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Production and nutritional value of Mulato II grass forage harvested at different cutting intervals and intensities

Producción y valor nutricional de forraje de pasto Mulato II cosechado a diferente intervalo e intensidad de corte

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ABSTRACT

Agronomic management in grasslands directly influences yield, nutritional value, and the morphological and structural characteristics of grasses. The objective was to evaluate the productive performance of Mulato II grass under different cutting intervals and intensities. Cutting intervals of 2, 4, 6, 8, 10, and 12 weeks and cutting heights of 10 and 20 cm were evaluated using a randomized complete block design with three replications. Yield, morphological composition, nutritional value, growth rate, and morphological and structural characteristics were assessed. The highest total dry matter yield was obtained at 10- and 12-week intervals (8011 and 7167 kg ha^{-1}, respectively) at a cutting height of 10 cm. Crude protein content was highest at the 4-week interval with cutting heights of 10 and 20 cm (139 and 129 g kg^{-1} DM, respectively), and at the 6-week interval with a cutting height of 10 cm (119 g kg^{-1} DM). The highest acid and neutral detergent fiber contents were recorded at the 8-week interval at both cutting heights, while the highest lignin content was observed at the 8-week interval and 20 cm cutting height (41 g kg^{-1} DM). Extending the cutting interval resulted in increased forage production; however, nutritional value decreased.

KEY WORDS: *Yield*; growth rate; nutritional value, Urochloa hybrid.

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RESUMEN

El manejo agronómico en la pradera incide directamente sobre el rendimiento, valor nutritivo, características morfológicas y estructurales de los pastos. El objetivo fue evaluar el comportamiento productivo de pasto Mulato II a diferente intervalo e intensidad de corte. Se evaluaron intervalos de 2, 4, 6, 8, 10 y 12 semanas e intensidades de corte de 10 y 20 cm, mediante un diseño de bloques completos al azar con tres repeticiones. Se evaluó el rendimiento, composición morfológica, valor nutritivo, tasa de crecimiento, características morfológicas y estructurales. El rendimiento de materia seca total fue mayor a intervalo de 10 y 12 semanas (8011 y 7167 kg ha^{-1}, respectivamente) a intensidad de 10 cm. El contenido de proteína fue mayor a intervalo de 4 semanas a intensidad de 10 y 20 cm (139 y 129 g kg^{-1} DM), respectivamente y, en la sexta semana a intensidad de 10 cm (119 g kg^{-1} DM). El mayor contenido fibra detergente ácida y neutra se obtuvo a intervalo de 8 semanas a intensidades de 10 y 20 cm y el contenido de lignina a intervalo de corte de 8 semanas a intensidad de 20 cm (41 g kg^{-1} DM). Prolongar el intervalo de corte indujo mayor producción de forraje, sin embargo, el valor nutricional disminuyó.

PALABRAS CLAVE: Rendimiento; tasa de crecimiento; valor nutritivo, *Urochloa híbrido*.

Introduction

In tropical regions, grasses are the primary source of feed for ruminants; however, environmental conditions and agronomic management of pastures directly affect their yield and quality, making both the nutritional value and dry matter production variable (Garay-Martínez *et al.,* 2018; Torres *et al.,* 2020). Among the grasses used, pastures are the most prominent, as they represent the most abundant feed source for ruminants and are readily accessible to most livestock producers. Pasture utilization can take different forms, such as direct grazing of forage species in grasslands or pastures (Enríquez *et al.,* 2021), or through cutting and transporting the forage to confinement areas to be offered either alone or mixed with other ingredients (Morby & Fraser, 2021). Although pastures have traditionally been classified as a low-nutritional-value feed source, this largely depends on the agronomic management applied to the grassland (Godina-Rodríguez *et al.,* 2023). Forage yield varies with cutting interval (Garay-Martínez *et al.,* 2018; Godina-Rodríguez *et al.,* 2022) and directly influences the nutritional value of the harvested forage (Rojas-García *et al.,* 2018).

