

Harvest Time and Fertility Effects on Yield and Quality of Forage from Alfalfa, Hybrid Bromegrass and Their Mixture

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Abstract

A field experiment with 24 treatments consisting of three perennial forage crops [alfalfa (*Medicago sativa* L. cv. AC Longview), hybrid bromegrass (*Bromus riparius* Rehm & *Bromus inermis* Leyss. cv. AC Success) and their mixture], four Cut 1 dates (approximately June 20, July 10, July 30 or August 20), and two fertilizer levels (unfertilized and fertilized) was established in late May 2014, on a Black Chernozem [Udic Boroll] silty clay soil. Forage dry matter yield [DMY], and concentration ($\text{g}\cdot\text{kg}^{-1}$ DM) of crude protein [CP], total digestible nutrients [TDN] and acid detergent fiber [ADF] data were collected over 3 years from 2015 to 2017. The fertilizer treatments were imposed in 2016 and 2017. Forage crops were initially cut at four Cut 1 dates, and again cut [Cut 2] in autumn (September 2 in 2015, November 7 in 2016 and October 5 in 2017). For all three forage crops, forage DMY usually increased when Cut 1 was delayed. Delaying Cut 1 reduced forage DMY for Cut 2. Total DMY (Cut 1 + Cut 2) for all three forage crops was highest from the combination of July 10 and late Autumn cuts. Alfalfa-bromegrass mixture produced higher DMY than bromegrass or alfalfa alone. Fertilizer application resulted in a significant increase in Cut 1 and total DMY for bromegrass. The CP concentration in Cut 1 forage usually declined as the forage crops matured. The CP concentration was highest for alfalfa, followed by alfalfa-bromegrass mixture, and much lower for bromegrass. There was little or no effect of forage crop maturity on the TDN and ADF concentrations in forage. The TDN concentration was higher and ADF concentration was lower in forage from alfalfa or alfalfa-bromegrass mixture than bromegrass. Fertilizer application significantly increased CP concentration for alfalfa-bromegrass mixture. De-

laying harvesting for Cut 1 increased ADF yield and TDN yield until Late July, but CP yield generally decreased with crop maturity. The ADF yield and TDN yield were higher for alfalfa-bromegrass mixture than bromegrass or alfalfa alone, and CP yield was similar for alfalfa and alfalfa-bromegrass mixture but considerably higher than bromegrass. Fertilizer application increased CP yield and ADF yield for bromegrass and alfalfa-bromegrass mixture, and TDN yield only for bromegrass. In conclusion, total DMY (Cut 1 + Cut 2) was highest for a combination of Early July and Autumn cuts. Forage yield was highest for alfalfa-bromegrass mixture, followed by alfalfa and lowest for bromegrass. The CP and TDN concentrations were higher, and ADF concentrations were lower in forage from alfalfa or alfalfa-bromegrass mixture than bromegrass.

Keywords

Alfalfa, Bromegrass, Cutting Stage, Fertility, Forage, Harvest Time, Hay, Mixture, Quality, Yield

1. Introduction

Decisions on when to cut perennial forage crops for hay are based on consideration of both quantity and quality of forage. Protein and energy contents (or concentrations) of hay generally decline and dry matter yield (DMY) increase with advancing plant maturity [1] [2] [3] [4]. Recommendations for the optimum combination of forage yield and quality have historically been to cut alfalfa at the 10% bloom stage and grasses at anthesis [5] [6]. Yu [7] in a study in Western Canada found the best combination of protein and energy for hay was when alfalfa was cut at the late bud stage and timothy was cut at the pre-bloom head stage. More recently, alfalfa height has been used as a predictor of NDF values for alfalfa, alfalfa-grass mixture and grass stands. Recent research by Cornell University on alfalfa-grass mixtures suggests cutting alfalfa stands when alfalfa is 28 inches tall and 50:50 alfalfa-grass stands when nearby alfalfa is 22 inches tall [8].

Producers must also work around inclement weather to manage significant acres with limited equipment and manpower to make the final decision on when to harvest. As a result, in rain fed environments the haying season often takes weeks or months before completion and forage quality often suffers. Producers know that forage cut in late July or early August in northeast Saskatchewan will have lower protein and energy content than hay cut in late June or early July [2] [9]. However little information is available to producers on how a combination of factors such as fertility, initial harvest stage and crop type can influence hay yield and quality under the same growing and environmental conditions. Having more information on how hay quality and yield are affected by cutting date and fertility would help producers in determining appropriate harvest dates for Cut 1

harvest dates for optimum hay in terms of protein and energy contents as well as DMY [10]. It will also assist them in determining if their current hay cutting schedule could be modified to better suit their livestock winter feeding requirements in terms of protein and energy intake.

