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Daily forage accumulation rates and nutritional value of Tifton 85 in the western region of Santa Catarina State, Brazil

Taxas de acúmulo diário de forragem e valor nutritivo de Tifton 85 na Região Oeste Catarinense

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Highlights

The annual forage yield exceeded 25 Mg ha^{-1}, with a moderate fertilizer rate.
Four months (December to March) concentrated 54% of the annual dry matter yield.
Daily dry matter accumulation (average of the three-year period) was 73 kg ha^{-1}.
The chemical composition of the forage was higher in summer and spring.
Forage restriction was more pronounced quantitatively than qualitatively.

Abstract

This study aimed to determine the daily dry matter accumulation rate (DAR) and the chemical composition of Tifton 85 under the conditions of the western region of Santa Catarina State, Brazil, where this forage is widely cultivated. The experiment was conducted from 2019 to 2021 on a 0.96 ha pasture established in 2012 and managed under rotational grazing with dairy cows. On the last day of each month, accumulated forage was collected from twelve exclusion cages (three per replicate), representing monthly forage growth. This process was repeated monthly with new sampling points. Monthly dry matter yield was converted into daily accumulation. The monthly forage samples were mixed in equal proportions to form seasonal composite samples, which were then subjected to chemical analysis. Annual dry matter

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yield ranged from 25.4 to 27.3 Mg ha^{-1}, with a strong concentration (67%) between summer and fall. A significant month × year interaction was observed, with the forage accumulation curve in the third year differing from that of the first two. The three-year average DAR ranged from 25 kg ha^{-1} (July) to 146 kg ha^{-1} (January), confirming the well-known seasonality of forage production. Daily accumulation rate was positively correlated with mean maximum, average, and minimum temperatures, as well as with the percentage of rainy days in the month, and negatively correlated with the proportion of days with minimum temperatures below 15 ºC. The year × season interaction affected the chemical composition, which was generally superior in summer and spring, though values remained satisfactory in fall and winter. Given the observed forage accumulation curve, adjustments in stocking rate and forage planning are necessary for the efficient use of Tifton 85.
Key words: *Cynodon.* Growth curve. Monthly yield. Pasture. Seasonality.

Resumo

O trabalho visou a determinar a taxa de acúmulo diário de matéria seca (TAD) e a composição bromatológica de Tifton 85 nas condições da Região Oeste de Santa Catarina, onde a forrageira é amplamente cultivada. O experimento foi conduzido durante os anos de 2019 a 2021 em uma pastagem de 0,96 ha, implantada em 2012 e submetida a pastoreio rotacionado com vacas leiteiras. No último dia de cada mês foi coletada a forragem acumulada no interior de doze gaiolas de exclusão (três por repetição), representando o crescimento mensal de forragem. A cada mês, o processo foi repetido e novos pontos eram amostrados. A produção de matéria seca mensal foi convertida em acúmulo diário. As amostras mensais de forragem foram misturadas em partes iguais formando amostras por estação do ano, sendo submetidas à análise bromatológica. A produção anual de matéria seca variou de 25,4 a 27,3 Mg ha^{-1}, com forte concentração (67%) entre verão e outono. Houve efeito significativo da interação mês x ano, com diferença na curva de acúmulo de forragem do terceiro ano em relação aos dois primeiros. A média trienal da TAD situou-se entre 25 kg ha^{-1} (julho) e 146 kg ha^{-1} (janeiro), atestando a reconhecida estacionalidade de produção da forrageira. A TAD foi correlacionada positivamente com a média de temperaturas máximas, médias e mínimas e com o percentual de dias chuvosos no mês, e negativamente com a proporção de dias com temperatura mínima menor do que 15 °C. A interação ano x estação afetou os parâmetros bromatológicos, os quais, de modo geral, foram superiores no verão e primavera, mas com valores satisfatórios também no outono e inverno. Face à curva de acúmulo de forragem, ajustes na carga animal e ações de planejamento forrageiro são necessários para a adequada utilização do Tifton 85.
Palavras-chave: Curva de crescimento. Cynodon. Estacionalidade. Pastagem. Produção mensal.