In Tamaulipas state, the introduction of tropical grasses such as Buffel grass (*Penissetum ciliare*) reduced the grazing coefficient from 12 to 4 ha per animal unit (Hanselka, 1985). This

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led to widespread acceptance among livestock producers for its use in ruminant feeding, to the extent that by 2007, approximately 260,000 ha in Tamaulipas were established with this forage species (Díaz *et al.,* 2007). The introduction of forage species into specific agroecological regions is an ongoing process aimed at establishing species with improved forage traits in terms of yield and quality (Enríquez *et al.,* 2021). In this regard, Garay-Martínez *et al.* (2018) evaluated *Urochloa* cultivars (Cayman, Cobra, Mulato II, and Insurgente) and Buffel grass cv. H-17 as a control under different cutting intervals (4, 6, and 8 weeks). They found that total dry matter yields were highest at the 8-week interval, with *Urochloa* cultivars outperforming Buffel grass cv. H-17 during both the dry and rainy seasons; however, cutting intensity is also a key factor affecting forage yield (Godina-Rodríguez *et al.,* 2022) and nutritional value (Rojas-García *et al.,* 2018), in addition to inducing changes in growth rate (Calzada-Marín *et al.,* 2014), specific leaf area, and leaf area index (Godina-Rodríguez *et al.,* 2022). Given this background, it is essential to consider these factors and determine the optimal timing for pasture utilization. Thus, the present study aimed to evaluate the productive performance of Mulato II grass under different cutting intervals and intensities.

Material and Methods

Experimental site location

The experiment was conducted at the “Ingeniero Herminio García González” Animal Science Research Station of the Faculty of Engineering and Sciences, Universidad Autónoma de Tamaulipas, located at geographic coordinates 23° 56’ 26.5” N and 99° 05’ 59.9” W, at an altitude of 193 masl. The evaluation period spanned from May to September 2021.

Climatic and edaphic characteristics

The experimental site’s climate is semi-arid, classified as BS1 (h’) hw (Vargas *et al.,* 2007). The average annual temperature and precipitation are 24 °C and 740 mm, respectively (SMN, 2010) (Figure 1).

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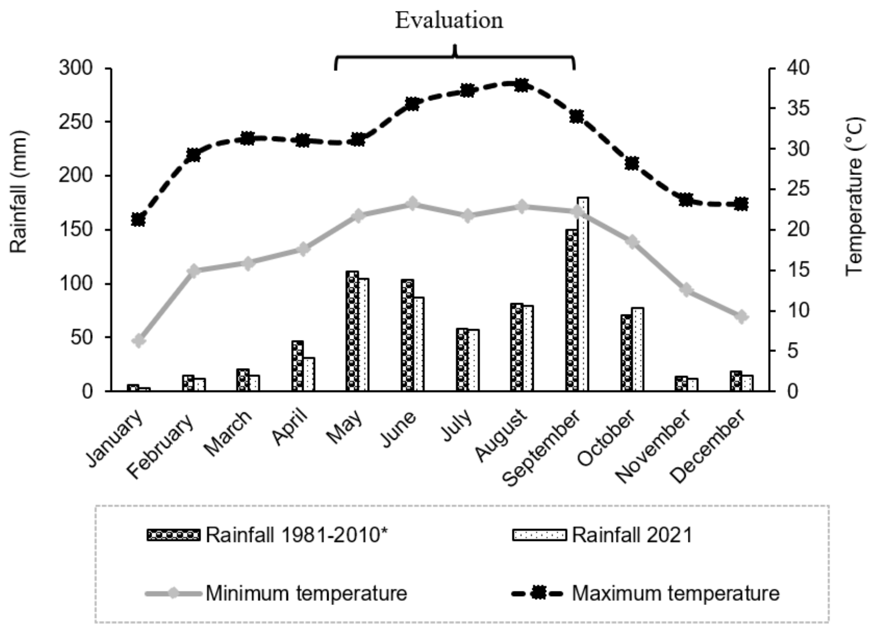

Figure 1. Temperature and rainfall monthly accumulated during 2021 and accumulated rainfall over 29 years in Guémez, Tamaulipas (SMN*)

The soil is clayey, with an alkaline pH of 8.3 (Garay-Martínez *et al.,* 2018). However, a soil analysis was conducted to determine the percentages of sand, silt, and clay, as well as the pH value. In addition, the concentrations of total carbonates, sodium adsorption ratio, organic matter content (%), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), and zinc (Zn) were determined and expressed in mg kg^{-1} (Table 1).

