Published online September 7, 2017

Forage & Grazinglands

Influence of Height-Based Management on Forage Nutritive Value of Four Warm-Season Forage Grasses

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Abstract

Harvest timing is an influential factor in providing animals with high quality forage. Height-based management is commonly practiced to determine timing of cutting or grazing. This study aimed to observe nutritive value changes in tall- and short-growing warm-season grasses with repeated cuttings. The experiment was conducted at the University of Tennessee Plateau AgResearch and Education Center in Crossville, TN, from 2013 to 2015. Four forages were evaluated, each for 2 yr: switchgrass [*Panicum virgatum* (L.) cv. Alamo], bermudagrass [*Cynodon dactylon* (L.) Pers. cv. Vaughn's #1], a sorghum × sudangrass hybrid [*Sorghum bicolor* (L.) Moench × *Sorghum sudanese* (P.) Stapf, cv. FSG208BMR], and crabgrass [*Digitaria sanguinalis* (L.) cv. Quick-N-Big]. Height-prescribed cutting treatments were established for each species, replicated four times, and arranged in a randomized complete block design. The regrowth forage was sampled weekly for nutritive value analysis using near-infrared spectroscopy and morphological composition on a dry mass basis. Most nutritive value variables did not differ between first and second cut at 1 and 2 wk postcutting ($P < 0.05$) but often differed at 3 wk postcutting. Similar patterns were observed for morphological components. In all cases, crude protein (CP) was positively correlated with proportion of lamina ($r > 0.50$). A negative linear relationship was observed between CP and herbage mass in switchgrass, sorghum × sudangrass, and bermudagrass ($r^2 > 0.20$, $P < 0.05$). This information can be used by producers to determine appropriate cutting frequency and estimate forage nutritive value in the field from herbage mass (HM).

Core Ideas

- Change in nutritive value was analyzed based on height for warm-season grasses.
- Herbage mass was estimated for each species at designated height.
- Predictive models based on herbage mass may be helpful for producers.

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Received 7 Oct. 2016.
Accepted 20 June 2017.

Abbreviations: ADF, acid detergent fiber; C_3, cool-season grasses; C_4, warm-season grasses; CP, crude protein; DM, dry matter; HM, herbage mass; NDF, neutral detergent fiber; NDFD, neutral detergent fiber digestibility; NIRS, near-infrared spectroscopy.

Conversions: For unit conversions relevant to this article, see Table A.

Published in Crop Forage Turfgrass Manage. Volume 3. doi:10.2134/cftm2016.10.0067

Forage Management and Nutritive Value

Sward height is commonly used to determine the appropriate time for cutting or grazing warm- and cool-season forage grasses based on plant maturity and accumulated herbage mass (HM) at designated heights. It is known that forage nutritive value declines with maturity and that digestibility decreases following the first forage harvest (Jarl and Helleday, 1951; Vona et al., 1984; George and Obermann, 1989; Moore et al., 1991; Burns et al., 1997; Difante et al., 2008; Nave et al., 2013; Richner et al., 2014; Temu et al., 2014). Warm-season grasses mature quickly, in turn developing high levels of fiber, especially lignin, in response to warm temperatures and low water availability (Buxton and Fales, 1994; Beck et al., 2015). Rapid

Table A. Useful conversions.

To convert Column 1 to Column 2, multiply by	Column 1 Suggested Unit	Column 2 SI Unit
0.304	foot, ft	meter, m
2.54	inch	centimeter, cm (10^{-2} m)
0.405	acre	hectare, ha
9.29×10^{-2}	square foot, sq ft	square meter, sq m
0.454	pound, lb	kilogram, kg
1.12	pound per acre, lb/acre	kilogram per hectare, kg/ha

regrowth rates of these grasses during mid-summer can be beneficial for producers who need additional forage when growth of cool-season grasses is reduced (Griffin and Jung, 1983; Madakadze et al., 1998; Iptas and Brohi, 2003; Trocsanyi et al., 2009). Warm-season forage should be harvested at a point where forage nutritive value and yield meet the goals of the production system, with attentive detail given to appropriate management.

Recommended harvest height varies by species due to the location of the meristem and the growth habit of the grass (Anderson and Matches, 1983; Kilcer et al., 2005; Hirata et al., 2010). When grazed or harvested for hay, defoliation should not occur below the meristem for best stand persistence, overall plant health, and animal performance (Burns and Fisher, 2008).

This experiment studied two tall-growing, upright grass species (switchgrass and sorghum × sudangrass) and two short-growing, prostrate grasses (bermudagrass and crabgrass) using height regimes as recommended by George and Obermann (1989), Ball et al. (2007), and Burns and Fisher (2008). The objective of this study was to observe how forage nutritive value changes in tall- and short-growing warm-season grasses with repeated cuttings under the hypothesis that nutritive value would be greater in early-than late-season cuttings and decrease as HM increases. The results of this experiment could aid in determining the appropriate number of harvests for these species and predicting nutritive value in the field in terms of hay production or rotational grazing events for livestock.

Site Description

This study was conducted at the Plateau AgResearch and Education Center in Crossville, TN (36° 0′ N, 85° 7′ W, 580-m elevation) from June to September 2013 to 2015 (simultaneously with the study of Gelley et al., 2016). Experimental units were 9.8- × 14.8-ft plots arranged in a randomized complete block design with four replications. Cuttings were considered our treatments; therefore, the warm-season annuals sorghum × sudangrass and crabgrass had three treatments (cuttings) with four replications, and the warm-season perennials switchgrass and bermudagrass had four treatments (cuttings) with four replications.