The objective of this study was to determine the effects of Cut 1 date on forage (hay) yield and quality of fertilized and unfertilized hybrid bromegrass, alfalfa and a mixture of the two crops during the first three years of production in the Parkland region of Saskatchewan, Canada.

2. Materials and Methods

In the 3-year (from 2015 to 2017) field experiment, forage stands were established during summer 2014 on a field previously cropped to annual grains and oilseeds at the Agriculture and Agri-Food Canada (AAFC) Research Farm, Melfort, Saskatchewan (52°44'N 104°47'W), on a thick Black Chernozem (Udic Boroll) silty clay soil, with 6.4 pH and 8.2% organic matter. Soil tests (0 - 15 cm depth) at the start of this experiment indicated nutrient levels of 80 kg nitrate-N ha⁻¹, 65 kg available P ha⁻¹, 670 kg exchangeable K ha⁻¹ and 17 kg sulphate-S ha⁻¹.

There were 24 treatments consisting of three forage crops, four harvest dates and two fertilizer levels, arranged in a randomized complete block design (RCBD) with four replications (with total of 96 plots). Individual plots were 1.2 m × 6 m in size, with four rows spaced 30 cm apart in each plot.

The alfalfa (*Medicago sativa* L. cv. AC Longview), hybrid bromegrass (*Bromus riparius* Rehm & *Bromus inermis* Leyss. cv. AC Success) and their mixture were seeded (1 cm deep) in late May 2014. The seeding rate was 9 kg·ha⁻¹ for pure alfalfa, 9 kg·ha⁻¹ for pure bromegrass, and 3.4 kg alfalfa ha⁻¹ + 5.6 kg bromegrass ha⁻¹ for alfalfa-bromegrass mixture. The emergence of all forage crop types was excellent in all experimental plots. The four cutting dates for Cut 1 in 2015, 2016 and 2017 were approximately June 20 (Late June), July 10 (Early July), July 30 (Late July) or August 20 (Late August), based on the early bud, 25% bloom, full flower (100% bloom), and seed set stages of alfalfa, respectively. In addition to Cut 1, all crops were again cut (Cut 2) in autumn (September 2 in 2015, November 7 in 2016 and October 5 in 2017). The two fertilizer application levels, applied only in 2016 and 2017, were unfertilized or fertilized at 67 N + 11.2 P₂O₅ + 0 S kg·ha⁻¹ for bromegrass, 33.5 N + 22.4 P₂O₅ + 5.6 S kg·ha⁻¹ for alfalfa-grass mixture, and 0 N + 44.8 P₂O₅ + 11.2 S kg·ha⁻¹ for alfalfa treatments. Fertilizers were broadcast in the spring each year. No herbicide was applied during the course of the study.

For each harvest time, all four crop rows were cut about 5 cm above the soil surface for hay, using a mechanical harvester (Haldrup forage harvester, Haldrup GmbH, Justus-von-Liebig Str. Ilshofen, Germany D-74532). Fresh mass of the harvested material was measured. Sub-samples of about 200 g fresh mass for each plot were weighed and dried in a forced air oven at 60°C for dry matter

yield (DMY) and quality.

Forage samples from each Cut 1 harvest date were collected for forage quality. Dry sub samples were combined from replicates one + two, and three + four, finely ground, and then sent for quality analysis, to the Central Testing Lab in Winnipeg (Unit 9 - 851 Lagimodiere Blvd Winnipeg, Manitoba Canada). Samples were analyzed for total N [11], to calculate crude protein [CP], as total N concentration \times 6.25. Acid detergent fiber [ADF] was determined by the lignin in animal feed method [12]. Neutral detergent fiber [NDF] was determined after digestion of samples in neutral detergent solution with Labconco digestion unit ([13]; Labconco, Kansas City, Mo). Total digestible nutrient [TDN] was calculated from the ADF and NDF. The yield ($\text{kg}\cdot\text{ha}^{-1}$) of each nutrient (ADF, CP or TDN) in forage was calculated as DMY ($\text{kg}\cdot\text{ha}^{-1}$) of forage multiplied by concentration ($\text{g}\cdot\text{kg}^{-1}$) of the nutrient in forage divided by 1000.

