Delayed harvest affects mineral and NDF concentrations, and digestibility of timothy

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Pelletier, S., Tremblay, G. F., Bélanger, G., Seguin, P., Drapeau, R. and Allard, G. 2008. **Delayed harvest affects mineral and NDF concentrations, and digestibility of timothy.** Can. J. Anim. Sci. **88**: 325–329. A 1-wk delay after late heading in the harvest of timothy spring growth reduced dietary cation–anion difference (−17%), in vitro digestibilities of dry matter (−7%) and neutral detergent fiber (−10%), and increased neutral detergent fiber concentration (+5%). In summer regrowth, the harvest delay tended to have similar effects, but variations (1−6%) were smaller.

Key words: Nutritive value, stages of development, *Phleum pratense* L., metabolic disorders

Pelletier, S., Tremblay, G. F., Bélanger, G., Seguin, P., Drapeau, R. et Allard, G. 2008. **Un report de la récolte affecte la digestibilité et les concentrations en minéraux et en fibres NDF de la fléole des prés.** Can. J. Anim. Sci. **88**: 325–329. Un report d'une semaine après le stade fin épiaison dans la récolte de printemps de la fléole des prés a diminué la différence alimentaire cations anions (−17%), les digestibilités *in vitro* de la matière sèche (−7%) et de la fibre au détergent neutre (−10%), et a augmenté la concentration en fibres au détergent neutre (+5%). À la repousse d'été, le report de la récolte tendait à avoir des effets similaires, mais les variations étaient moins grandes (de 1 à 6%).

Mots clés: Valeur nutritive, stades de développement, *Phleum pratense* L., désordres métaboliques

The nutritive value of forages fed to ruminants can be estimated by the concentration of neutral detergent fiber (NDF), the in vitro true digestibility of dry matter (IVTD) and the in vitro digestibility of NDF (dNDF) (Bélanger et al. 2001). Forage grass tetany (GT) index and dietary cation–anion difference (DCAD) are other important indicators of nutritive value. The GT index determines the risk of a cow developing hypomagnesaemia, and is calculated using the following equation:

$$\text{GT index} = K^{+}/(Ca^{2+} + Mg^{2+}) \quad \text{(Kemp and 't Hart 1957)} \qquad (1)$$

The risk of the occurrence of grass tetany is greatly increased in cattle grazing forages with a GT index higher than 2.2 (Kemp and 't Hart 1957). The DCAD is related to hypocalcaemia incidence and can be calculated using the following equation:

$$\text{DCAD} = [(K^{+} + Na^{+}) - (Cl^{-} + 0.6\ S^{2-})] \quad \text{(Goff et al. 2004)} \qquad (2)$$

where DCAD is expressed in $\text{mmol}_c\ \text{kg}^{-1}$ of dry matter (DM). Dry dairy cows should be fed a ration with a DCAD of around $-42\ \text{mmol}_c\ \text{kg}^{-1}$ DM during the transition period, which is 3–4 wk before calving (Pelletier et al. 2008a). If anionic salts are being added to the ration to lower its DCAD, the DCAD value of the fed forage should be less than 290 $\text{mmol}_c\ \text{kg}^{-1}$ DM to avoid a negative effect of these salts on DM intake (Pelletier et al. 2008a). Forage DCAD of timothy can be efficiently decreased to this acceptable value with appropriate K management and by applying Cl fertilization (Pelletier et al. 2007a, b).

Advancing maturity can affect DM yield, DCAD, mineral and NDF concentrations, and DM digestibility of timothy forage (Bélanger et al. 2001; Pelletier et al. 2006). Most studies, however, focused on changes prior to late heading in the spring growth and on only a few variables of nutritive value. Our objective was to assess

Abbreviations: DCAD, dietary cation-anion difference; **DM**, dry matter; **dNDF**, in vitro digestibility of neutral detergent fiber; **GT**, grass tetany; **IVTD**, in vitro true digestibility of dry matter; **NDF**, neutral detergent fiber; **NIRS**, near infrared spectrophotometer the effect of a 1-wk delay in harvest after late heading on NDF concentration, DM and NDF digestibilities, and DCAD and GT indices of timothy in spring growth and summer regrowth.