Introduction

Tifton 85 is a warm-season, stoloniferous, rhizomatous perennial grass that is an interspecific hybrid resulting from a cross between Tifton 68 (*Cynodon nlemfuensis*) and a *Cynodon dactylon* genotype. This forage is recognized for its high productivity, nutritional value, tolerance to trampling, and adaptability to various climate and soil conditions (Benites et al., 2016). It is considered the best *Cynodon* cultivar ever released and the most preferred for the establishment of new areas in Brazil, being successfully adopted in both tropical and subtropical regions (Pedreira, 2013; Pequeno et al., 2015; V. J. Silva et al., 2015).

Sanches et al. (2015, 2017) highlight the significant role of the *Cynodon* genus in the intensification of dairy cattle farming. In the state of Santa Catarina, Brazil, it is among the most widely used forage species, particularly in the western region (Jochims et al., 2017), occupying, on average, 45 to 50% of the forage production area on top-performing farms of the state (Fernandes & Valois, 2021). Although it is more tolerant to cold, frost, and drought than other *Cynodon* cultivars (Taffarel et al., 2016), its growth under subtropical conditions is strongly influenced by the time of year – high during the warm season and limited in the colder months (Farias et al., 2018), resulting in marked seasonal variability in forage availability (Cecato et al., 2001; A. M. Teixeira et al., 2013; Ziech et al., 2016; Schmidt, 2022; Sanches et al., 2023). Moreover, interannual variation in forage production may be even more pronounced than seasonal fluctuations (Chapman et al., 2009).

Schmidt (2022) points out that aligning forage availability with herd requirements is one of the major challenges in dairy cattle farming on warm-season perennial pastures. Farrell et al. (2023) further assert that synchronizing feed demand with pasture growth is essential for reducing diet costs and increasing system profitability. Thus, understanding the intensity of growth variations (within and between years) is fundamental for proper forage planning and pasture mass management in grazing-based production systems. One of the main obstacles to effective forage budgeting is the near-total lack of data on the growth curves of major species throughout the year under actual livestock production systems and the specific environmental characteristics of each region (Barioni et al., 2011).

It is therefore evident that estimating forage accumulation (FA) is essential for adjusting management practices and achieving satisfactory productive outcomes (Moreira et al., 2015). Forage accumulation is defined as the increase in forage mass in a given area over a specified period, representing net forage production during that interval (Pedreira et al., 2005). Knowing the daily production allows for determining the seasonal carrying capacity of the pasture and appropriately adjusting the stocking rate (Castillo-Gallegos et al., 2023). It also supports decisions regarding supplementary feeding (roughage or concentrate), nitrogen fertilization, forage conservation (what, how much, and when), and the strategic use of additional forage crops (Chapman et al., 2009; Castillo-Gallegos et al., 2023; C. S. P. Teixeira et al., 2024).

This study aimed to quantify the daily forage accumulation over three years and assess the seasonal chemical composition of Tifton 85 pasture under the environmental conditions of the western region of Santa Catarina, Brazil.

Materials and Methods

Location, climate, and soil

The study was conducted at Fazenda Primavera, the headquarters of the Professional Education Center (CEDUP) in the municipality of Campo Erê, SC, Brazil, located in the West Santa Catarina Mesoregion. The experimental area covered 0.96 ha (94 m × 102 m) and was situated at latitude 26º26'49" S and longitude 53º04'33" W, at an altitude of 884 m. According to the Köppen classification, the local climate is Cfb, characterized as temperate with mild summers and no dry season (Pandolfo et al., 2002). Based on data from the Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina [EPAGRI] (2024), the average annual rainfall between 1987 and 2012 was 1,935.85 mm. The soil in the area is classified as a dystric Latosol (Empresa Brasileira de Pesquisa Agropecuária [EMBRAPA], 2004; H. G. Santos et al., 2018), with gently undulating topography.

Pasture

The study evaluated a pure stand of Tifton 85 (*Cynodon dactylon* × *Cynodon nlemfuensis* cv. Tifton 68), established in 2012 using conventional soil preparation method. During the experimental period, the pasture was well maintained, with minimal weed infestation. It was used to feed lactating dairy cows through rotational grazing, with short grazing periods and target canopy heights of approximately 30 cm at entry and 10 cm at exit.

