

ORIGINAL ARTICLE

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Seasonal and diurnal variation in forage nutritive value of cool-season grasses as predicted by near-infrared reflectance spectroscopy (NIRS)

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Abstract

A better understanding of seasonal and diurnal variation in forage nutritive value may help to maximize protein intake and digestibility for grazing livestock. Forage nutritive value was evaluated in four cool-season grasses common to Kentucky pastures: orchardgrass (*Dactylis glomerata* L.; OG), perennial ryegrass (*Lolium perenne* L. ssp. *perenne*; PRG), Kentucky bluegrass (*Poa pratensis* L.; KBG), and tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.; TF]. In 2015 and 2017, 10 cool-season grass cultivars representing four species, planted in quadruplicate (40 plots) in central Kentucky, were maintained vegetatively with 2–4 week mowing and sampled in the morning and the afternoon at the same times every 2–4 weeks, from May to November. Near-infrared reflectance spectroscopy (NIRS) was used to predict dry matter (DM) and in vitro true dry matter digestibility (IVTDMD), as well as concentrations of acid detergent fiber (ADF), neutral detergent fiber (NDF), and crude protein (CP). On most harvest dates, ADF and NDF were higher in the morning than in the afternoon, and highest in KBG and TF species. Concentrations of CP did not have a consistent diurnal pattern across harvest dates. On most harvest dates, IVTDMD increased in the afternoon and was highest in PRG. The results could inform grazing management for weight gain in beef cattle or weight loss in overweight horses.

Plain Language Summary

Knowing the nutritive value of forages (crude protein, fiber, and digestibility) at different times of the day and year may help in selecting highly digestible forage for beef cattle or lactating mares, or less digestible forage for overweight horses. Near-infrared reflectance spectroscopy was used to predict the nutritive value of

Abbreviations: ADF, acid detergent fiber; CP, crude protein; DM, dry matter; IVTDMD, in vitro true dry matter digestibility; KBG, Kentucky bluegrass; LS, least squares; NIRS, near-infrared reflectance spectroscopy; OG, orchardgrass; PRG, perennial ryegrass; SEC, standard error of calibration; SECV, standard error of cross-validation; TF, tall fescue; WSC, water-soluble carbohydrates.

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orchardgrass, perennial ryegrass, Kentucky bluegrass, and tall fescue maintained as vegetative monocultures in central Kentucky and harvested in the morning and afternoon, monthly from May to November. Afternoon samples of perennial ryegrass had the highest predicted digestibilities (i.e., in vitro true dry matter digestibility), and Kentucky bluegrass and tall fescue were highest in fiber (i.e., acid detergent fiber and neutral detergent fiber). The results of the study could inform grazing management for weight gain in beef cattle or weight loss in overweight horses.

1 | INTRODUCTION

Pasture grasses are an important part of the diet of horses and other grazing animals in Kentucky (Olson et al., 2025). The nutritive value of grasses can be assessed by measuring acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), and in vitro true dry matter digestibility (IVTDMD). Diurnal variation in ADF, NDF, CP, and IVTDMD was observed in tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.; TF] hay harvested at sunrise and sundown, with increased ADF and NDF at sunrise and increased CP and IVTDMD at sundown (Fisher et al., 1999). Examining more species, freshly cut, could provide valuable information about optimal grazing times and desirable species for grazing beef cattle, lactating mares, or overweight horses. In meadow fescue (*Festuca pratensis* Hud.) harvested at different times of the day in September, decreases in ADF, NDF, and CP were observed as the day progressed, while IVTDMD did not vary (Gregorini et al., 2009). In orchardgrass (*Dactylis glomerata* L.; OG) grown in Utah and harvested at different times of the day in June, August, and October, no diurnal variation in NDF, CP, or IVTDMD was observed in October, and times of maximum CP and IVTDMD differed between June and August (Griggs et al., 2007). Grasses, including Kentucky bluegrass (*Poa pratensis* L.; KBG) and TF, differed among species and between harvest times in ADF, NDF, and IVTDMD (Pelletier et al., 2010). Variation in CP was not determined in that study. Grasses, including OG, KBG, TF, and perennial ryegrass (*Lolium perenne* L. ssp. *perenne*; PRG), differed in NDF and CP when grazed monthly and harvested in spring and summer, but ADF and IVTDMD were not determined (Allen et al., 2013). The goal of this study was to assess seasonal and diurnal variation in forage nutritive value in monoculture plots of OG, PRG, KBG, and TF managed in central Kentucky under simulated intensive grazing (vegetative, 10–25 cm height).