The study was part of a larger experiment described in detail by Pelletier et al. (2007a) in which we reported the influence of Cl and N fertilizer applications on timothy DCAD. Briefly, timothy (*Phleum pratense* L. 'Champ') was sown at three locations in the province of Quebec: Sainte-Anne-de-Bellevue (hereafter called Sainte-Anne), Normandin, and Saint-Augustin-de-Desmaures (hereafter called Saint-Augustin). Ten fertilizer treatments (seasonal applications of 0, 80, 160, and 240 kg Cl ha^{-1} as $CaCl_2$, 160 kg Cl ha^{-1} as NH_4Cl, all combined with N fertilization to provide 70 or 140 kg N ha^{-1} as NH_4NO_3 for $CaCl_2$ treatments or a mix of NH_4NO_3 and NH_4Cl for NH_4Cl treatments) were applied in a split application: 60% prior to the start of spring growth and 40% after the first harvest. Stages of development at harvest were chosen based on previous results (Pelletier et al. 2006). Half of the forage plots were harvested to a 5-cm height when timothy reached the late heading stage and the other half were harvested 7 d later, in both spring growth and summer regrowth of two production years. Plots were harvested with a self-propelled flail forage harvester (Carter MGF Co., Inc., Brookston, IN) at Normandin and with a REM flail forage harvester (Swift Machine & Welding, Swift Current, SK) at Sainte-Anne and Saint-Augustin. A sample of approximately 500 g was taken from each plot, weighed and then dried at 55°C in a forced-draft oven for 3 d. Samples were then ground using a Wiley mill (Standard model 3, Arthur H. Thomas Co., Philadelphia, PA) to pass through a 1-mm screen.

Sample preparation and analyses are described in Pelletier et al. (2007a). All samples were chemically analyzed for mineral composition. Briefly, K and Mg in ground forage samples were extracted using a method adapted from Isaac and Johnson (1976). Chloride was extracted using a method adapted from Liu (1998) and the extraction of S followed a method adapted from Mills and Jones (1996). Sodium and Ca were extracted by dry ashing (Miller 1998). Sulfur in plant digests was analyzed using an automated continuous-flow injection analyzer. Concentrations of K, Ca, Mg, and Na were determined by atomic absorption, and Cl was measured by ion chromatography. The GT index was calculated with Eq. 1 and the DCAD was calculated with Eq. 2, with each element expressed in $mmol_c$ kg^{-1} DM (mg g^{-1} DM $\times 1000 \times$ valence/atomic weight); 1 $mmol_c$ kg^{-1} DM equals 1 mEq kg^{-1} DM.

All ground forage samples were scanned using a near-infrared spectrophotometer (NIRS) (FOSS NIRsystems 6500, Silver Spring, MD). Samples with the highest relative significant spectra were selected as calibration set and analyzed in duplicate for NDF concentration and IVTD. The NDF concentration was determined using the Ankom Fiber Analyzer (Ankom Technology, Fairport, NY). The IVTD was measured using the method of Goering and Van Soest (1970) based on a 48-h incubation with buffered rumen fluid followed by a NDF wash of the post-digestion residues. The NDF concentration and IVTD were then predicted in all samples using the selected NIRS calibration equations and the dNDF was calculated with the following equation:

$$\mathrm{dNDF} = 1000 - [(1000 - \mathrm{IVTD})/(\mathrm{NDF}/1000)] \qquad (3)$$

Data were analyzed by analysis of variance as a split-split-split-plot design with locations as main plots, stages of development as sub-plots, fertilizer treatments as sub-sub-plots, and harvests as sub-sub-sub-plots. Production years and replicates within locations were considered to be random effects, and harvests within years were considered to be repeated measurements. Data were analyzed using the Mixed procedure (Littell et al. 1996) with the Repeated option of SAS software (SAS Institute, Inc. 1999). The covariance structure that yielded the lowest Akaike's information criterion and Bayesian information criterion values for each variable was used: unstructured (UN) covariance structure for DM yield, GT index, Na, Mg, NDF, and IVTD; compound symmetry (CS) covariance structure for K, Ca, Cl, S, and dNDF; and variance components (VC) covariance structure for DCAD.

Plots were not re-randomized each year. Years were not treated as repeated measurements because there was no residual effect of Cl and N fertilizations in the spring of the second year. Indeed, soil Cl, NO_3, and NH_4 contents at the beginning of the second year were not significantly different among fertilization treatments. Pooled SEMs were calculated from standard errors given in the difference of least square means output of SAS software (SAS Institute, Inc. 1999). Statistical differences between least square means were determined using the PDIFF test with the LSMEANS statement at $P < 0.05$.

The effect of fertilizer treatments on forage DM yield, DCAD (Pelletier et al. 2007a), digestibility, and NDF concentration at late heading (Pelletier et al. 2008b) have been published previously. The main focus here is the effect of the delay in harvesting. The triple interaction between location, harvest, and stage of development ($L \times H \times S$) was significant for all variates except timothy dNDF (Table 1). Therefore, DM yield, DCAD, GT index, mineral and NDF concentrations, and digestibilities of DM and NDF of timothy are presented for each location, harvest, and stage of development (Table 1).