In 2013, three species were tested: switchgrass, sorghum × sudangrass, and bermudagrass. In 2014, crabgrass was added to the experiment, bermudagrass omitted due to winterkill, and both switchgrass and sorghum × sudangrass were tested for a second year. In 2015, bermudagrass and crabgrass were tested for a second year.

Before the experiment began, all existing vegetation above 8 inches for switchgrass and above 3 inches for bermudagrass was harvested, and warm-season annual plots were tilled and seeded. Switchgrass and bermudagrass plots were previously established in 2008. Due to winterkill during the winter of 2013/2014, bermudagrass was re-established via sprigging at 12.4 ft^3/acre in May 2014. Sorghum × sudangrass was broadcast seeded at 45 lb/acre on 6 June 2013 and on 3 June 2014. Crabgrass was broadcast seeded at 5 lb/acre on 27 May 2014 and 20 May 2015.

Results presented by Gelley et al. (2016) documented the influence of using the calendar year to dictate harvest and the influence of that management system on forage nutritive value and herbage mass for these species using similar methods. Treatments were a single cut made on varying dates to the sward without a reoccurring harvest, after which changes in nutritive value and herbage mass accumulation (HMA) were mapped to detect predictable patterns of change. In contrast, the present study compared nutritive value and HMA in plots that were harvested multiple times throughout the growing season.

Height-based cutting regimes were imposed on each species. Switchgrass and sorghum × sudangrass were cut at 8-inch stubble height when plant height averaged 30 inch while bermudagrass and crabgrass were cut at 3-inch stubble height when plant height averaged 12 inches. These cutting regimes were recommended based on the location of the meristems of each species. Plots were measured weekly for average sward height and cut each time the sward reached its target height as assigned by species (Table 1).

Soil conditions on location were Lonewood loam (loamy residuum weathered from sandstone, fine-loamy, siliceous, semiactive, mesic Typic Hapludults, 2–5% slopes, well-drained, 40–80 inches to paralithic bedrock) and Ramsey loam (loamy residuum weathered from sandstone, loamy,

Table 1. Dates of cuts from the 2013–2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

	Cutting Dates			
	First Cut	Second Cut	Third Cut	Fourth Cut
Switchgrass				
2013	5 June	1 July	1 August	4 September
2014	6 June	7 July	1 August	14 August
Sorghum × Sudangrass				
2013	1 July	1 August	4 September	n/a
2014	7 July	1 August	14 August	n/a
Bermudagrass				
2013	5 June	1 July	1 August	4 September
2015	4 June	18 June	6 July	3 August
Crabgrass				
2014	7 July	1 August	14 August	n/a
2015	13 July	3 August	28 August	n/a

siliceous, subactive, mesic Lithic Dystrudepts, 5–12% slopes, somewhat excessively drained). Initial soil nutrient levels of the experimental site were pH = 5.8, P = 29.4 lb/acre, K = 108.8 lb/acre, Ca = 2092 lb/acre, and Mg = 104.4 lb/acre.

Nitrogen fertilizer was applied each year at the rate of 60 lb/acre to all plots. In 2013, fertilization took place on 5 June for sorghum × sudangrass and on 6 June for switchgrass and bermudagrass. In 2014, switchgrass was fertilized on 6 May, and sorghum × sudangrass and crabgrass were fertilized on 20 May in 2014. In 2015, bermudagrass and crabgrass were fertilized on 1 May.

Measurements

Forage samples were collected weekly during periods of rapid regrowth from June to July and were collected on alternate weeks during periods of slow regrowth from August to September to characterize morphological composition and forage nutritive value. Maturity was communicated in terms of time passed since previous cut and referred to as "weeks post cutting" (Tables 2, 3, 4, and 5).

One 1-ft^2 sample was harvested within each experimental unit per sampling date. Sample quadrants were selected randomly on each sampling date while never repeatedly sampling the same area. The vertical subsamples were then separated by morphological components (green lamina, dead material, stem+sheath) and dried at 140°F for 72 h to determine the proportion of each morphological component. Subsamples were recombined with their corresponding components, and dry mass (DM) of the whole sample was used to determine HM for the experimental unit before forage nutritive value analysis.

Samples were ground through a 1-mm sieve with a Wiley Mill Grinder (Thomas Scientific, Swedesboro, NJ) in preparation for near-infrared spectroscopy (NIRS). Samples were analyzed for multiple quality factors on a DM basis, with

Table 2. Selected nutritive value parameters of switchgrass cuttings by maturity averaged across the 2013 and 2014 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