Growing season (May to September) precipitation and temperature data were collected from the AAFC Melfort Research Farm weather station, by Environment Canada (Table 1). In 2015, the growing season precipitation was much below normal for May, much higher than normal for September, near normal for June and August, and almost twice the normal for July. In 2016, the growing season precipitation was much below normal for May, much higher than normal for August, only slightly higher than normal for September, near normal for June, and about 1.7 times than normal for July. In 2017, precipitation was near normal for May and June while it was much below normal in July, August and September. Total of growing season precipitation was above long-term average in 2015 and 2016, while it was lower than long-term average in 2017. Growing season monthly mean temperatures were slightly higher than normal in all the three years of this study.

Data on forage DMY (Cut 1, Cut 2, and total DMY), and Cut 1 nutritive values (CP, ADF and TDN concentrations; CP, ADF, and TDN yield) were analyzed

Table 1. Total monthly precipitation and mean monthly temperatures in May, June, July, August and September (growing season), and total annual precipitation and mean annual temperatures for 2015, 2016 and 2017 at Melfort, Saskatchewan, Canada. Their long-term values are also presented.

Month	Total Precipitation (mm)				Mean Temperature (°C)			
	2015	2016	2017	Long-term	2015	2016	2017	Long-term
May	7.1	16.8	46.4	42.9	11.2	15.4	11.6	10.7
June	54.8	53.2	44.1	54.3	17.0	17.2	17.7	15.9
July	149.8	128.7	33.3	76.7	17.7	19.2	19.1	17.5
August	57.4	80.8	3.1	52.4	17.3	16.3	18.2	16.8
September	70.0	41.3	13.2	38.7	12.9	13.7	15.0	10.8
Total/mean	339.1	320.8	140.1	265.0	15.2	16.4	16.3	14.3
Total/mean annual	459.8	458.0	263.5	395.8	3.3	3.0	2.5	1.3

considering factorial set of treatments arranged in a randomized complete block design (RCBD) using Proc Mixed Model procedure of SAS 9.4 [14]. In Proc Mixed Model, the harvest management (4 Cut 1 times), forage crop types (bromegrass, alfalfa, and brome-alfalfa mixture), fertilizer (unfertilized and fertilized) and their interactions were considered as fixed effects, while the replication, year and replication \times harvest management were set as random effects. Statistical significance was declared at $P = 0.05$, and means were separated using Least Square Means comparison.

3. Results

For the measured parameters, almost all the main effects of forage crop, fertility and Cut 1 date; and the interactions of forage crop \times fertility, and forage crop \times Cut 1 date were significant; while almost all the fertility \times Cut 1, and forage crop \times fertility \times Cut 1 date interactions were not significant. Thus, the means for forage crop \times fertility interaction, forage crop \times Cut 1 date interaction, forage crop, Cut 1 date and fertility only are presented.

Dry matter yield (DMY)

The interaction effects of forage crop \times fertility were significant for Cut 1 and total DMY, and of forage crop \times Cut 1 date were significant for both cuts and total DMY, but the fertility \times Cut 1 date and forage crop \times fertility \times Cut 1 date were not significant (Table 2). Significant fertility effect was observed for Cut 1 DMY of bromegrass, and for total DMY of bromegrass and alfalfa-bromegrass mixture. With delay in Cut 1, the DMY for Cut 1 increased up to Late July for alfalfa and alfalfa-bromegrass mixture and up to Late August for bromegrass, and total DMY increased up to Early July for all three forage crop types, while it always decreased for Cut 2.

Table 2. The dry matter yield (DMY, $\text{kg}\cdot\text{ha}^{-1}$ —average of 2015, 2016, and 2017) of alfalfa, bromegrass, and alfalfa-bromegrass mixture forage, for the Cut 1, Cut 2 and total with and without fertilizer at Melfort, Saskatchewan, Canada.