2 | MATERIALS AND METHODS

2.1 | Site selection

Cool-season grasses were planted at the University of Kentucky Spindletop Research Farm (Lexington, KY, 38°06'35"

N, 84°29'28" W) on September 8, 2014. The soil was a Bluegrass–Maury silt loam type. Soil samples were taken randomly across the planting site and analyzed by the University of Kentucky Regulatory Services. The following fertility treatments were applied based on the analyses: 50 lb ac⁻¹ (56 kg ha⁻¹) nitrogen as urea ammonium nitrate, 2996 lb ac⁻¹ (3364 kg ha⁻¹) pelletized lime, and 20 lb ac⁻¹ (22 kg ha⁻¹) K₂O as a potassium source (Prince, 2017). Other forage establishment procedures and the experimental design for the 2014 planting have been described (Kramer et al., 2020). The same site was used for replanting cool-season grasses on September 6, 2016, and the same experimental design was used, except that instead of excluding nitrogen from half the plots as in 2015, all plots received nitrogen in 2017 (140 lb ac⁻¹ [157 kg ha⁻¹], applied in March, May, and August as 50 [56], 40 [45], and 50 [56] lb ac⁻¹ [kg ha⁻¹], respectively). Species evaluated in both sampling years were OG (cultivars 'Per-sist' and 'Quickdraw'), PRG (cultivars 'Linn' and 'Aberzest'), KBG (cultivars 'Ginger' and 'Barderbey'), and TF (cultivars 'Cajun II' and 'Bronson'). For each pair of cultivars listed for a species, the former was early maturing, and the latter was late maturing. An additional PRG cultivar ('Calibra') and an additional OG cultivar ('Profit') were planted in case of cultivar persistence issues, leading to 10 cultivars per experimental block.

2.2 | Forage sampling

Grasses planted in September 2014 were sampled from May through November 2015, and grasses planted in September 2016 were sampled from May through November 2017.

Plots were mowed to 10 cm every 2 weeks, except that from July to October of both harvest years plots were mowed every 4 weeks because of high temperatures and a lack of moisture limited growth. This mowing frequency simulated an intensive rotational grazing schedule with grasses maintained at a vegetative height of 10–25 cm. In 2015, samples for nutritive value analysis were harvested every 2–4 weeks, as described previously (Kramer et al., 2020). In 2017, plots were harvested monthly. Harvest dates used for statistical analysis are listed in Table 1.

TABLE 1 Harvest dates used in the final analysis of this study.

Harvest number	2015	2017
1	May 13	May 11
2	June 10	June 7
3	July 8	July 6
4	Aug. 19	Aug. 2
5	Sept. 15	Sept. 28
6	Oct. 13	Oct. 26
7	Nov. 3	Nov. 21

Forage samples (100 g) were clipped to 5 cm with hand shears. Samples were flash frozen in liquid nitrogen and stored at -20°C until they could be freeze dried (models 24DX54 and 18DX48SA, Botanique Preservation Equipment; and model 36 $\times$ 66GPF, VirTis SP Industries). Freeze-dried samples were ground through a 1-mm mesh in a cyclone mill (UDY Corporation).

2.3 | Analysis of dry matter and quality components by near-infrared reflectance spectroscopy

Ground samples were scanned with a spectrometer for measuring near-infrared reflectance spectroscopy (NIRS; model 6500, FOSS) with ISI software (Infrasoft International, L.L.C.). The grass hay equation (2015 and 2017 release years) published by the NIRS Forage and Feed Testing Consortium was used to predict ADF, NDF, CP, dry matter (DM), and IVTDMD after 30 hours (IVTDMD₃₀). This equation is based on wet chemistry data that are updated annually. Standard errors of calibration (SEC) and cross-validation (SECV), respectively, for the above parameters were as follows in 2015: ADF 1.72, 1.84; NDF 2.31, 2.45; CP 0.90, 0.942; DM 0.238, 0.311; and IVTDMD₃₀ 4.700, 5.49. In 2017, SEC and SECV were 1.68 and 1.76 for ADF; 2.32 and 2.40 for NDF; 0.948 and 0.994 for CP; 0.35 and 0.378 for DM; and 5.08 and 6.20 for IVTDMD₃₀.