Soil fertility management

A soil analysis conducted in October 2018 for the 0–10 cm layer showed the following results: clay content = 44%; pH in water = 5.8; SMP index = 6.0; phosphorus = 5.4 mg/dm³; potassium = 348.0 mg/dm³; organic matter = 4.9%; aluminum = 0 cmolc/dm³; calcium = 10.3 cmolc/dm³; magnesium = 4.1 cmolc/dm³; hydrogen + aluminum = 4.36 cmolc/dm³; cation-exchange capacity (CEC) at pH 7.0 = 19.64 cmolc/dm³; base saturation at CEC pH 7.0 = 77.78%.

Fertilization management followed the standard practice adopted on the farm. In 2019, the area received 180 kg of monoammonium phosphate (MAP, 9% N, 48% P_2O_5) and 200 kg of potassium chloride (58% K_2O), equivalent to 187.5 kg ha^{-1} and 208.3 kg ha^{-1}, respectively. No fertilization was applied in 2020. In 2021, the area was fertilized with 150 kg of MAP and 150 kg of potassium chloride, corresponding to 156.3 kg ha^{-1} of each product.

Experimental design and treatments (factors)

The experiment was carried out over three years (2019, 2020, and 2021) using a completely randomized design with a factorial arrangement and four replicates. For the variable "dry matter accumulation rate", the factors considered were month (n = 12) and year (n = 3). For variables related to the chemical composition and nutritional value of the forage, the factors were season (n = 4) and year (n = 3).

Sampling and collection protocol

Forage collections were carried out on the last day of each month throughout the three-year period. A square frame measuring 0.5 m on each side (0.25 m²) was used as the sampling unit. Three collection stations (CS) were randomly selected within each replicate, ensuring they were representative of the total area in terms of forage availability, totaling 12 sampling points per month.

The "non-pairing" technique (Gardner, 1986; Zanine et al., 2006; A. P. S. Santos et al., 2021) was employed using paired sampling. At each CS, two similar points, A and B, were chosen. At point A, forage within the frame was cut to 5 cm above the ground and an exclusion cage was placed to prevent grazing. Point B was only marked, with no cage or alterations made to the vegetation. In total, 12 exclusion cages were used.

In the following month, forage under the exclusion cage at point A was harvested again at 5 cm above the ground. Point B from the previous month became the new point A, and a new point B was selected for the following month's sampling.

Forage from each of the 12 sampling locations was collected into plastic bags and immediately weighed to determine fresh matter yield. Samples were then dried in a forced-air oven at 55 ºC for at least 72 h and reweighed to determine dry matter content. The dried material was subsequently ground in a Wiley-type mill.

Forage parameters collected, evaluated, and/or calculated

Monthly forage accumulation rate (FA) was estimated as the amount of forage collected at point A of each CS in month “m,” when the exclusion cage that had been placed in the previous month (“m−1”) was removed. Thus, the amount harvested represented the forage growth in the time interval between the collections of months “m−1” and “m”, that is, the FA during month “m”.

The monthly FA for a given replicate “r” in a given month “m” was the arithmetic mean of the FA from the three CS within that replicate. Daily FA was calculated by dividing monthly FA by the number of days in the respective month.

Forage chemical composition was assessed based on the seasons of the year. Samples from each month corresponding to a given season were pooled in equal parts, maintaining the individuality of each replicate. Seasons were defined as follows: fall (March, April, May), winter (June, July, August), spring (September, October, November), and summer (December, January, February). In 2019, the summer season included only January and February. In 2020, summer included samples from December 2019, January, and February 2020. In 2021, it included samples from December 2020, January, and February 2021. December 2021 was excluded from this analysis.

The chemical and nutritional parameters were evaluated using a near-infrared spectrophotometer (NIR), including crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), mineral matter (MM), total digestible nutrients (TDN), net energy for maintenance, net energy for lactation, and net energy for gain.

The nutritional evaluation also included the estimated dry matter digestibility (EDMD).