DMY ($\text{kg}\cdot\text{ha}^{-1}$)				
<u>Forage Crop \times Fertility Interaction Effects</u>				
Crop	Fertility	Cut 1	Cut 2	Total
Alfalfa	No	5454b ^a	2597	8051c
	Yes	5529b	2628	8156c
Bromegrass	No	5505b	1237	6742d
	Yes	6921a	1373	8294bc
Alfalfa + Bromegrass	No	6556a	2470	9026ab
	Yes	6876a	2550	9426a
P values		0.0002	0.797	<0.0001
SEM		329	598	440

Continued

<u>Forage Crop × Cut 1 Date Interaction Effects</u>				
	Time of first harvest	Cut 1	Cut 2	Total
Alfalfa	Late June	4030g	3607a	7637ef
	Early July	5928cde	3659a	9588b
	Late July	6272cd	2362bc	8633cd
	Late August	5735de	822e	6556g
Bromegrass	Late June	4784f	2537b	7321efg
	Early July	6154cd	1782d	7936de
	Late July	6530bc	670e	7200fg
	Late August	7383a	231f	7614ef
Alfalfa + Bromegrass	Late June	5374ef	3830a	9204bc
	Early July	7060ab	3568a	10628a
	Late July	7343a	2116cd	9460bc
	Late August	7085ab	527ef	7612ef
P values		0.0443	<0.0001	<0.0001
SEM		370	603	473
<u>Forage Crop Means</u>				
Crop		Cut 1	Cut 2	Total
Alfalfa		5491c	2612a	8104b
Bromegrass		6213b	1305b	7518b
Alfalfa + Bromegrass		6716a	2510a	9226a
P values		0.0006	<0.0001	0.0014
SEM		306	595	422
<u>Cut 1 Date Means</u>				
Cut date		Cut 1	Cut 2	Total
Late June		4729b	3325a	8054b
Early July		6381a	3003b	9384a
Late July		6715a	1716c	8431b
Late August		6734a	527d	7261c
P values		<0.0001	<0.0001	<0.0001
SEM		308	593	400
<u>Fertility Means</u>				
Fertility		Cut 1	Cut 2	Total
Unfertilized		5838b	2101a	7939b
Fertilized		6442a	2184a	8625a
P values		<0.0001	0.1997	<0.0001
SEM		291	591	387

*The same lowercase letters within a column for a particular treatment or interaction effect indicate no significant difference between treatments at $P = 0.05$.

The mean effect of forage crops was significant for the DMY of both cuts and total DMY (**Table 2**). The DMY sequences were alfalfa-bromegrass mixture > bromegrass > alfalfa for Cut 1; alfalfa-bromegrass mixture and alfalfa > bromegrass for Cut 2; and alfalfa-bromegrass mixture > bromegrass and alfalfa for their total DMY.

Like forage crops, the DMY of both cuts and total DMY showed significant effect of Cut 1 dates (**Table 2**). The Cut 1 DMY from Early July, Late July and Late August was greater than from the Late June. The Cut 2 DMY always declined with delay in Cut 1 date. Total DMY was significantly higher for the Early July and lower for the Late August cut compared to the Late June and Late July Cut 1 dates. The cut 1 DMY and total DMY showed significant increase from the fertilizer application but Cut 2 DMY was not influenced by the fertilizer application (**Table 2**).

Crude protein (CP) concentration and yield

The interaction effects of forage crop × fertility were significant for both the CP concentration and CP yield (**Table 3** and **Table 4**). Fertilizer application significantly increased the CP concentration of alfalfa-bromegrass mixture only, and it increased the CP yield of bromegrass and alfalfa-bromegrass mixture.

Significant interaction effects of forage crop × Cut 1 date were for both the CP concentration and CP yield (**Table 3** and **Table 4**). For all the forage crops, there was a trend of significant decline in CP concentration with the delay in Cut 1 date from Late June until Late July, and with no significant change between the Late July and Late August dates. The CP yield was significantly greater from Early July and lower from Late August than the other two Cut 1 dates of Alfalfa; significantly greater from the Late June and Early July than the two later Cut 1 dates of the bromegrass and alfalfa-bromegrass mixture.

Table 3. Concentration ($\text{g}\cdot\text{kg}^{-1}$ DM) of crude protein (CP), acid detergent fiber (ADF) and total digestible nutrients (TDN) in alfalfa, bromegrass, and alfalfa-bromegrass mixture forage (average of 2015, 2016 and 2017), harvested at different dates of Cut 1 with and without fertilizer at Melfort, Saskatchewan, Canada.