Table 1. Chemical and physical characteristics of the soil at the experimental site.

pH	tN	OM	tCa	P	K	Fe	Zn	Sand	Silt	Clay	SAR
	%			mg kg^{-1}				%			
8.0	0.23	3.8	37.9	2.15	0.72	7.08	0.52	12.8	28.7	58.5	0.87

tN: total nitrogen; OM: organic matter; tCa: total carbonates; P: phosphorus; K: potassium; Fe: iron; Zn: zinc; SAR: sodium adsorption ratio.

Revista Bio ciencias
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Treatments and agronomic management

The treatments consisted of cutting intervals (2, 4, 6, 8, 10, and 12 weeks) and cutting intensities (10 and 20 cm). The evaluation was carried out during the peak rainfall season in 2021, when the pasture was seven months post-establishment. Before evaluation, a uniformity cut was performed according to the cutting intensity under study: 10 and 20 cm of residual height. The total area used was 2,500 m^2, with 25 m^2 plots (5x5 m) were established for each treatment. For each regrowth age, forage was randomly harvested, with three replications per treatment. The effective sampling area was 1 m^2, where measurements of the evaluated variables were taken. During the establishment period, the pasture was fertilized with 50 kg ha^{-1} of N, P, and K.

Variables evaluated in pasture forage

Plant height

To estimate plant height, three readings were taken to obtain the average height (cm) at each cutting intensity within each experimental unit (1 m^2), using a graduated wooden ruler. Measurements were taken from the soil surface to the most homogeneous point at the apex of the leaves.

Leaf area

To estimate leaf area, ten leaf blades from five stems per sample were selected and measured using a leaf area integrator model CL-202 (CID Bio-Science® Inc., USA), which reports leaf area in cm^2.

Dry matter yield and morphological composition

To determine dry matter (DM) yield and morphological composition, the harvested forage from each treatment was weighed immediately to obtain the fresh forage yield (FFY). Subsequently, a 300 g subsample was taken and separated into its morphological components: leaf (leaf blade + sheath), stem, and senescent material (leaf blades with more than 50 % chlorotic tissue). The samples were dried in a forced-air oven (OMS60, Thermo Scientific®, USA) at 55 °C until reaching constant weight. Each morphological component was weighed before (fresh weight, FW) and after drying (dry weight, DW) using an analytical balance (CQT 2601, ADAM®, USA) to determine the percentage of dry matter content.

Response variables

Crop growth rate, leaf area index, and specific leaf area

Using dry matter yield data, the crop growth rate, leaf area index, and specific leaf area were estimated based on the following formulas:

Revista Bio ciencias
ISSN 2007-3380

Crop growth rate:

$$CGR = \frac{HF}{T}$$

Where: CGR = Crop Growth Rate (kg ha^{-1} d^{-1}), HF = Harvested forage (kg ha^{-1}), and T = Time (days).

Leaf area index:

$$LAI = \frac{LA}{S}$$

Where: LAI = Leaf Area Index, LA = Leaf area, and S = Surface area occupied (1 m^2)

Specific leaf area:

$$SLA = \frac{LA}{DWLA}$$

Where: SLA = Specific Leaf Area (cm^2 g^{-1}), LA = Leaf area of the sample (cm^2), and DWLA = Dry weight of leaf area (g).

Forage nutritional value

To determine the nutritional value of the forage, only cutting intervals of 4, 6, and 8 weeks were considered. Crude protein content was estimated following the methodology described by AOAC (2000), while the contents of acid detergent fiber, neutral detergent fiber, and lignin were determined using the methodology described by Van Soest *et al.* (1991).

Statistical analysis

The data from the evaluated variables were analyzed using the GLM procedure (SAS, 2002), in a randomized complete block design. Tukey's test was applied for mean comparisons (p =0.05).

Results and Discussion

Plant height

Plant height differed among the treatments evaluated (p =0.05). The greatest plant height was obtained with a 10-week cutting interval at a 20 cm cutting intensity, with an average of 101 cm (Table 2). When harvesting at a 12-week interval, plant height was similar between cutting

Revista Bio ciencias
ISSN 2007-3380

intensities, as well as for the 10-week interval at 10 cm and the 8-week interval at 20 cm. The reduction in plant height beyond the 12-week interval was due to lodging of the plants caused by their height and wind action.