Stage of maturity	First Cut	Second Cut	Third Cut	Fourth Cut	*P*
Weeks post cutting		†CP %			
1	11.3^{a}‡	12.3^{a}	9.0^{a}	.	0.2338
2	13.9^{a}	12.7^{ab}	11.0^{b}	8.2^{c}	< 0.0001
3	15.1^{a}	12.2^{b}	9.6^{b}	.	0.0005
		†ADF %			
1	41.9^{ab}	40.1^{b}	44.5^{a}	.	0.0447
2	38.2^{b}	39.6^{b}	40.0^{ab}	44.8^{a}	0.0073
3	37.1^{b}	40.3^{a}	42.9^{a}	.	0.0041
		†NDF %			
1	63.2^{a}	60.7^{a}	66.1^{a}	.	0.1498
2	57.4^{b}	60.5^{b}	61.0^{b}	67.1^{a}	0.0005
3	57.0^{b}	61.5^{a}	65.2^{a}	.	0.0014
		†NDFD %			
1	59.1^{a}	56.5^{ab}	50.3^{b}	.	0.0295
2	58.0^{a}	57.0^{ab}	53.0^{b}	43.4^{c}	< 0.0001
3	60.6^{a}	55.2^{b}	47.7^{c}	.	0.0002

† CP, crude protein; ADF, acid detergent fiber; NDF neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

‡ Means within a row without a common superscript letter differ ($P < 0.05$).

Table 3. Selected nutritive value parameters of sorghum × sudangrass cuttings by maturity averaged across the 2014 and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

Stage of maturity	First Cut	Second Cut	Third Cut	*P*
Weeks post cutting		†CP %		
1	17.7^{a}‡	13.3^{b}	9.7^{b}	0.0003
2	14.8^{a}	13.1^{ab}	10.2^{b}	0.0214
3	13.5^{a}	11.6^{a}	.	0.2869
4	10.8^{a}	11.8^{a}	10.5^{a}	0.496
		†ADF %		
1	33.5^{c}	38.9^{b}	50.0^{a}	< 0.0001
2	37.8^{b}	42.5^{ab}	45.7^{a}	0.029
3	40.9^{a}	42.4^{a}	.	0.5596
4	42.7^{ab}	41.7^{b}	45.2^{a}	0.0233
		†NDF %		
1	50.7^{c}	60.1^{b}	72.3^{a}	< 0.0001
2	56.1^{b}	60.6^{ab}	67.4^{a}	0.0143
3	60.7^{a}	63.8^{a}	.	0.4343
4	63.5^{a}	62.0^{a}	66.3^{a}	0.0875
		†NDFD %		
1	55.7^{a}	53.4^{ab}	50.7^{b}	0.0541
2	54.9^{a}	49.9^{a}	49.2 ^{a}	0.2105
3	55.7^{a}	51.3^{b}	.	0.0401
4	56.0^{a}	52.6^{b}	47.2^{c}	< 0.0001

† CP, crude protein; ADF, acid detergent fiber; NDF neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

‡ Means within a row without a common superscript letter differ ($P < 0.05$).

Table 4. Selected nutritive value parameters of bermudagrass cuttings by maturity averaged across the 2013 and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

Stage of maturity	First Cut	Second Cut	Third Cut	Fourth Cut	*P*
Weeks post cutting			†CP %		
1	14.5[a]‡	12.3[ab]	13.0[ab]	7.6[b]	0.0539
2	17.4[a]	14.4[b]	10.5[c]	9.5[c]	< 0.0001
3	14.7[a]	10.9[b]	11.4[b]	8.2[c]	< 0.0001
4	.	.	8.3[a]	6.2[a]	0.0666
			†ADF %		
1	37.9[a]	38.9[a]	36.0[a]	41.2[a]	0.5396
2	33.4[b]	37.3[a]	39.4[a]	39.0[a]	< 0.0001
3	35.1[c]	40.9[ab]	36.8[bc]	44.0[a]	0.002
4	.	.	40.0[b]	43.1[a]	0.0206
			†NDF %		
1	59.6[a]	61.7[a]	57.6[a]	59.9[a]	0.6834
2	55.2[b]	60.4[a]	61.1[a]	62.0 [a]	< 0.0001
3	57.8[b]	64.0[a]	56.2[b]	63.8[a]	0.0009
4	.	.	61.5[b]	66.4[a]	0.0122
			†NDFD %		
1	46.4[a]	49.4[a]	55.3[a]	43.9[a]	0.1467
2	57.0[a]	53.2[a]	48.3[b]	45.6[b]	0.0005
3	54.9[a]	46.5[ab]	53.7[a]	44.2[b]	0.0058
4	.	.	43.3[a]	37.9[b]	0.0186

† CP, crude protein; ADF, acid detergent fiber; NDF neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

‡ Means within a row without a common superscript letter differ ($P < 0.05$).

Table 5. Selected nutritive value parameters of crabgrass cuttings by maturity averaged across the 2014 and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

Stage of maturity	First Cut	Second Cut	Third Cut	*P*
Weeks post cutting		†CP %		
1	10.2[a]‡	10. 8[a]	8.9[a]	0.5161
2	13.1[a]	11.5[a]	10.7[a]	0.1817
3	12.7[a]	11.0[a]	.	0.1336
		†ADF %		
1	49.3[a]	44.7[a]	48.8[a]	0.3612
2	42.5[a]	42.5[a]	43.0[a]	0.9792
3	39.5[b]	43.6[a]	.	0.0149
		†NDF %		
1	66.7[a]	63.2[a]	67.4[a]	0.4761
2	59.3[a]	60.1[a]	62.3[a]	0.5886
3	56.2[b]	61.1[a]	.	0.0243
		†NDFD %		
1	54.0[a]	50.1[a]	48.1[a]	0.3399
2	52.9[a]	50.4[a]	49.8[a]	0.6636
3	52.6[a]	48.2[b]	.	0.0061

† CP, crude protein; ADF, acid detergent fiber; NDF neutral detergent fiber; NDFD, neutral detergent fiber digestibility.