2.4 | Weather data collection

Weekly total precipitation and average weekly temperatures were recorded from weather stations (Campbell Scientific) located at the Spindletop Research Farm.

2.5 | Statistical model

Predicted values were analyzed using SAS 9.3 PROC GLIMMIX as a randomized complete block, split-split plot in time

experimental design. Species (4), harvest (7), time of day (2), as well as their interactions, were treated as fixed effects, with block by species (4) treated as random. The split-split plot in time was the combination of the harvest and time of day interaction. Therefore, that interaction was used as a repeated measure. Compound symmetry covariance structure was used. From 2015 and 2017, 866 samples were predicted with the NIRS and analyzed. Some samples were lost in May 2015 due to lyophilizer issues and considered as missing data. Statistical difference was determined at $P \leq .05$. Statistical trends were observed at $.05 < P \leq .10$. Statistical analyses were performed for each year separately. All main effects and interactions were significant ($P < .05$) except for the species by time-of-day interaction ($P > .05$) and the species by harvest date by time-of-day interaction ($P > .05$).

Statistical differences between treatments were determined by a least squares (LS) means comparison test. SEMs were determined from the variance calculated in the ANOVA table and adjusted for missing data.

3 | RESULTS

3.1 | Weather patterns

Mean weekly temperatures in 2015 began at 71.4°F in early May and peaked at 79.7°F in early June (Figure 1A). Temperatures decreased from September to November. Mean weekly temperatures in 2017 began at 56.3°F in early May and peaked at 78.8°F in late July (Figure 1B). Temperatures declined from September to November, reaching a low of 41.9°F in mid November. Total weekly precipitation in 2015 had maxima in mid June, mid July, late September, and late October. Total weekly precipitation in 2017 had maxima in mid June, early July, late August, and early October. Total precipitation for the 2017 study period was nearly twice that of the 2015 study period (52.0 vs. 26.5 inches).

3.2 | Diurnal effects on seasonal variation in fiber, CP, and digestibility

Time of day influenced seasonal variation in ADF, NDF, CP, and IVTDMD ($P \leq .05$ for all variables in 2015 and 2017). In 2015, monthly ADF was 3.4%–13% higher in the morning than in the afternoon ($P \leq .05$; Table 2). Across the season, ADF ranged from 18.6% (October, afternoon) to 32.7% (May, morning). In 2017, ADF was 1.3%–22% higher in the morning than in the afternoon ($P \leq .05$), except in November, when morning and afternoon values did not differ ($P \geq .10$). Concentrations of ADF in 2017 ranged from 22.4% (November, afternoon) to 30.3% (July, morning).

In 2015, monthly NDF was 2.9%–19% higher in the morning than in the afternoon ($P \leq .05$), ranging from 39.6%

TABLE 2 Diurnal variation in forage nutritive value (percentage dry matter [% DM]) of orchardgrass (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L. ssp. *perenne*), Kentucky bluegrass (*Poa pratensis* L.), and tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.] during 2015 and 2017. Least squares means for the morning (am) and afternoon (pm) harvests in Lexington, KY, and SEMs are shown.