Table 2. Morphological, structural characteristics, and crop growth rate in Mulato II grass harvested at different cutting intervals and intensities.

Interval	Intensity	PH		CGR		LAI		SLA	
(Weeks)	(cm)	cm		kg ha^{-1} d^{-1}		(Dimensionless)		cm^2 g	
2	10	36	h	84	ab	3.7	abc	248	a
	20	45	g	75	ab	2.3	d	229	a
4	10	49	gf	72	ab	3	abcd	197	b
	20	54	ef	65	b	3.2	abcd	191	bc
6	10	57	ed	76	ab	2.7	bcd	180	bc
	20	65	d	68	b	2.7	bcd	166	bc
8	10	80	c	69	b	3.8	ab	169	bc
	20	95	ab	100	ab	3.6	abc	159	bc
10	10	91	b	114	a	4	a	156	bc
	20	101	a	87	ab	4	a	155	bc
12	10	93	b	84	ab	3.2	abcd	159	bc
	20	90	b	71	ab	3.4	abcd	151	c

PH: plant height, CGR: crop growth rate, LAI: leaf area index, and SLA: specific leaf area. Different values between columns indicate a statistically significant difference (Tukey; p =0.05).

When harvested at a more severe intensity (10 cm), the plant exhibits a lower percentage of leaf blades, and consequently, its photosynthetic rate decreases and regrowth occurs more slowly (Yasuoka *et al.,* 2018). In this regard, Liu *et al.* (2018) state that the interval between defoliations should be greater than 4 weeks, as after this period the plant can recover and translocate the nutrients stored and generated through the newly developed leaf area. This explains why plant height did not differ significantly when harvested at 8-, 10-, and 12-week intervals with cutting intensities of 10 and 20 cm, except at the 10-week interval with 20 cm intensity, which was greater, since the plant achieves a balance between the nutrients produced. In a study conducted by Rojas *et al.* (2020), where different cutting intervals (1, 2, 3, 4, 5, 6, 7, 8, and 9 weeks) were evaluated, no significant differences in plant height were observed between cutting intensities (10 and 15 cm). This could be attributed to the smaller difference in cutting intensity (5 cm) compared to the 10 cm range used in this study. In that study, lower plant heights were also observed, with a maximum value of 66 and 74 cm at 8-week intervals and cutting intensities of 10 and 15 cm, respectively. In contrast, the present study recorded heights of 80 and 92 cm for cutting intensities of 10 and 20 cm, respectively.

Crop growth rate

The crop growth rate differed among treatments (*p* =0.05). The highest growth rate was observed at the 10-week cutting interval with a 10 cm cutting intensity, reaching 114 kg ha^{-1} d^{-1}. This corresponds to the peak growth phase of the grass. However, once the grass reaches its maximum growth point, the growth rate tends to decline, as was observed at the 12-week interval. This decline is attributed to forage loss due to senescence (Calzada-Marín *et al.,* 2014). Favorable temperature and precipitation conditions contributed to high growth rates. In this context, Garay *et al.* (2019) reported higher growth rates during the rainy season when evaluating Buffel grass at different cutting intervals, whereas during the dry season, growth rates decreased by up to 90 %. Similarly, Espinoza *et al.* (2017), when evaluating different cultivars across three locations, recorded crop growth rates for Mulato II of 11, 15, 45, and 80 kg ha^{-1} d^{-1} under rainfall levels of 343, 522, 903, and 487 mm, respectively. However, despite receiving higher precipitation (903 mm), the growth rate was not the highest, likely due to the elevation and sandy soils at the site, which retain less moisture.

Leaf area index

Significant differences were found in leaf area index among treatments (*p* = 0.05). Maximum values of 4.0 were obtained when harvested at a 10-week interval and cutting intensities of both 10 and 20 cm, which coincided with the highest dry matter yields. In a study by Garay *et al.* (2018), in which the cultivar Mulato II was evaluated at cutting intervals of 4, 6, and 8 weeks with a residual height of 15 cm, LAI values of 0.4, 0.5, and 0.7, respectively, were reported. These values are lower than those obtained in the present study at the same cutting intervals, likely due to the cutting intensities used in this research.