Concentration ($\text{g}\cdot\text{kg}^{-1}$ DM)				
<u>Forage Crop × Fertility Interaction Effects</u>				
Crop	Fertility	ADF	CP	TDN
Alfalfa	No	382a ^a	139a	578a
	Yes	379a	138a	582a
Bromegrass	No	389a	83d	571a
	Yes	396a	85d	563a
Alfalfa + Bromegrass	No	376a	104c	585a
	Yes	387a	125b	573a
P values		0.0590	0.0104	0.0589
SEM		5.2	4.0	5.6

Continued

<u>Forage Crop × Cut 1 Date Interaction Effects</u>				
	Time of first harvest	ADF	CP	TDN
Alfalfa	Late June	369a	174a	592a
	Early July	388a	152b	571a
	Late July	385a	122cd	575a
	Late August	378a	107de	582a
Bromegrass	Late June	395a	126c	564a
	Early July	388a	103e	572a
	Late July	401a	55f	558a
	Late August	387a	52f	573a
Alfalfa + Bromegrass	Late June	378a	142b	582a
	Early July	376a	121cd	585a
	Late July	390a	95e	570a
	Late August	380a	102e	580a
P values		0.0771	0.0128	0.0765
SEM		6.2	5.7	6.6
<u>Forage Crop Means</u>				
Crop		ADF	CP	TDN
Alfalfa		380b	139a	580a
Bromegrass		393a	84c	567b
Alfalfa + Bromegrass		381b	115b	579a
P values		0.0001	<0.0001	0.0001
SEM		4.7	2.8	5.0
<u>Cut 1 Date Means</u>				
Cut date		ADF	CP	TDN
Late June		381b	147a	579a
Early July		384b	125b	576a
Late July		392a	91c	568b
Late August		382b	87c	578a
P values		0.0135	<0.0001	0.0134
SEM		4.8	3.2	5.2
<u>Fertility Means</u>				
Fertility		ADF	CP	TDN
Unfertilized		382a	109b	578a
Fertilized		387a	116a	573a
P values		0.0515	0.0261	0.0516
SEM		4.5	2.2	4.8

*The same lowercase letters within a column for a particular treatment or interaction effect indicate no significant difference between treatments at $P = 0.05$.

Table 4. Yield ($\text{kg}\cdot\text{ha}^{-1}$) of crude protein (CP), acid detergent fiber (ADF) and total digestible nutrients (TDN) for alfalfa, bromegrass and alfalfa-bromegrass mixture forage (average of 2015, 2016 and 2017), harvested at different dates of Cut 1 with and without fertilizer at Melfort, Saskatchewan, Canada.

Yield ($\text{kg}\cdot\text{ha}^{-1}$)				
<u>Forage Crop \times Fertility Interaction Effects</u>				
Crop	Fertility	ADF	CP	TDN
Alfalfa	No	2304c ^a	828a	3460b
	Yes	2308c	836a	3537b
Bromegrass	No	1991d	412d	2907c
	Yes	2866a	590c	4064a
Alfalfa + Bromegrass	No	2579b	711b	4015a
	Yes	2797a	893a	4151a
P values		<.0001	0.0027	<.0001
SEM		67.6	29.0	95.5
<u>Forage Crop \times Cut 1 Date Interaction Effects</u>				
	Time of first harvest	ADF	CP	TDN
Alfalfa	Late June	1890g	887b	3011e
	Early July	2625bcd	1025a	3847b
	Late July	2618cd	834bc	3911b
	Late August	2090fg	581e	3224de
Bromegrass	Late June	2047g	657de	2927e
	Early July	2326ef	616de	3426cd
	Late July	2686bc	372f	3703bc
	Late August	2655bc	359f	3885b
Alfalfa + Bromegrass	Late June	2371de	893b	3646bc
	Early July	2880ab	926ab	4488a
	Late July	2988a	723cd	4375a
	Late August	2513cde	665de	3824b
P values		0.0030	0.0155	<.0001
SEM		93.4	41.0	128.0
<u>Forage Crop Means</u>				
Crop		ADF	CP	TDN
Alfalfa		2306b	832a	3498b
Bromegrass		2428b	501b	3485b
Alfalfa + Bromegrass		2688a	802a	4083a
P values		0.0011	<0.0001	0.0004
SEM		50.1	19.9	74.0

Continued

Cut 1 Date Means				
Cut date	ADF	CP	TDN	
Late June	2103d	812a	3195c	
Early July	2610b	856a	3920a	
Late July	2764a	643b	3996a	
Late August	2419c	535c	3644b	
P values	<0.0001	<0.0001	<0.0001	
SEM	54.4	23.1	79.7	
Fertility Means				
Fertility	ADF	CP	TDN	
Unfertilized	2291b	650b	3461b	
Fertilized	2657a	773a	3917a	
P values	<0.0001	<0.0001	<0.0001	
SEM	40.1	16.3	57.8	

^aThe same lowercase letters within a column for a particular treatment or interaction effect indicate no significant difference between treatments at P = 0.05.