‡ Means within a row without a common superscript letter differ ($P < 0.05$).

CP, acid detergent fiber (ADF), neutral detergent fiber (NDF), and neutral detergent fiber digestibility (NDFD) of particular interest for this experiment, using a FOSS 5000 NIRS instrument (FOSS NIRS, Laurel, MD). Equations for the forage nutritive analyses were standardized and checked for accuracy using the 2013 Mixed Hay Equation developed by the NIRS Forage and Feed Consortium (NIRSC, Hillsboro, WI). Software used for NIRS analysis was Win ISI II supplied by Infrasoft International LLC (State College, PA). The Global *H* statistical test compared the samples against the model and samples from distinct datasets within the database for accurate results, where all forage samples fit the equation ($H < 3.0$) and are reported accordingly (Murray and Cowe, 2004).

Data Analysis

Differences between least square means by treatment for CP, ADF, NDF, or NDFD were evaluated using the PROC MIXED procedures of SAS (SAS for Windows V 9.4, SAS Institute, Cary, NC). Fixed effects were cutting events and stage of maturity (weeks postcutting). Year and rep were random effects. Simple regression analysis (PROC REG) in SAS was used to determine the relationship between HM and CP, as well as, between HM and NDFD, across the height-based cutting regimes. Differences between least squares means by treatment for morphological composition variables of green-lamina proportion, dead proportion, and stem+sheath proportion were tested for each species using the PROC MIXED procedures of SAS. Treatment was a fixed effect, and year was a random effect. Pearson Correlation Coefficients (PROC CORR) were used in SAS (SAS for Windows V 9.4, SAS Institute, Cary, NC) to test existent relationships between forage nutritive value (CP and NDFD) and the different morphological composition variables (green-lamina proportion, dead proportion, stem+sheath proportion, and HM) within each height-based cut. All results were evaluated for significance at $P < 0.05$.

Weather

In 2013 from June to September, temperature was 0.5°F below the 30-yr average, and precipitation was 28% above the 30-yr average (17.7 inch). In 2014 from June to September, temperature was 1°F above the 30-yr average, and precipitation was 10% above the 30-yr average. In 2015 from June through September, temperature was 1.5°F above the 30-yr average, and precipitation was 69% above the 30-yr average (Fig. 1).

Forage Nutritive Value by Maturity

In all species, the observed ranges of CP, ADF, NDF, and NDFD were comparable to those recorded in other experiments (Bosworth et al., 1980; Griffin and Jung, 1983; Vona et al., 1984; Teutsch et al., 2005; Starks et. al., 2006; Beck et al., 2015 Burns and Fisher, 2008; Temu et al., 2014; Gelley et al., 2016). It