Specific leaf area

The specific leaf area decreased as plant age increased (Garay-Martínez *et al.,* 2018). In this regard, increasing the cutting interval led to a reduction in SLA (*p* = 0.05); thus, the highest SLA values were observed at the 2-week interval, while the lowest were recorded at the 12-week interval (Table 2). This trend is expected, as a longer cutting interval allows the plant to develop a greater total leaf area, resulting in a denser leaf structure and a lower ratio of leaf area to dry mass. In a study conducted by Garay-Martínez *et al.* (2018), evaluating the Mulato II cultivar at cutting intervals of 4, 6, and 8 weeks and a residual cutting height of 15 cm, SLA values of 199, 189, and 185 cm^2 g^{-1} were reported during the peak rainfall season, these values are comparable to those obtained in the present study at the 4-week interval (197 and 191 cm^2 g^{-1} for 10 and 20 cm cutting intensities, respectively). However, the values differed at the 6- and 8-week intervals, likely due to the different cutting intensities used in this study.

Total and morphological component dry matter yield

Total and component dry matter yield varied with changes in cutting interval and intensity (Table 3), overall, dry matter accumulation increased as the cutting interval was extended. The highest leaf dry matter yields were recorded at cutting intervals of 10 and 12 weeks with a cutting height of 10 cm, reaching 5578 and 4212 kg ha^{-1}, respectively. Conversely, the lowest yield was observed at the 2-week interval with a cutting height of 20 cm (1056 kg ha^{-1}). These results align with findings by Rojas *et al.* (2020), who reported the greatest leaf accumulation at a 5-week cutting interval for the Mulato II cultivar. Stem accumulation began to appear from the 6-week interval, with the lowest yield of 300 and 206 kg ha^{-1} observed at 6 weeks and cutting heights of 10 and 20 cm, respectively. The highest stem yields occurred at 8, 10, and 12-week intervals, though no significant differences were found among these treatments. Regarding senescent material, the lowest values were recorded at the 6-week interval for both cutting intensities at 10 and 20 cm (231 and 190 kg ha^{-1}, respectively), with no significant differences between cutting heights. The highest amount of senescent biomass was observed at the 12-week interval and 10 cm cutting height, reaching 1369 kg ha^{-1}.

Table 3. Total dry matter yield and by morphological component in Mulato II grass at different cutting intervals and intensities in Güémez, Tamaulipas.

Interval (Weeks)	Intensity (cm)	DMl		DMs		DMsm		TDM	
		kg ha^{-1}							
2	10	1180	ef	-		-		1180	h
	20	1056	f	-		-		1056	h
4	10	2032	def	-		-		2032	fgh
	20	1836	def	-		-		1836	gh
6	10	2814	bcd	300	c	231	d	3346	efg
	20	2484	cdef	206	c	190	d	2881	fgh
8	10	2694	bcde	731	bc	484	cd	3911	def
	20	3699	bc	1126	ab	781	bc	5607	bcd
10	10	5578	a	1516	ab	982	b	8011	a
	20	3843	bc	1351	ab	912	b	6107	bc
12	10	4212	ab	1585	a	1369	a	7167	ab
	20	2802	bcd	1118	ab	897	b	4818	cde

(-) Absence of the component at the time of sampling; DMl: dry matter leaf; DMs: dry matter stem; DMsm: Dry matter senescent matter; TDM: total dry matter. Different literals between columns (a, b, c, d, e, f, g, h) indicate statistical differences (Tukey; p =0.05).