The CP concentration sequence was alfalfa > alfalfa-bromegrass mixture > bromegrass. But the CP yield was significantly greater for the alfalfa and alfalfa-bromegrass mixture than bromegrass.

The CP concentration was highest with Late June Cut 1 date and declined with delay in Cut 1 date until Late July, and further delay in Cut 1 had no effect on the CP concentration. The CP yield for the Late June and Early July Cut 1 dates were not significantly different from each other and were higher than both later Cut 1 dates. Also, the Late July date had significantly more CP yield than Late August. Fertilizer application significantly increased both the CP concentration and CP yield.

Total digestible nutrients (TDN) concentration and yield

The TDN concentration was not significantly affected by the forage crop × fertility interaction (**Table 3**). But fertilizer application tremendously improved the TDN yield of bromegrass, while there was only small (not significant) improvement for the alfalfa and alfalfa-bromegrass mixture (**Table 4**).

The forage crop × Cut 1 date interaction did not significantly affect the TDN concentration (**Table 3**), while it did influence the TDN yield (**Table 4**). The TDN yield from Alfalfa and alfalfa-bromegrass mixture was significantly greater for the Early and Late July Cut 1 treatments than the other two Cut 1 date treatments, but for bromegrass it increased with delay in Cut 1 until Late August.

Bromegrass had lower TDN concentration than the alfalfa and alfalfa-bromegrass mixture (**Table 3**) and alfalfa-bromegrass mixture produced significantly more TDN yield than both the alfalfa and bromegrass (**Table 4**).

The TDN concentration was significantly lower for the Late July Cut 1 than

other dates, even though the difference was about 10 g·kg⁻¹ only (Table 3). But the TDN yield was significantly greater from July Cut 1 dates than the earlier or later dates, and it was also greater with the Late August date Cut 1 than Late June Cut 1 date (Table 4). Fertilizer application did not affect the TDN concentration (Table 3), but it significantly increased TDN yield (Table 4).

Acid detergent fiber (ADF) concentration and yield

Both the forage crop × fertility and crop × Cut 1 date interactions were not significant for the ADF concentration (Table 3), but they had significant effect on the ADF yield (Table 4). The ADF yield for bromegrass and alfalfa-bromegrass mixture significantly increased by fertilizer application, but not for alfalfa.

Both Early July and Late July Cut 1 dates produced significantly more ADF yield than the Late June or Late August Cut 1 date for alfalfa and alfalfa-bromegrass mixture (Table 4). But the bromegrass ADF yield was significantly greater for the Late July and Late August Cut 1 dates than the earlier Cut 1 dates.

Bromegrass had higher ADF concentration than both the alfalfa and alfalfa-bromegrass mixture crop types (Table 3), and alfalfa-bromegrass mixture had higher ADF yield than both sole crops (Table 4)

The ADF concentration was higher with Late July Cut 1 treatment than the other dates of Cut 1 (Table 3), and the ADF yield showed a sequence of Late July > Early July > Late August > Late June (Table 4). Fertilizer application did not have a significant effect on the ADF concentration (Table 3), but it significantly increased the ADF yield (Table 4).

4. Discussion

In this study, delaying the timing of haying resulted in higher DMY of the Cut 1, which is consistent with a study (Pullman, Washington, USA) by Austenson [15]. If hay of forage grass is being cut only once, delaying haying until later in the growing season would be reasonable consideration to obtain maximum DMY.

However, a delay in harvest may result in a loss of both the protein content and digestibility of the grass and legume hay. Other studies in western Canada have found decline in hay quality with advancing plant maturity [2] [7] [16]. This loss would be most significant for stands consisting of bromegrass alone. Where alfalfa is included in the mix and makes up approximately half of the mixture or where alfalfa is grown alone, the decline in protein and digestibility will not be as great. In a field study in Saskatchewan, Canada, Yu *et al.* [7] found that as plant maturity advanced, crude protein was reduced in both alfalfa and timothy, and fibre was affected very little in alfalfa but increased in timothy.