Meteorological data

The values of the monthly meteorological variables observed during the study period were obtained from the Agritempo Sistema de Monitoramento Agrometeorológico database (2024). The following were considered: the average minimum, mean, and maximum temperatures; accumulated precipitation; the percentage of days with rain (any volume) or with rain in volumes equal to or greater than 5 mm, 10 mm, 15 mm, and 20 mm; and the percentage of days with minimum or mean temperatures below 15 °C. Historical averages (from 1987 to 2012) were also recorded for minimum, mean, and maximum temperatures, and precipitation (EPAGRI, 2020). Some of these parameters are presented in Tables 1 and 2.

Table 1
Meteorological data for the municipality of Campo Erê: historical average (1987 to 2012) and records from 2019, 2020, and 2021 referring to the average minimum temperature, average mean temperature, monthly precipitation, and the percentage of days with rainfall, per month

	Average minimum temperature (ºC)				Average mean temperature (ºC)			
	HA	2019	2020	2021	HA	2019	2020	2021
January	16.67	19.83	18.88	19.66	21.82	25.43	24.13	23.82
February	16.03	17.96	17.87	18.52	21.68	23.57	23.70	23.85
March	15.83	16.63	17.10	19.08	21.29	21.96	23.87	24.21
April	13.98	16.05	12.05	15.95	18.48	20.93	19.00	21.14
May	10.62	14.35	9.40	13.31	15.67	18.16	15.51	18.19
June	9.07	12.53	12.14	11.33	13.53	18.22	17.02	15.26
July	8.71	8.71	12.05	10.65	14.10	14.06	16.42	15.62
August	9.95	9.54	14.20	15.11	15.72	16.42	18.74	19.74
September	10.91	13.16	16.87	17.00	16.25	19.70	22.28	21.94
October	13.48	16.66	18.28	16.59	18.76	22.68	24.07	20.73
November	14.75	17.71	17.76	18.97	20.50	23.35	23.44	24.25
December	16.50	16.89	19.36	19.58	21.94	22.91	24.46	25.90
	Monthly precipitation (mm)				Days with rainfall (%)			
	HA	2019	2020	2021	HA	2019	2020	2021
January	157.1	173.1	171.4	210.5	35.16	74.19	61.29	67.74
February	144.9	137.2	42.6	33.1	37.43	46.43	31.03	64.29
March	140.5	171.1	49.7	107.2	33.10	51.61	32.26	48.39
April	184.2	197.1	73.2	30.6	32.03	26.67	23.33	53.33
May	157.1	370.6	264.1	74.1	27.90	29.03	29.03	54.84
June	156.1	38.8	214.0	122.1	28.90	46.67	50.00	26.67
July	116.7	37.2	288.5	77.0	26.22	25.81	45.16	41.94
August	96.8	17.6	295.7	30.5	22.58	25.81	25.81	41.94
September	168.8	51.3	56.2	203.0	31.53	43.33	40.00	43.33
October	259.0	117.4	64.3	305.6	38.39	64.52	35.48	51.61
November	162.7	188.1	84.5	124.1	28.90	40.00	46.67	46.67
December	192.0	129.8	202.1	52.6	35.03	38.71	45.16	51.61

HA: historical average from 1987 to 2012.
Sources: EPAGRI (2020); AGRITEMPO (2024).

Table 2
Meteorological data for the Municipality of Campo Erê from 2019 to 2021: proportion of days per month with minimum or mean temperatures below 15 ºC

	Days with minimum temperature below 15 ºC (%)			Days with mean temperature below 15 ºC (%)		
	HA	2019	2020	HA	2019	2020
January	0	0	0	0	0	0
February	3.57	13.79	14.28	0	0	0
March	6.45	19.35	19.35	0	0	0
April	26.67	73.33	30.00	0	13.33	0
May	64.52	87.10	48.39	22.58	32.26	16.13
June	83.33	66.67	76.67	36.67	36.67	20.00
July	74.19	45.16	96.77	38.71	41.94	54.84
August	54.84	51.61	87.10	19.35	16.13	41.94
September	30.00	40.00	70.00	3.33	3.33	13.33
October	32.26	9.68	29.03	0	0	0
November	0	26.67	13.33	0	0	0
December	3.22	3.22	25.81	0	0	0

Source: AGRITEMPO (2024).

Pearson's correlations between some meteorological variables and the daily dry matter accumulation rate and chemical parameters were evaluated.