Variable responses	Month										P value
	Year	Time	May	June	July	Aug.	Sept.	Oct.	Nov.	SEM	
ADF	2015	am	32.7*	30.2*	30.7*	30.1*	29.1*	21.9*	21.3*	0.4	<.0001
		pm	30.0	28.3	29.7	27.8	28.0	18.6	18.8	0.3	
	2017	am	28.5*	25.0*	30.3*	30.2*	27.5*	27.5*	22.6	0.3	<.0001
		pm	25.1	22.7	28.5	28.1	25.8	22.5	22.4	0.3	
NDF	2015	am	59.6*	56.7*	59.7*	58.0*	57.3*	47.5*	44.5*	0.7	<.0001
		pm	55.0	52.5	58.0	52.2	54.9	40.1	39.6	0.5	
	2017	am	53.5*	48.2*	58.8*	57.7*	56.4*	57.0*	46.4	0.7	<.0001
		pm	47.1	43.4	55.0	53.6	52.6	46.1	45.3	0.7	
IVTDMD	2015	am	65.5	74.7	72.6	70.6	66.8	83.5	89.4	0.8	<.0001
		pm	74.0*	79.4*	72.5	76.4*	70.0*	91.2*	93.4*	0.6	
	2017	am	70.4	79.3	75.0	68.9	69.4	77.1	85.9	0.7	<.0001
		pm	76.1*	82.8*	78.5*	73.5*	72.1*	86.5*	86.8	0.7	
CP	2015	am	10.8	16.1	17.8 [#]	16.4*	14.7	26.9*	23.4*	0.4	.0014
		pm	11.5	15.7	17.2	15.5	14.3	25.1	22.1	0.3	
	2017	am	19.0	21.8*	18.5*	15.7	18.3 [#]	18.7	18.5*	0.3	.0001
		pm	18.9	20.6	17.5	15.4	17.7	19.8*	17.1	0.3	

Abbreviations: ADF, acid detergent fiber; CP, crude protein; IVTDMD, in vitro true dry matter digestibility; NDF, neutral detergent fiber.

*Indicates significant differences between time within harvest ($P \leq .05$).

[#]Indicates a trend for differences between time within harvest ($.05 < P \leq .10$).

(November, afternoon) to 59.7% (July, morning). The NDF concentrations in 2017 were 6.9%–24% higher in the morning than in the afternoon ($P \leq .05$), except in November, when morning and afternoon concentrations did not differ ($P \geq .10$). The NDF concentrations in 2017 ranged from 43.4% (June, afternoon) to 58.8% (July, morning).

In 2015, CP ranged from 10.8% (May, morning) to 26.9% (October, morning; Table 2). Concentrations were ~6% higher in the morning than in the afternoon in August, October, and November ($P \leq .05$), with a trend ($P \leq .10$) toward being 3.5% higher in the morning of July. They did not differ in May, June, or September ($P \geq .10$). In 2017, CP ranged from 15.4% (August, afternoon) to 21.8% (June, morning). Concentrations in May and August did not differ between morning and afternoon ($P \geq .10$). September saw a trend ($P \leq .10$) for 3.4% higher CP in the morning. In October, CP was 5.9% higher in the afternoon; in June, July, and November, morning concentrations of CP were 5.8% to 8.2% higher than afternoon concentrations ($P \leq .05$).

Monthly IVTDMD in 2015 was higher in the afternoon than in the morning ($P \leq .05$) except in July, when morning and afternoon values did not differ ($P \geq .10$). The IVTDMD ranged from 65.5% (May, morning) to 93.4% (November, afternoon). In 2017, IVTDMD ranged from 68.9% (August, morning) to 86.8% (November, afternoon).

Morning and afternoon IVTDMD did not differ in November 2017 ($P \geq .10$).

3.3 | Species effects on seasonal variations in fiber, CP, and digestibility

Species influenced mean monthly ADF, NDF, CP, and IVTDMD ($P \leq .05$ in all cases; Table 3). In 2015, KBG had the highest ADF from June through September ($P \leq .05$). TF had the highest ADF in May ($P \leq .05$) but did not differ from KBG in October and November ($P \geq .10$). In 2017, KBG had the highest ADF in every harvest month except for October, when the ADF was highest in TF (Table 3). In both years, the species with the lowest ADF were OG and PRG, although on some dates (May, June, and August 2017), OG and TF had similar ADF concentrations.

In 2015, KBG had the highest NDF from June through September, as well as in November ($P \leq .05$; Table 3). The NDF concentrations in KBG and TF were equally high in October, and in May, TF had the highest NDF concentrations. In 2017, OG had the highest NDF in November, and NDF in TF and OG did not differ. KBG had the highest NDF from May through July. PRG had among the lowest monthly NDF values in both years.

