high enough to maintain cows at midpregnancy and will not meet requirements in late pregnancy (NRC, 1996).

Others working with tall fescue have reported crude protein concentration of whole plant and both green and dead leaves remains relatively constant over winter (Taylor and Templeton, 1976; Ocumpaugh and Matches, 1977; Burns and Chamblee, 2000b). However, Taylor and Templeton (1976) observed that protein concentration increases in dead leaves as the winter progresses. Increases in protein content of dead leaves may be due to differential leaching of materials from dead leaves where protein is somewhat resistant to leaching (Taylor and Templeton, 1976). Thus, in the current study, there may have been a predominance of leached-out, dead tissue in spring harvests, resulting in higher protein concentration.

Most species followed the general pattern of increasing WSC concentration in fall and then decreasing over winter (Table 7) as described for tall fescue by others (Taylor and Templeton, 1976; Ocumpaugh and Matches, 1977; Burns and Chamblee, 2000a, 2000b). However, meadow bromegrass–alfalfa, timothy, Kentucky bluegrass, and quackgrass did not follow this pattern between September and October. This lack of an increase in WSC for Kentucky bluegrass was in agreement with Taylor and Templeton (1976). In October, creeping red fescue was higher than all except crested wheatgrass, which was higher than all others except smooth bromegrass. While significant differences existed for WSC concentration in April, the range from numerical highest (crested wheatgrass) to lowest (meadow bromegrass–alfalfa) was narrow at only 26 g kg<sup>-1</sup>. In April, crested wheatgrass and creeping red fescue were higher than alfalfa and the alfalfa–meadow bromegrass mixture for WSC concentration. Kentucky bluegrass was also higher than alfalfa.

Taylor and Templeton (1976) and Burns and Chamblee (2000b) determined as much as seven times the total nonstructural carbohydrate concentration in green compared with dead leaves. As winter progresses, the proportion of dead material increases, resulting in decreased sward sugar concentration. Sugars are readily respired and translocated from senescing leaves and leached from dead leaves (Ocumpaugh and Matches, 1977). Sugar concentration tends to decline in concert with IVDOM concentration as both reflect portions of cell soluble material.

#### Year × Harvest Effect

Although year × harvest × species interactions were not significant for nutritive value, year did impact and

modify the general trends for nutritive value of harvests, averaged over species. For IVDOM concentration (Fig. 1b), there were small and inconsistent differences among September and October harvests and years. However, in 1999, there was a much larger decline (219 g kg<sup>-1</sup>) from October to April, which resulted in IVDOM concentration 117 g kg<sup>-1</sup> lower than the lower of the other 2 yr.

Year impacted NDF and ADF concentrations differently over harvests (Fig. 1c and 1d). For NDF, September and October 2000 harvests had concentrations significantly higher than the other 2 yr (Fig. 1c). Also, in 1999, NDF decreased between September and October. However, all years increased to very high and similar values by April for both NDF and ADF. Generally, the trends among years and harvests found in ADF concentration (Fig. 1d) were opposite to those found in IVDOM (Fig. 1b). The various trends for NDF and ADF with harvest among years are no doubt products of live and dead leaf material and leaf loss as affected by climate discussed previously and reported by others (e.g., Burns and Chamblee, 2000b).

Similar to IVDOM, a large loss occurred for WSC concentration from October to April (Fig. 1c). However, 1999 differed from other years at the October harvest in that average WSC concentration increased substantially from the September to October harvest, whereas in the other years, the two harvests were similar.

Averaged over species, protein concentration exhibited inconsistent patterns over years, but October and April protein concentrations for 1999 were decidedly lower than the other 2 yr (Fig. 1f). Average protein concentrations in those years (approximately 77 g kg<sup>-1</sup>) compared with those averaged over all years (approximately 90 g kg<sup>-1</sup>) indicate that many species would not meet minimum protein requirements of cows in midpregnancy (NRC, 1996). Timothy, crested wheatgrass, and smooth bromegrass all have low average protein concentrations (Table 7) and therefore would be of major concern.

#### Year × Species Effect

Generally, the year × species effect did not affect nutritive value of the stockpiled forages. However, ADF concentration did show a significant interaction effect (data not shown). The apparent reason for the interaction was that crested wheatgrass had a higher ADF concentration in 1999 (375 g kg<sup>-1</sup>) than in 1998 or 2000 (333 and 359 g kg<sup>-1</sup>, respectively) whereas for all other species, ADF concentration was similar over years. Averaged over harvests, creeping red fescue had consistently lower ADF concentrations than all other species-years except crested wheatgrass, which was similar in 1998 and 2000. Acid detergent fiber concentration of crested wheatgrass was lower than that of alfalfa, the bromegrass–alfalfa mixture, and smooth bromegrass for all years and was lower than that of meadow bromegrass and orchardgrass in 1998 and 2000. This information supports the previous discussion of the species × harvest effect where we indicated that creeping red fescue usu-

ally had the lowest ADF concentration. Since ADF concentration is inversely related to total digestible nutrient concentration and digestible energy (NRC, 1996), these attributes of nutritive value should be higher for creeping red fescue than for the other species throughout the stockpiled grazing season.

### SUMMARY AND CONCLUSIONS

During years of above-average rainfall timothy, crested wheatgrass and orchardgrass appeared advantageous for forage mass. In addition, timothy had low dry matter losses over winter. In years of below-average rainfall, the bromegrasses had stable and relatively high forage masses; smooth and meadow bromegrass had above-average and average overwinter dry matter losses, respectively. Alfalfa and meadow bromegrass–alfalfa were suitable for grazing only during September and October because of large dry matter losses over winter. Species found in old or naturalized pastures, such as Kentucky bluegrass and creeping red fescue, had relatively low forage masses. Quackgrass, however, yielded well under good conditions, and overwinter dry matter loss was below average.

Nutritive requirements for midpregnancy brood cows appear easily met by stockpiled forages from early to late fall but could be compromised as cows move toward calving in spring (NRC, 1996). Minimum protein concentration for brood cows during midpregnancy is 70 g kg<sup>-1</sup> (NRC, 1996). In 1999, mean protein concentration was 77 g kg<sup>-1</sup>. Species such as timothy, smooth bromegrass, and crested wheatgrass might not meet these requirements every year without supplementation. Nitrogen fertilization during accumulation may or may not be effective in increasing protein content (Burns and Chamblee, 2000a, 2000b).

Neutral detergent fiber and IVDOM concentrations during spring may be too high and low, respectively, to meet requirements of cows, especially in late pregnancy (NRC, 1996). Alfalfa and smooth bromegrass are particularly unsuitable on this basis. However, the NDF and IVDOM concentrations of creeping red fescue indicate that this species has the best chance of meeting requirements during winter and spring. The IVDOM concentrations of meadow bromegrass, creeping red fescue, and crested wheatgrass appeared most stable over fall, winter, and spring. The relatively high spring time IVDOM concentration and overall stable yield of meadow bromegrass make it as attractive for stockpiling as creeping red fescue.

As in other studies, we would recommend grazing before high losses of yield and nutritive value occur for all species. There appears potential to use stockpiled forages, grasses in particular, to extend the grazing season and to reduce winter feed costs. Further research is required to determine actual losses under snow. Preliminary information suggests that high losses occur in late winter and after snowmelt.

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