Statistical analysis

The data related to the daily dry matter accumulation rate, according to the month, and the chemical data, according to the season, were subjected to analysis of variance, with means compared by Tukey's test at 5% probability.

Results and Discussion

The annual dry matter yield ranged from 25.4 to 27.3 Mg ha^{-1}, approaching the values observed by A. M. Teixeira et al. (2013), Gomes et al. (2015, 2018), Sanches et al. (2016), and Lima et al. (2023), and exceeding those indicated by Pequeno et al. (2015), Schmidt et al. (2021), and Sanches et al. (2023).

Regarding the seasonal distribution of forage yield, on average over the three years of evaluation, the months of January, February, and March accounted for 42.7% of the annual forage amount, followed by October to December with 26.8%, April to June (18.6%), and, finally, July to September (11.9%). It can be seen, therefore, that approximately 70% of the annual pasture yield occurred between October and March, in agreement with the observations of Olivo et al. (2019), Lima et al. (2023), and Sanches et al. (2023).

The daily dry matter accumulation rate (DAR), presented in Table 3, was significantly affected by the month and the month × year interaction ($P<0.01$), with no effect of the year ($P>0.05$). The average annual DAR ranged from 69.84 to 74.86 kg ha^{-1}.

Table 3
Daily dry matter accumulation rate (kg ha^{-1}) in Tifton 85 pasture according to the month and year of evaluation

Month	Year			Monthly average
	2019	2020	2021	
January	175.84 Aa	181.80 Aa	79.62 Bbc	145.75 ± 57.30 a
February	119.95 ABb	141.69 Aa	99.76 Bb	120.46 ± 24.09 ab
March	93.33 Bbc	80.95 Bbc	159.04 Aa	111.10 ± 38.23 ab
April	34.33 Bd	42.72 Bcd	100.59 Ab	59.21 ± 35.89 cde
May	38.02 Ad	49.10 Abcd	78.65 Abc	55.26 ± 23.57 de
June	36.58 Ad	42.99 Acd	65.69 Abcd	48.42 ± 16.25 de
July	24.16 Ad	15.91 Ad	35.70 Ad	25.26 ± 11.28 e
August	16.94 Bd	12.21 Bd	62.96 Abcd	30.70 ± 24.50 e
September	38.42 Ad	72.17 Abc	31.69 Ad	47.42 ± 22.06 de
October	52.80 ABcd	74.69 Abc	30.83 Bd	52.77 ± 23.02 de
November	101.96 Ab	85.05 ABb	51.82 Bcd	79.61 ± 26.58 bcd
December	105.76 Ab	90.30 Ab	101.96 Ab	99.34 ± 20.6 bc
Annual average	69.84 ± 48.63	74.13 ± 51.05	74.86 ± 38.82	72.94 ± 44.07

Means followed by the same uppercase letter in the row or lowercase letter in the column do not differ significantly according to Tukey's test at 5%.

The month × year interaction reflected the difference in the forage production curve of the third year compared to the first two. The yields in January, February, October, and November were higher in 2019 and 2020, while those in March, April, and August were more significant in the third year. On average, over the three years, the values observed between December and April exceeded those described by Fagundes et al. (2012) and Moreira et al. (2015). It is also worth noting that in the first two years, the variation in DAR between the most and least productive months (January vs. August) was 10 to 15 times, whereas in 2021 this difference was much less marked, falling to five times (March vs. October), representing a more uniform distribution of forage. However, it is undeniable that the seasonality of production was striking in all three years (Figure 1).