TABLE 3 Species by harvest date effects on fiber, crude protein (CP), and digestibility results (percentage dry matter [% DM]) for four cool-season grass species harvested from May to November 2015 and 2017. Least squares means for each species within harvest date, and SEMs across species within harvest date, are shown.

Variable responses	Month								
	Year	Species	May	June	July	Aug.	Sept.	Oct.	Nov.
ADF	2015	TF	32.5a	29.2b	30.8b	30.2b	29.2b	21.9a	21.8a
		KBG	31.2b	31.5a	32.7a	31.0a	33.0a	22.1a	22.2a
		PRG	30.6bc	28.6bc	27.8d	26.2d	26.2c	18.6b	18.1b
		OG	29.9c	27.7c	29.3c	28.5c	25.8c	18.4b	18.1b
		SEM	0.5	0.4	0.4	0.4	0.4	0.4	0.4
	2017	TF	26.2b	22.9b	30.5b	28.8bc	27.1b	26.5a	23.3b
		KBG	29.6a	26.6a	31.3a	30.9a	27.7a	24.7bc	24.1a
		PRG	25.3c	22.9b	26.9d	27.8c	25.3c	23.5c	19.5c
		OG	26.6b	22.9b	29.0c	29.1b	26.6b	25.2b	23.0b
		SEM	0.5	0.5	0.5	0.5	0.5	0.5	0.5
NDF	2015	TF	60.0a	54.1b	59.6b	56.8b	56.2b	46.4a	43.9b
		KBG	57.4b	59.1a	62.2a	57.4a	62.6a	45.7a	45.2a
		PRG	53.5c	52.1c	55.6d	51.1d	53.4c	40.3c	37.9d
		OG	57.5b	53.2bc	57.8c	55.3c	52.4c	42.7b	41.0c
		SEM	0.9	0.7	0.7	0.7	0.7	0.7	0.7
	2017	TF	49.0b	45.0b	57.6b	54.3b	53.9b	53.4a	45.5c
		KBG	56.6a	50.6a	60.2a	57.5a	56.1a	49.9b	47.8b
		PRG	52.0c	42.8c	52.5c	54.1b	52.0c	49.8b	40.4d
		OG	53.9b	44.6b	57.1b	56.6a	55.8a	53.2a	49.6a
		SEM	0.9	0.9	0.9	0.9	0.9	0.9	0.9
CP	2015	TF	12.0b	16.5a	17.3b	15.3c	13.1c	23.8c	20.3c
		KBG	10.8c	14.5b	15.3c	13.4d	11.8d	25.7b	21.9b
		PRG	9.7d	15.9a	19.0a	17.8a	15.6b	26.8ab	24.4a
		OG	13.0a	16.8a	18.4a	17.1b	17.4a	27.6a	24.5a
		SEM	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	2017	TF	21.0a	22.5a	18.3b	15.7b	17.4c	18.2c	16.4c
		KBG	16.3c	19.1c	16.5c	14.2c	17.8bc	19.5b	17.5b
		PRG	19.1b	21.0b	18.1b	14.7c	18.8a	20.3a	18.8a
		OG	19.3b	22.2a	19.1a	17.4a	18.0b	19.0b	18.5a
		SEM	0.4	0.4	0.4	0.4	0.4	0.4	0.4
IVTDMD	2015	TF	68.9b	78.0ab	72.7b	73.1b	71.0a	85.7b	92.0b
		KBG	69.5b	73.2c	70.0c	70.7c	63.4c	85.7b	87.2d
		PRG	74.0a	80.1a	74.9a	77.3a	69.6b	91.1a	95.9a
		OG	69.2b	76.9b	72.8b	72.9b	69.5b	86.9b	90.5c
		SEM	1.0	0.8	0.8	0.8	0.8	0.8	0.8
	2017	TF	75.3ab	83.7a	79.3b	74.6a	73.2a	83.0a	88.0b
		KBG	68.0c	78.3b	73.8c	70.0c	68.9b	83.6a	83.5c
		PRG	76.2a	82.4a	81.2a	73.1b	72.3a	82.8a	93.6a
		OG	73.6b	79.7b	72.8c	67.3d	68.4b	77.8b	80.3d
		SEM	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Note: $P < .0001$ for all variable responses in both harvest years. Means lacking a common letter differ within harvest between species ($P \leq .05$).