Revista Bio ciencias
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Total dry matter yield (TDMY) varied significantly according to cutting intervals and intensities (*p* =0.05). The lowest TDMY values were observed at the 2-week interval, with no significant differences between cutting heights, 1180 and 1056 kg ha^{-1} for 10 and 20 cm, respectively. In contrast, the highest TDMY values were recorded at 10- and 12-week intervals with a 10 cm cutting height, yielding 8,011 and 7,167 kg ha^{-1}, respectively. The trend of increasing total and morphological component dry matter yield with longer cutting intervals and appropriate cutting intensities has been widely reported. For instance, Rojas *et al.* (2020), in their evaluation of the Mulato II cultivar across cutting intervals of 1, 2, 3, 4, 5 ,6, 7,8, and 9 weeks and cutting heights of 10 and 15 cm, observed increases in dry matter yield. However, the yields were lower than those reported in this study, likely due to the environmental conditions at their experimental site. Similarly, Garay-Martínez *et al.* (2018) reported total dry matter yields of 8.7, 9.0, and 9.1 t ha^{-1} for the Mulato II cultivar at 4-, 6-, and 8-week intervals, respectively, values that exceed those obtained in this study. These discrepancies are also attributed to environmental conditions and cultivar responses. From this perspective, the present evaluation helped identify the peak production point for Mulato II, which occurred at the 10-week interval. Beyond this point, total dry matter yield declined. A similar trend was observed by Rojas *et al.* (2020), although their peak occurred at 8 weeks, again due to differences in environmental conditions.

Crude protein, acid detergent fiber, neutral detergent fiber, and lignin content in forage

Crude protein (CP) content differed significantly across cutting intervals and intensities (*p* =0.05). The highest CP content was observed at the 4-week interval, with values of 139 and 129 g kg^{-1} DM for cutting heights of 10 and 20 cm, respectively. Thereafter, CP content decreased by 39 % and 41 % at the 8-week interval for 10 and 20 cm cutting heights, respectively, likely due to a higher proportion of stem tissue in the harvested forage (Figure 2). As reported by Torres *et al.* (2020), stem is the morphological component with the lowest CP content and digestibility compared to leaves. Garay et *al.* (2020) reported a similar trend when evaluating different *Urochloa* hybrids at cutting intervals of 4, 6, and 8 weeks with a cutting height of 15 cm. They found CP contents of 113, 99, and 92 g kg^{-1} DM, respectively, supporting the findings of the current study. The decline in CP content is primarily attributed to an increase in structural carbohydrates (cellulose, hemicellulose, and lignin), which accumulate in plant cell walls as cutting intervals are extended (Monção *et al.,* 2019). Accordingly, acid detergent fiber (ADF), neutral detergent fiber (NDF), and lignin (LIG) contents increased with longer cutting intervals, with significant differences between intervals and cutting heights (Figure 3).

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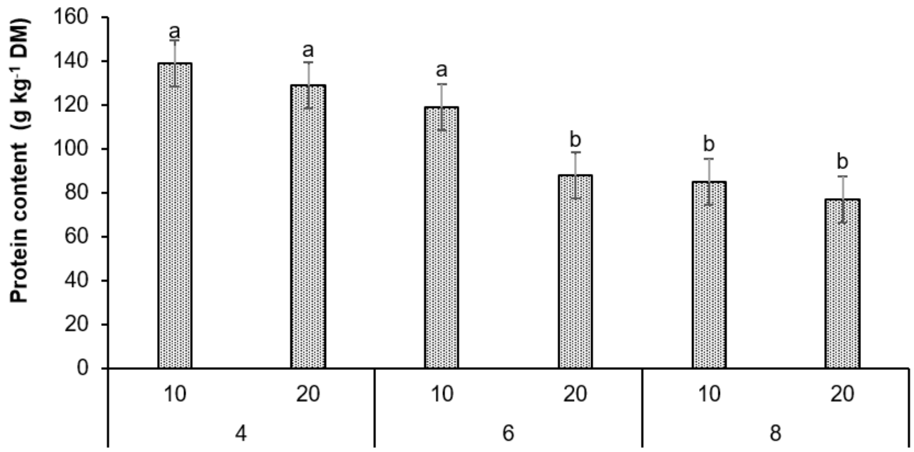

Figure 2. Crude protein (CP) content in Mulato II grass at different interval (4, 6, and 8 weeks) and cutting intensity (10 and 20 cm).