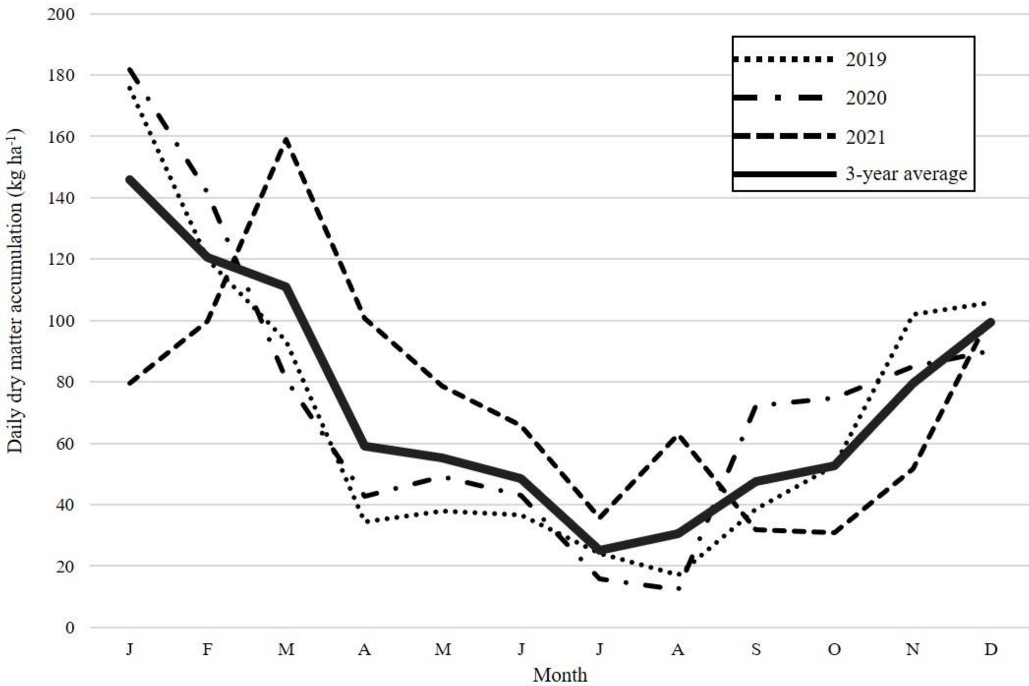

Figure 1. Average daily dry matter accumulation rates of Tifton 85, by month of evaluation, in the years 2019, 2020, and 2021, and three-year average.

Forage production was closely related to the meteorological variables observed throughout the study. Over the three years, correlations of 0.74, 0.73, and 0.69 were observed between DAR and the average values of maximum, mean, and minimum temperatures of the month, respectively (P<0.01). It is worth noting that the temperatures recorded in the three-year period were higher than the historical average (1987 to 2012). The correlations between DAR and the proportion (percentage) of rainy days in the month (0.49) and between DAR and the proportion of days with a minimum temperature below 15 °C (-0.65), considered the lowest base temperature for growth of the species (W. J. Silva & Silva, 2009; E. A. Silva et al., 2012), were also significant (P<0.01). The correlation with the monthly precipitation index was not significant (P>0.05).

In 2019 and 2020, the highest DAR was recorded in January, exceeding 175 kg of dry matter ha^{-1}, followed by February and December, in that order. The yields in March and November were also significant. In these five months, the average minimum temperatures were close to or above 17 °C, above the basal limit of 15 °C, and on few days fell below this level. In addition, the average mean temperature was 22 °C or higher, also well suited to the growth of the species. With the exception of January, the proportion of rainy days was 52% or less, indicating a long period of full sunlight, essential for good plant development.

In these first two years, the lowest DARs occurred from April to August, extending into September and October 2019, with yields between 12 and 49 kg of dry matter ha^{-1}. A high proportion of days with minimum temperatures below 15 °C (up to 87%), low average minimum temperatures, and low rainfall (June to September 2019) are factors that explain the limited forage yield.

In 2021, March was the month with the highest DAR, with 150 kg of dry matter ha^{-1}, followed by December, April, and February (around 100 kg of dry matter ha^{-1}). In these months, the average temperatures were satisfactory (21 to 26 °C), the average minimum temperatures ranged from 18.5 to 19.5 °C (except in April), and there were fewer than 30% of days with a minimum temperature below 15 °C. Precipitation was limited in February, April, and December, but rainfall in the previous months may have provided favorable conditions for forage growth. January, the month with the highest DARs in the previous two years, showed only average production, determined by the high incidence of cloudy days and low light levels due to intense precipitation (more than two-thirds of days with rain). Fagundes et al. (2011), evaluating the DARs of the first four months, found the highest yield in February and the lowest precisely in January.

On the other hand, the lowest DAR in 2021 was recorded between June and November, indicating that growth limitations extended beyond the coldest season into spring. During this period, especially until September, a high proportion of days had minimum temperatures below 15 °C, along with low precipitation in July and August.