Abbreviations: ADF, acid detergent fiber; IVTDMD, in vitro true dry matter digestibility; KBG, Kentucky bluegrass; NDF, neutral detergent fiber; OG, orchardgrass; PRG, perennial ryegrass; TF, tall fescue.

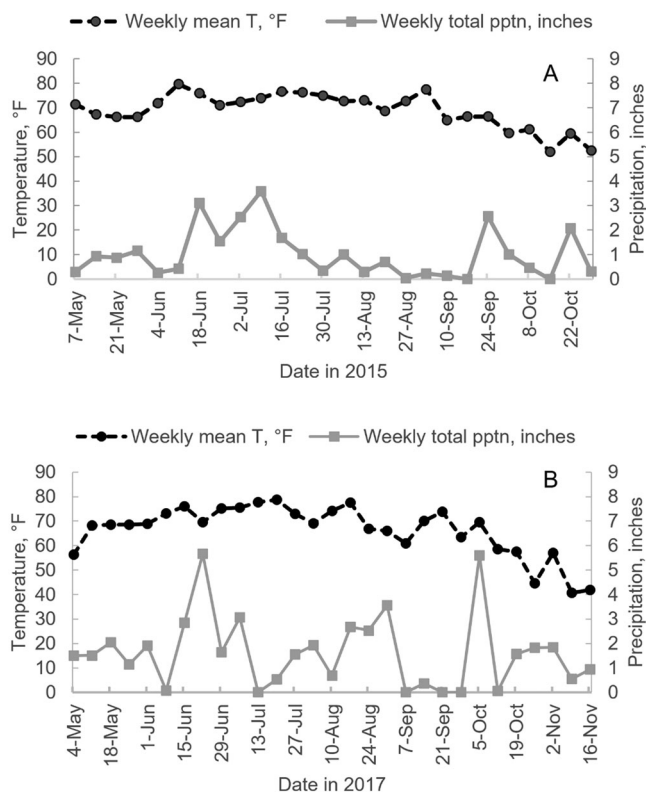


FIGURE 1 Weekly mean temperature (°F) and weekly total precipitation (in inches) over the 2015 and 2017 study periods. Pptn, precipitation.

Species with the highest CP concentrations in 2015 were OG and PRG, except in May, June, and October (Table 3). In 2017, OG, PRG, and TF had the highest CP concentrations from May through July. The CP in November 2017 was highest in OG and PRG.

The IVTDMD in 2015 was highest in PRG, except in June, when it was as high in TF, and in September, when IVTDMD was highest in TF (Table 3). The IVTDMD was lowest in KBG, except in May and October, when it did not differ from that of OG or TF. In 2017, PRG and TF had the highest monthly IVTDMD except in July and November (highest IVTDMD in PRG on those dates), and in August (highest IVTDMD in TF). The IVTDMD in 2017 was lowest in OG and KBG, except that in October 2017 it did not differ among PRG, KBG, or TF.

4 | DISCUSSION

Because ADF was <35% on all harvest dates, the forages would have a quality standard of 1 (31%–35% ADF) or prime (<31% ADF) on a scale ranging from 5 (>45% ADF) to prime (Ball et al., 2015). The ADF of forages in the Italian Alps has been reported to increase as the number of days from the first cut increase from 45 to 60 or 75 days (Bovolenta et al., 2008).

Hence, it may be concluded that the consistently low ADF in the current study was due to the mowing of plots every 14–28 days, which kept the grasses in a vegetative state.