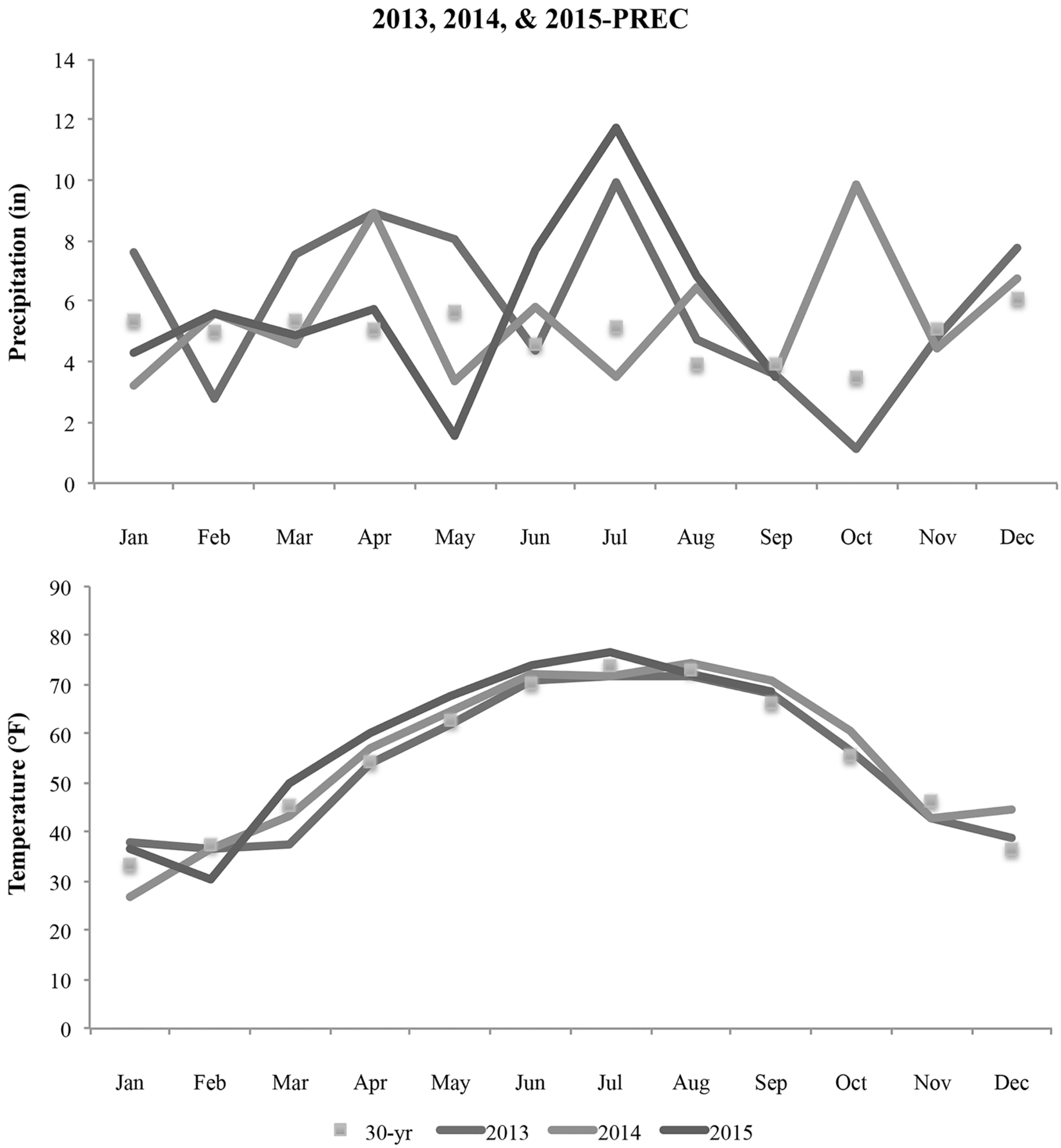

Fig. 1. Weather for Crossville, TN, including 30-yr average, 2013, 2014, and 2015.

was expected that nutritive value would differ among cuts of each species, with earlier cuts producing herbage with higher nutritive value than later cuts when the samples were compared at similar stages of maturity (weeks postcutting) (Tables 2, 3, 4, and 5). When compared by weeks postcutting, nutritive value differed as expected, decreasing after multiple cuts.

For the tall-growing species, most variables differed at 1 and 2 wk postcutting, but the difference in ADF and NDF contents became less apparent at 3 and 4 wk postcutting (Tables 2 and 3). In switchgrass, CP did not differ among cuttings at 1 wk postcutting, but after 3 wk, the first cut had a greater CP content than the other seasonal cuttings (Table 2). After 3 wk of regrowth following first cut, forage contained less ADF, NDF and had greater NDFD than the other cuts. These results correspond with the findings of Koshi et al. (1982) and Kering et al. (2013), which suggested multiple cuts per season would produce higher quality forage throughout the growing season

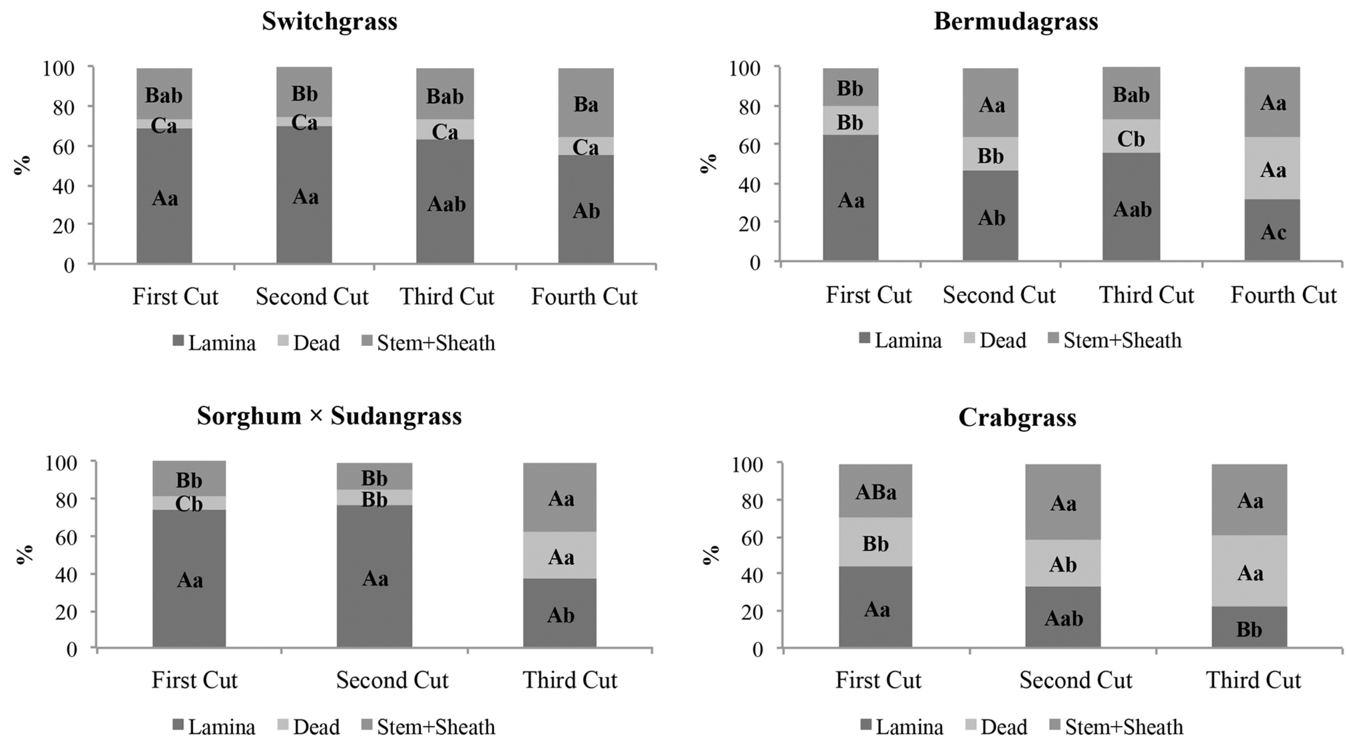

Fig. 2. Morphological composition (lamina, stem+sheath, and dead material) for the 2013, 2014, and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN. Capital letters indicate differences among proportions of lamina, dead, and stem+sheath within each cutting (by column). Lowercase letters indicate differences among cuttings for each morphological component (by row).