Delaying harvest increased DM yield of timothy spring growth at Sainte-Anne and Saint-Augustin ($P < 0.05$), but did not affect DM yield of timothy grown at Normandin. In summer regrowth, delaying harvest decreased DM yield at Normandin and Sainte-Anne ($P < 0.05$) but increased it at Saint-Augustin

Table 1. Dry matter (DM) yield, dietary cation-anion difference (DCAD), grass tetany (GT) index, concentrations of K, Na, Ca, Mg, Cl, S, and neutral detergent fiber (NDF), in vitro true digestibility of DM (IVTD), and in vitro digestibility of NDF (dNDF) of timothy grown at three locations in the province of Quebec and harvested at two stages of development during spring growth and summer regrowth (average values over 10 fertilizer treatments[z] and 2 production years, 2003 and 2004)

Location (L)	Harvest (H)	Stage of development (S)	DM yield (Mg ha^{-1})	DCAD[y] (mmol$_c$ kg^{-1} DM)[x]	GT[w] index	K	Na	Ca	Mg	Cl	S	NDF	IVTD	dNDF (g kg^{-1} NDF)
						(g kg^{-1} DM)						(g kg^{-1} DM)		
Normandin	Spring	1[v]	3.76	386*a*	2.3	31.0*a*	0.029*a*	4.49*a*	1.51	11.95	1.92*a*	600*a*	849*a*	748*a*
		2	3.69	298*b*	2.2	27.2*b*	0.035*b*	4.19*b*	1.35	11.83	1.78*b*	638*b*	796*b*	680*b*
	Summer	1	2.59*a*	265*a*	1.9	25.7*a*	0.017	4.68*a*	1.49	11.39	1.91	574*a*	838*a*	718*a*
		2	1.95*b*	239*b*	1.9	24.6*b*	0.029	4.50*b*	1.37	11.41	1.87	592*b*	810*b*	680*b*
Sainte-Anne	Spring	1	3.70*a*	360*a*	3.1*a*	28.9*a*	0.012	2.96*a*	1.17	10.83	1.99	604*a*	851*a*	755*a*
		2	4.16*b*	318*b*	2.7*b*	26.8*b*	0.016	3.34*b*	1.16	10.59	1.89	643*b*	793*b*	678*b*
	Summer	1	1.45*a*	266*a*	1.5	22.7*a*	0.029	5.16	1.70	8.53	2.02*a*	509	877	761
		2	1.00*b*	241*b*	1.4	21.6*b*	0.021	5.10	1.72	8.12	2.21*b*	507	877	757
Saint-Augustin	Spring	1	4.22*a*	294*a*	1.6	24.6*a*	0.037	6.23*a*	1.20	9.14*a*	2.13*a*	651*a*	778*a*	661*a*
		2	5.34*b*	246*b*	1.5	21.6*b*	0.016	5.79*b*	1.06	8.39*b*	1.88*b*	674*b*	719*b*	586*b*
	Summer	1	3.34*a*	224*a*	1.1	22.6	0.083	8.31	1.44	9.57*a*	2.41*a*	577	805	664
		2	3.73*b*	248*b*	1.2	22.1	0.052	7.37	1.28	8.36*b*	2.23*b*	583	802	663
SEM (n = 80; df = 420)			0.359	11.8	0.08	0.77	0.0061	0.377	0.048	0.530	0.058	7.7	7.6	9.5
P-value														
L × S × H			<0.001	0.006	0.010	0.002	0.038	0.004	<0.001	<0.001	<0.001	0.002	0.033	0.341

[z]Seasonal applications of 0, 80, 160, and 240 kg Cl ha^{-1} as $CaCl_2$ and 160 kg Cl ha^{-1} as NH_4Cl, all combined with N fertilization to provide 70 or 140 kg N ha^{-1} as NH_4NO_3 for $CaCl_2$ treatments or a mix of NH_4NO_3 and NH_4Cl for NH_4Cl treatments.
[y]DCAD calculated with the equation: $(K^+ + Na^+)-(Cl^- + 0.6\ S^{2-})$ (Goff et al. 2004).
[x]1 mmol$_c$ kg^{-1} DM = 1 mEq kg^{-1} DM.
[w]GT index calculated with the equation: $K^+/(Ca^{2+} + Mg^{2+})$ (Kemp and 't Hart 1957).
[v]1 = late heading stage of development; 2 = 7 d after the late heading stage of development.
SEM = pooled standard error of the means.
a–b Means in a column for the two stages of development within harvest and location with different letters differ ($P < 0.05$).

($P < 0.05$) (Table 1). The stages of development at harvest in this study were late compared with the recommended practice of harvesting timothy at early heading. In spring growth, the increase in DM yield with the delayed harvest observed at two locations was appreciable. In another experiment, Pelletier et al. (2006) reported an increase in timothy DM yield with advancing maturity from stem elongation to early flowering in spring growth, but the increase was less between the last two stages (late heading and early flowering) than between the first two stages of development (stem elongation and early heading).