On most harvest dates, ADF and NDF were higher in the morning than in the afternoon, in agreement with results of studies on TF hay (Fisher et al., 1999), meadow fescue (Gregorini et al., 2009), various cool-season grasses, including KBG and TF (Pelletier et al., 2010), and grass mixtures (Weinert-Nelson et al., 2022). Evening decreases in fiber (such as ADF and NDF) have been attributed to dilution with increased nonstructural carbohydrates (Fisher et al., 1999). Because concentrations of water-soluble carbohydrates (WSC) were higher in the afternoon than in the morning in a 1-year study of the same grass species (Kramer et al., 2020), dilution of ADF and NDF with increased WSC is plausible. On most harvest dates, KBG had the highest NDF, in agreement with results obtained by Hockensmith et al. (1997) for vegetative samples of six cool-season grasses, including OG (49%), KBG (56%), and TF (52%). Concentrations of NDF in this study were in a range similar to that reported for a mixture of OG, KBG, and TF (54%; Weinert-Nelson et al., 2022).

Morning CP was not consistently higher or lower than afternoon CP in this study, and other studies have reported no effect of time of day (Burner & Belesky, 2004), effects only in certain months (Griggs et al., 2007), higher CP at sunset in TF hay (Fisher et al., 1999), and higher CP in the morning for fresh meadow fescue (Gregorini et al., 2009) and fresh PRG (Delagarde et al., 2000). Evening decreases in CP were attributed by Delagarde et al. (2000) to dilution with the increased amounts of soluble carbohydrates. Later final sampling times in the studies by Delagarde et al. (2000) and Gregorini et al. (2009) (after 6:00 pm, compared with 3:00–4:00 pm in the present study) may have allowed more time for soluble carbohydrate concentrations to increase, which may have led to greater dilution of CP and thus a consistent trend for lower CP concentrations at the end of the day.

Species differences in CP, with the highest values mostly in OG and PRG, were somewhat similar to those found among cool-season grasses grown in Utah and harvested from May to November (Jensen et al., 2017). In that study, OG and PRG had higher CP on average than KBG and TF, although concentrations varied among harvests. Allen et al. (2013) found that OG, PRG, and TF had similar CP in spring, while KBG had 20% lower CP, and in the fall, none of the 11 studied forage species differed in CP.

Afternoon IVTDMD was >90% in October and November 2015, and >85% in October and November 2017 (Table 2). Similar digestibilities (87%–93%) were determined for OG and for diploid and tetraploid PRG cultivars in Utah (Jensen et al., 2003), although the high IVTDMD in that study was possibly due to its being determined after 48 h (the present study used an equation for IVTDMD determined after 30 h of

digestion). TF hay had IVTDMD of 82%–89% (Fisher et al., 1999), and OG in Utah had IVTDMD of 87%–92% in October, depending on the height at which it was harvested (Griggs et al., 2007). The relatively high IVTDMD in the present study may be related to the frequent harvesting, as Hall (1998) found the highest digestible DM in grasses harvested at a 35-day interval, compared with a 70- and a 45-day interval. Hence, grazing at monthly intervals may provide forage high in IVTDMD.

5 | CONCLUSIONS

Forage nutritive value predicted by NIRS indicated that in monthly harvests of OG, PRG, KBG, and TF collected in the morning and afternoon, ADF was <35% in all species and at all collection times. Biweekly to monthly defoliation appeared associated with relatively low ADF; hence, regular grazing might ensure relatively low ADF as well. Among species, OG and PRG were lowest in ADF and NDF. Species with the highest predicted CP on most harvest dates in 2015 and 2017 were OG and PRG. On most harvest dates, IVTDMD was higher in the afternoon than in the morning, as might be expected with lower afternoon ADF and NDF. The results of this study could be used to select forages high in IVTDMD for beef cattle, or lower in IVTDMD for overweight horses. The results could also be used to choose optimal times of the day and year for grazing, depending on the energy requirements of the grazing animal.

AUTHOR CONTRIBUTIONS

AnnMarie C. Riley: Formal analysis; investigation; writing—original draft. **Isabelle A. Kagan:** Writing—review and editing. **Brittany E. Davis:** Formal analysis; writing—review and editing. **Laurie M. Lawrence:** Conceptualization; methodology; writing—review and editing. **Chris D. Teutsch:** Methodology; writing—review and editing. **S. Ray Smith:** Conceptualization; investigation; supervision; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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