The lowest ADF values were recorded at 4- and 6-week cutting intervals, with no significant differences between these intervals or between cutting heights. Conversely, the highest ADF values (401 and 417 g kg^{-1} DM) were observed at the 8-week interval at 10 and 20 cm cutting heights, respectively, again with no significant differences between cutting intensities. The NDF content followed a similar pattern, increasing as the cutting interval extended from 4 to 8 weeks (p =0.05; Figure 3). The highest NDF values (745 and 731 g kg^{-1} DM), were recorded at the 8-week interval for cutting heights of 10 and 20 cm, respectively. No differences were found at the 4- and 6-week intervals. Lignin (LIG) content also increased with longer cutting intervals, with the highest values at 8 weeks. Unlike ADF and NDF, lignin content did show significant differences between cutting intensities; the 20 cm cutting height resulted in 7 g kg^{-1} DM more lignin than the 10 cm height (Figure 3).

The trends observed in ADF, NDF, and LIG content align with findings from several studies (Rojas-García *et al.,* 2018; Da Silva *et al.,* 2020). It is generally acknowledged that ruminants require certain levels of ADF and NDF to maintain rumen function and prevent disorders (Tekce & Gül, 2014). However, excessive intake of fibrous forages negatively affects both feed intake and digestibility (Guo *et al.,* 2022). High levels of ADF, NDF, and LIG can also disrupt the rumen microbiota, reducing microbial efficiency and ultimately compromising animal productivity (Wang *et al.,* 2020).

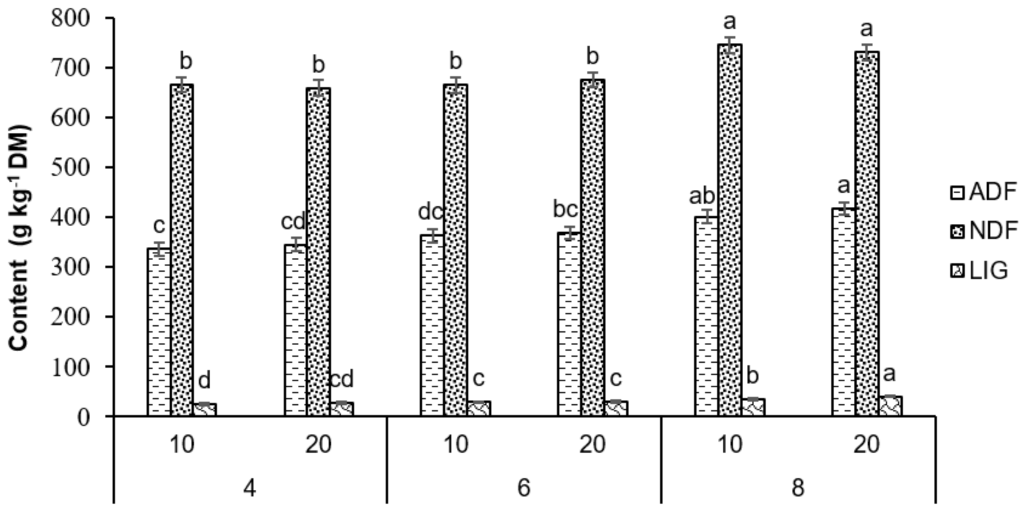

Figure 3. Acid detergent fiber (ADF), neutral detergent fiber (NDF) and lignin (LIG) content in Mulato II grass at different interval (4, 6, and 8 weeks) and cutting intensity (10 and 20 cm).

Conclusions

The cutting interval and intensity influenced the yield, quality, and the structural and morphological characteristics of Mulato II grass. The highest dry matter production in the Mulato II cultivar was obtained at 10- and 12-week intervals with a cutting intensity of 10 cm. The highest crude protein content was recorded at 4- and 6-week intervals with a cutting intensity of 10 cm, and at a 6-week interval with a 20 cm intensity. Meanwhile, the highest values of ADF and NDF were observed at 8-week intervals, with no significant differences between cutting intensities. Extending the cutting interval increased forage yield; however, the nutritional value decreased.

Author contributions

Work conceptualization: JEGR, JRGM, and FLR; Methodology development: JEGR, JRGM, and FLR; Software management: JFOO, JRGM; Experimental validation: JEGR, SJC, and JRGM; Data analysis: JEGR, JRGM, FLR, and JFOO; Data management: JEGR, JRGM, FLR, and JFOO; writing and draft preparation: JEGR, JRGM, and FLR; Writing, review, and editing: JEGR, SJC, and JRGM; Project administration: JEGR, JRGM, and SJC; Funding acquisition: JEGR, SJC, and JRGM.

All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

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