A 1-wk delay in harvest from late heading during spring growth decreased the forage DCAD by an average of 17% (-59 $mmol_c$ kg^{-1} DM) (Table 1); this decrease was significant ($P < 0.05$) at all locations. This is similar to results reported by Pelletier et al. (2006) in which the DCAD, when calculated with the equation proposed by Goff et al. (2004), was decreased by 37 $mmol_c$ kg^{-1} DM when timothy was harvested at early flowering compared the late heading. The decrease in forage DCAD observed in the present study can be explained by variations in forage K and Cl concentrations, the main determinants of DCAD (Pelletier et al. 2006, 2007a, b). Forage K concentration decreased significantly ($P < 0.05$) with the delay of harvest at all locations (average of -11% or -3.0 g kg^{-1} DM), whereas forage Cl concentration only decreased at Saint-Augustin ($P < 0.05$) by 0.75 g kg^{-1} DM (Table 1). This indicates that, on average over the 10 fertilizer treatments, the Cl applied at the beginning of spring growth was still efficient at maintaining a high forage Cl concentration in timothy harvested 1 wk after late heading. This high forage Cl concentration, combined with the concomitant decrease in forage K concentration, led to a decrease in DCAD of timothy harvested at the second stage of development in spring growth.

In summer regrowth, delaying harvest decreased the DCAD ($P < 0.05$) at Normandin and Sainte-Anne due to a decrease ($P < 0.05$) in timothy K concentration (Table 1). At Saint-Augustin, delaying harvest increased the DCAD ($P < 0.05$) because Cl concentration was decreased ($P < 0.05$) whereas K concentration was not affected (Table 1).

Averaged across fertilizer treatments, forage DCAD was generally greater than the recommended value for dry dairy cows 3 to 4 wk pre-calving (Table 1), although several Cl fertilization treatments applied to timothy during this study decreased forage DCAD to acceptable values (Pelletier et al. 2007a). The response of DCAD to the fertilizer treatments was affected by the stages of development ($P < 0.05$). The decrease in DCAD with delayed harvest was greater for forage not fertilized with Cl compared with forage fertilized with Cl (-57 vs. -28 $mmol_c$ kg^{-1} DM). Indeed, at the first stage of development, the DCAD of forage fertilized with Cl was already lower (269 $mmol_c$ kg^{-1} DM) than forage not fertilized with Cl (439 $mmol_c$ kg^{-1} DM) due to higher forage Cl concentration. Therefore, the potential decrease in DCAD between the first and second stages of development for forage not fertilized with Cl was higher than for forage fertilized with Cl. The decrease in DCAD was also greater for forage fertilized with the lowest level compared with the highest level of N fertilization (-37 vs. -31 $mmol_c$ kg^{-1} DM) (data not shown).

The timothy GT index tended to decrease with the 1-wk harvest delay, but the effect was significant ($P < 0.05$) only in spring growth at Sainte-Anne. The highest GT indices were associated with forage high in K and low in Ca and Mg concentrations (Table 1). The GT index was generally acceptable (< 2.2) (Kemp and 't Hart 1957) for cows except for the spring growth of forage grown at Sainte-Anne and Normandin. At these locations, the GT indices were equal to or greater than 2.2. Forages harvested in summer had an acceptable GT index for cows regardless of the stage of development and the location.

The NDF, IVTD, and dNDF values observed in the present study are similar to those reported by Claessens et al. (2004) and Bélanger et al. (2004). In spring growth, the 1-wk delay in harvesting resulted in greater NDF concentration and lower digestibilities of DM and NDF ($P < 0.05$) (Table 1). In summer regrowth, the same harvest delay decreased digestibilities of DM and NDF and increased NDF concentration only at Normandin ($P < 0.05$). The digestibility of timothy generally tended to be higher in summer regrowth than in spring growth. This is likely due to lower DM yield in summer regrowth. In their review, Bélanger et al. (2001) clearly demonstrated this negative relationship between DM yield and digestibility. Advancing maturity of timothy increases forage DM yield and NDF concentration, and decreases digestibilities of DM and NDF; the decline in nutritive value is less during summer regrowth than spring growth (Bélanger et al. 2001).

Delaying timothy harvest by 1 wk after the late-heading stage of development reduced forage DCAD at all three sites in the spring growth and tended to reduce the GT index. The effect of delaying timothy harvest in the summer regrowth was less pronounced and consistent. Consequently, the predicted risks for cows to develop hypocalcaemia or hypomagnaesemia were also decreased with delaying harvest in the spring growth. This delayed harvest, however, was associated with a decrease in in vitro true digestibility of DM and in vitro digestibility of NDF, and an increase in NDF concentration. Delaying harvest to reduce the DCAD and the grass tetany index should, therefore, be used with caution because of the negative effect it may have on forage digestibility and intake. The decision of when to harvest timothy forage will have a greater impact on nutritive value in spring growth than in summer regrowth.

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