than a single-cut system, and with the findings of Perry and Baltensperger (1979) and Anderson and Matches (1983), which observed decreases in switchgrass forage CP and digestibility in more mature plants. For sorghum × sudangrass, CP differed at 1 wk postcutting with the first cut greater than the remaining cuts, but at 3 and 4 wk postcutting, there were no differences. After 4 wk, the NDFD content of the first cut was greater than the others. Kilcer et al. (2005) had similar results for CP and digestibility, detecting no difference between cuts in a three-cut sorghum × sudangrass system.

For the short-growing species, only CP differed among cuts at 1 wk postcutting, but after 3 wk, differences for all nutritive value variables were apparent (Tables 4 and 5). In bermudagrass at 1 wk postcutting, CP content was greater for first than fourth cut, and at 3 wk postcutting, the first cut was greater than the subsequent cuts (Table 4). For ADF after 3 wk, the first cut had lower ADF content than the others. For NDF at 3 wk postcutting, the second and fourth cut had a greater NDF content than first and third cut. Neutral detergent fiber digestibility of bermudagrass was greater for the first and third cuts than fourth cut while the second cut did not differ from the others at 3 wk postcutting. These results correspond with the findings of Belesky et al. (1991), which determined that CP and digestibility decrease as stands mature. The cases in which first and third cuts did not differ can be explained by the high precipitation during July in both years. Third cut generally occurred after rainfall events, and the forage regrowth that resulted had low stem+sheath and high-lamina proportions, which were similar to what was observed for the first cut (Fig. 2). In the case of crabgrass, there were no differences in CP content among cuts from 1 to 3 wk post initiation (Table 5). This was likely due to the lack of change in stem+sheath material among cuts, which kept CP constant throughout the season (Fig. 2). Neither ADF nor NDF differed among cuttings until 3 wk post cutting, at which the first cut had lower ADF and NDF amounts and greater NDFD amounts than second cut (Table 5). These results support the statements of Dalrymple et al. (1999) as well as the results of Teutsch et al. (2005) and Beck et al. (2015) indicating that crabgrass produces forage of high nutritive value throughout the growing season with appropriate nitrogen fertilization, appropriate harvest intervals, and adequate moisture.

In multiple cases, there were no differences among cuts, most commonly between first and second cuts (Tables 2, 3, 4, and 5), which would suggest that nutritive value does not change between these cuts for these species when height-based management is used. However, this is dependent on how mature the regrowth is due to the accumulation of fiber in mature forage.

Differences among cuttings in CP, ADF, NDF, and NDFD were detected for tall- and short-growing species, except crabgrass, which showed no difference in CP among cuts, probably because stem+sheath proportion changed little during the growing season (Tables 1, 2, 3, 4, and 5). In most cases, nutritive value decreased from first to last cut. These findings correspond to the patterns observed in many warm- and cool-season grass studies where nutritive value is highest in young herbage regrowth and declines with maturity (Perry and Baltensperger, 1979; Bosworth et al., 1980; Belesky et al., 1991; Iptas and Brohi, 2003; Nave et al., 2013; Gelley et al., 2016). Correlations between morphological components and nutritive value variables indicated a positive relationship between proportion of lamina and CP content for all species ranging from 0.6967 to 0.8829, which allows us to tie morphology to a key component in determining forage nutritive value. In addition, yield and quality factors could be positively influenced under more generous fertilization programs (Perry and Baltensperger, 1979; Kering et al., 2013; Kilcer et al., 2005; Teutsch et al., 2005). However, many studies have documented that low rates of applied N can be successful in producing forage of adequate yields and nutritive value for beef cattle, which met the goal of the present study (Perry and Baltensperger, 1979; Belesky et al., 1991; Iptas and Brohi, 2003; Beck et al., 2015).

Morphological Composition

For all species, proportion of lamina material was greater with earlier cuts than later cuts, and proportions of stem+sheath and dead material were lower with earlier cuts than later cuts. This was expected because as the season progresses, these grasses develop quickly, accumulating fibrous stem material while the proportion of lamina tissue, which contains much of the plant CP, is reduced (Griffin and Jung, 1983; Gelley et al., 2016). Warm temperatures and low water availability contribute to this process (Buxton and Fales, 1994; Beck et al., 2015). Having above-average rainfall in all study years likely reduced or postponed the accumulation of stem+sheath, and therefore, the accumulation of fiber in all species. In addition, above-average rainfall may have resulted in substantial leaching of nitrate, reducing N availability for subsequent growth.