As would be expected, fertilizer application tended to improve total yield and quality of forage hay in this study. Other studies have found greater yield increases with the addition of fertilizer [2]. The low response to fertilizer in this study can be contributed to good soil nutrient status and the contribution of fixed N from the alfalfa in the alfalfa-bromegrass mixture.

The NRC [17] model predicts that a dry cow in early gestation requires 7 to 8% CP in the diet for maintenance, which increases to 11% to 13% CP in young growing or lactating cows. Protein levels in this study for alfalfa usually remained above 11% for the Late June and Early July treatments only. Bromegrass protein content reached 11% only with the Late June cut when fertilized.

Seeding a mixture of grass and alfalfa generally resulted in higher forage yields than monoculture alfalfa or bromegrass. Mixtures of a well-adapted grass, and alfalfa have been shown to produce as well as either of the components alone in northeast Saskatchewan, on land where alfalfa is adapted [18]. Malhi *et al.* [19] found that seeding alfalfa in mixed stands with bromegrass can generate savings in N fertilizer, without compromising on the forage yield, forage quality or net earnings.

When producers are considering a two-cut system in northeast Saskatchewan, they should aim to take the first cut in early July and the second cut in late August to maximize yield and provide a good combination of protein and TDN for beef cattle. Under a single cut system, cutting until late July would still be expected to provide a suitable combination of yield and quality of alfalfa and alfalfa bromegrass mixtures for beef cattle.

The late September cutting date of the Cut 2 is recommended in this area of Western Canada to avoid cutting during the critical fall period for alfalfa. However, late September is often a difficult time of the year to dry hay because of the cooler daytime temperature and shorter day length. Producers would need to consider this when adopting these dates for harvesting forage for hay.

Fertilization of newly seeded stands containing alfalfa in the first three production years may not result in a significant increase in DMY when soil nutrient status is adequate [1]. Foster *et al.* [18] found similar results and concluded that N fixation was adequate for the crop for the first three production years of alfalfa grass mixtures in a study at Melfort Saskatchewan. In this study, fertilizer had a significant effect on TDN. From a study near Mandan, North Dakota, U.S.A., Berdahl *et al.* [20] reported application of 50 kg N ha⁻¹ had no effect on *in vitro* dry matter digestibility or neutral detergent fibre levels of grass or alfalfa, but it did increase crude protein levels in grass monocultures. When bromegrass is seeded alone for hay, soil N will be depleted quickly, as N fertilization appears to increase DMY after the first production year.

5. Conclusion

With delaying cutting stage for Cut 1, forage DMY of all three forage crops generally increased for Cut 1, but it decreased for the Cut 2. When Cut 1 and Cut 2 forage yields were added, the highest yielding treatment of all three forage crops was the combination of July 10 and Autumn cuts. Alfalfa-bromegrass mixture yielded higher than alfalfa or bromegrass alone. The CP concentrations in Cut 1 forage usually declined as the forage crops matured. The CP concentrations were highest for alfalfa, followed by alfalfa-bromegrass mixture, with the lowest for

bromegrass. There was little or no effect of crop maturity on the TDN and ADF concentration in forage. The TDN concentrations were higher and ADF concentration was lower in forage from alfalfa or alfalfa-bromegrass mixture than bromegrass. Fertilizer application increased CP concentration only for alfalfa-bromegrass mixture. Delaying harvesting for Cut 1 increased ADF yield and TDN yield until Late July, but CP yield generally decreased with forage crop maturity. The ADF and TDN yields were higher for alfalfa-bromegrass mixture than bromegrass or alfalfa alone, and CP yield for alfalfa or alfalfa-bromegrass mixture was considerably higher than bromegrass. Fertilization increased CP yield and ADF yield for bromegrass and alfalfa-bromegrass mixture, and TDN yield only for bromegrass. In summary, forage yield of all three crops generally increased with delaying harvesting for Cut 1 but it decreased for Cut 2. Total DMY (Cut 1 + Cut 2) was highest for a combination of Early July and Autumn cuts. Forage yield was highest for alfalfa-bromegrass mixture, followed by alfalfa and lowest for bromegrass. The CP and TDN concentrations were higher, and ADF concentration was lower in forage from alfalfa or alfalfa-bromegrass mixture than bromegrass. Fertilizer application increased Cut 1 DMY, total DMY and TDN yield for bromegrass, CP concentration for alfalfa-bromegrass mixture, and CP and ADF yield for bromegrass and alfalfa-bromegrass mixture.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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