For switchgrass, morphological composition among cuts did not differ until the fourth cut. When proportions of lamina, dead, and stem+sheath were compared to one another by individual cuts for switchgrass, the pattern remained the same from the first to fourth cut, with lamina greater than stem+sheath, and stem+sheath greater than dead. For sorghum × sudangrass, the difference in morphological composition among cuts was observed after the third cut. When sorghum × sudangrass components were compared with one another, the proportion of lamina was greater than the proportion of stem+sheath for the first and second cuts, but for the third cut, there were no differences, which supports the idea that nutritive value can remain high in a multi-cut system, provided stem+sheath digestibility is relatively high (Perry and Baltensperger, 1979).

For bermudagrass, the proportion of dead did not differ among cuts until the fourth cut while the proportion of lamina and stem+sheath was variable among cuttings. In addition, when components were compared with one another by cut, the proportion of lamina was greater than the proportion of dead for first, second, and third cuts while the proportion of stem+sheath varied. This variation matches the pattern observed for bermudagrass nutritive value and can be explained by the heavy fluctuation of rainfall during 2013 and 2015 from June through September, which would have impacted the ratio of stem+sheath to lamina tissue between cuts (Fig. 1). For crabgrass, the proportion of dead material was greater following the third cut than the first and second cuts, stem+sheath material did not differ, and the proportion of lamina was greater following the first than the third cut. When components were compared with one another by cut, the proportion of lamina was greater than the proportion of dead for the first cut, no differences were observed for the second cut, and the proportion of lamina was less than the proportions of dead and stem+sheath for the third cut. These results confirm the relationships between cuts and nutritive value as previously discussed for crabgrass.

Relationships between Forage Nutritive Value Factors and Herbage Mass

Based on the generalized linear regression relationships across height-based cuts, the use of HM to predict CP was significant for switchgrass, sorghum × sudangrass, and bermudagrass as well as to predict NDFD of switchgrass (Fig. 3 and 4). However, these functions explained only from 18 to 37% of the variation in the nutritive value variables analyzed. Relationships between CP and HM were stronger for the tall-growing species (switchgrass: $r^2 = 0.28$, $P = 0.0067$; sorghum × sudangrass: $r^2 = 0.28$, $P = 0.0198$) than the short-growing species (bermudagrass: $r^2 = 0.20$, $P = 0.0420$; crabgrass: $r^2 = 0.18$, $P = 0.0897$). Negative linear regression relationships between NDFD and HM only existed for switchgrass ($r^2 = 0.37$, $P = 0.0012$) (Fig. 4). Nave et al. (2013) confirmed similar relationships between NDFD and HM in cool-season grasses. Additional support for the legitimacy of these relationships can be found through the correlation analysis of this experiment. As CP was negatively correlated to HM in switchgrass, sorghum × sudangrass, and bermudagrass ($r > -0.50$), NDFD was negatively correlated to HM in switchgrass ($r = -0.61$). The corresponding regression equations could be used to estimate nutritive value from herbage samples without costly laboratory analysis. These results correspond to the findings of Gelley et al. (2016).

Conclusions

Managing forage based on height is a practical method for producers; however, sward height is not necessarily an indication of nutritive value. Through this experiment, relationships between nutritive value and HM, as well as the differences in forage regrowth following repeated cuttings, were examined to evaluate the reliability of height-based management for four warm-season forage grasses.

After studying the effects of height-based management on CP and NDFD during years of adequate moisture and average

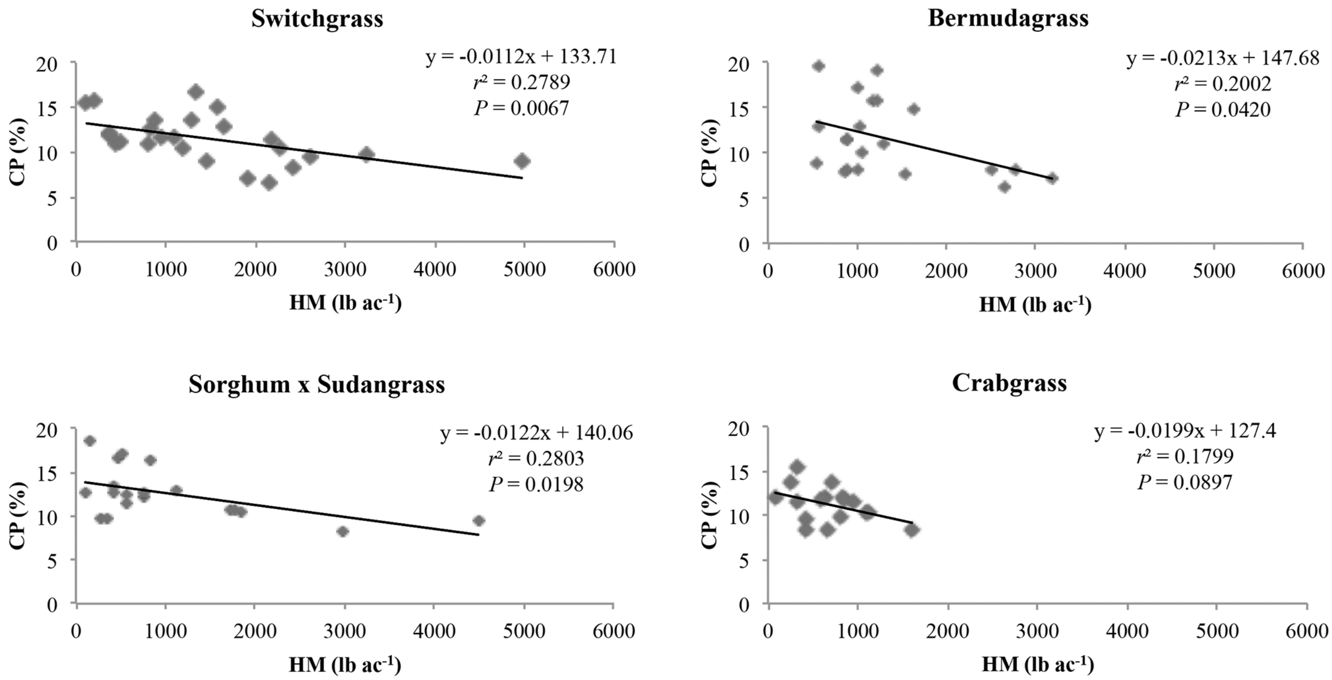

Fig. 3. Relationship between crude protein (CP) and herbage mass (HM) during the 2013, 2014, and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

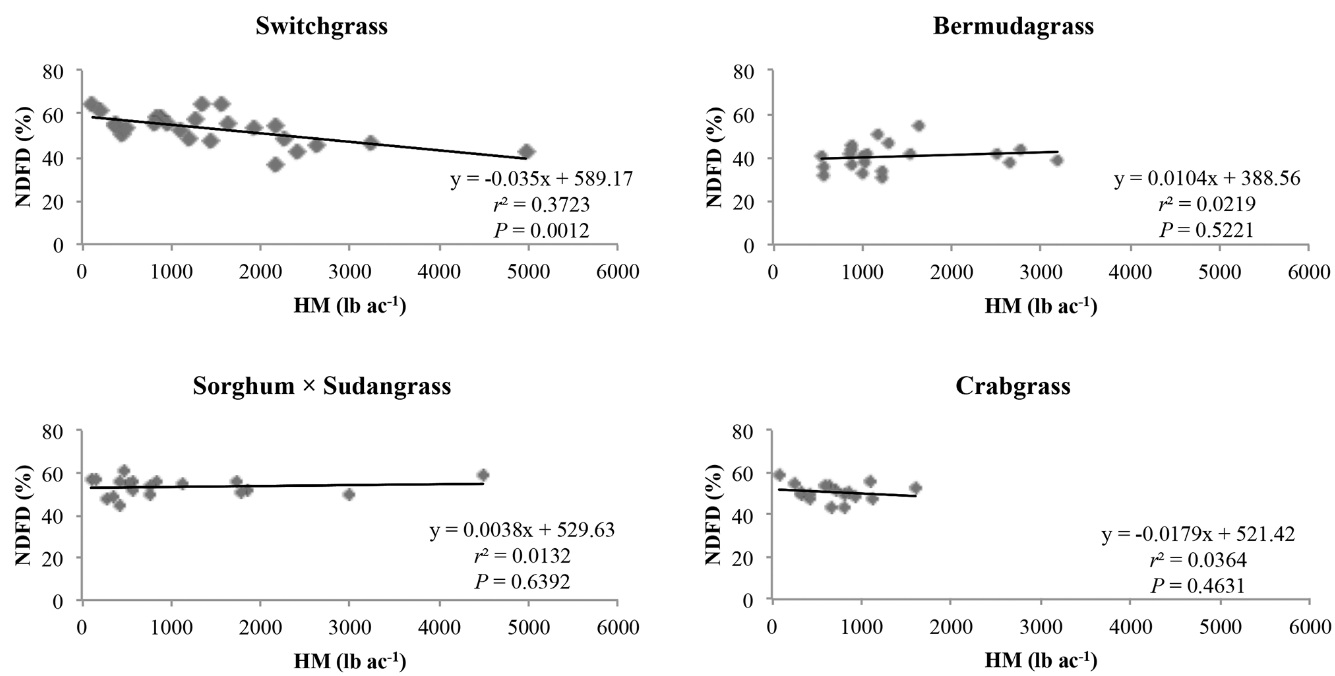

Fig. 4. Relationship between neutral detergent fiber digestibility (NDFD) and herbage mass (HM) during the 2013, 2014, and 2015 growing seasons at Plateau AgResearch and Education Center, Crossville, TN.

temperatures, we have compiled recommendations for the appropriate number of height-based cuts per growing season for each species. A three-cut system is suggested for switchgrass, bermudagrass, and crabgrass, and a two-cut system is recommended for sorghum × sudangrass. In some cases, difference in forage nutritive value between cuts was evident at 3 wk postcutting, suggesting plant maturity rather than sward height may be the best indicator of harvest timing. Predictive models based on other measurements, such as growing degree-days, may be helpful for determining ideal cutting time.

Results of this experiment suggest CP of switchgrass, sorghum × sudangrass, and bermudagrass can be predicted by HM. In the case of switchgrass, NDFD can also be predicted by HM. Herbage mass is a variable that can easily be measured in the field to estimate nutritive value based on the corresponding regression equations, which should be used with caution due to low r^2 values. Utilizing sward height measurements in combination with these predictive models could assist producers in harvesting or grazing forage of desirable nutritive value.

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