The chemical evaluation of the produced biomass revealed a highly significant season × year interaction ($P<0.01$), as well as significant effects for the individual factors season and year. The variation in climatic conditions across years and seasons influences the morphophysiological characteristics of plants, which accounts for the observed outcomes, as described below.

The CP content was higher in the summer of the first and second years, the winter of the second and third years, and the spring of the final year (Table 4). Typically, higher CP content is associated with active biomass formation and the development of new tissues, particularly during summer. However, in colder periods, limited canopy growth can result in higher N concentration in the forage, which, coupled with a reduced incidence of the Maillard reaction in plant tissues (due to lower temperatures), can lead to elevated CP levels. Schmidt (2022) observed higher CP content in Tifton 85 from May to August than from September to April, and Fioreli et al. (2018) reported higher protein content in spring than in summer or fall.

Table 4
Crude protein, acid detergent fiber, and neutral detergent fiber contents in Tifton 85 pasture according to the season and year of evaluation

Season	Year			Season average
	2019	2020	2021	
	Crude protein (%)			
Summer	15.77 a	13.60 a	10.82 b	12.40 ab
Fall	15.58 ab	11.49 b	9.56 b	12.21 b
Winter	15.17 ab	13.78 a	13.02 a	13.99 a
Spring	14.30 b	12.57 ab	13.94 a	13.60 ab
Annual average	15.20 A	12.86 B	11.83 B	
	Acid detergent fiber (%)			
Summer	29.85 c	28.91 b	32.67 c	30.48 b
Fall	31.93 b	32.59 a	35.70 b	33.40 a
Winter	35.69 a	29.89 b	37.73 a	34.43 a
Spring	30.22 bc	29.98 b	31.69 c	30.63 b
Annual average	31.92 B	30.34 B	34.45 A	
	Neutral detergent fiber (%)			
Summer	51.34 c	56.50 c	60.60 c	56.14 b
Fall	58.04 b	62.78 a	66.47 a	62.43 a
Winter	61.98 a	56.18 c	66.47 a	61.54 a
Spring	57.98 b	59.90 b	63.12 b	60.33 a
Annual average	57.33 B	58.84 B	64.16 A	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly according to Tukey's test at 5%.

In this study, CP levels in fall and summer were lower than those reported by Andrade et al. (2012), but winter values were comparable to those of Marchesan et al. (2013). Compared to the results of Sanches et al. (2016), higher CP content was found in spring, lower in fall, and similar in summer. Overall, the values aligned with the ranges indicated by Sanches et al. (2015) and Gomes et al. (2018).

Regarding ADF and NDF (Table 4), the highest levels were observed in winter (first and third years) and fall (second and third years). Andrade et al. (2012) and Fioreli et al. (2018) also reported higher ADF and NDF contents, respectively, in fall than in summer. In contrast, Gonçalves et al. (2002) and Sanches et al. (2016) found higher ADF and NDF values in spring and/or summer compared to fall and/or winter. These discrepancies reflect the influence of multiple interacting factors, such as climatic conditions, soil characteristics, and plant morphophysiology. In the present case, it is important to consider that the low temperatures typical of fall and winter in regions with a Cfb climate type contribute to cellular senescence and a higher proportion of dead plant material, favoring fiber accumulation.

The observed ADF values (28.9 to 37.7%) were lower than those reported by Neres et al. (2012), Rezende et al. (2015), and Taffarel et al. (2016), but consistent with those reported by Sanches et al. (2015) and Gomes et al. (2018). As for NDF, levels were lower than those cited by Neres et al. (2012), Sanches et al. (2015, 2017), and Taffarel et al. (2016), and similar to those found by Pequeno et al. (2015), Rezende et al. (2015), and Gomes et al. (2018).

In 2019, the highest MM contents were recorded in summer, fall, and spring, while in 2021, spring surpassed the other seasons (Table 5), as demonstrated by Fioreli et al. (2018). Mineral absorption generally follows the pattern of biomass accumulation, a process influenced by solar radiation and air temperature (Prado, 2008; Saldanha et al., 2016). In tropical grasses such as Tifton 85, this typically occurs during the hottest and/or rainiest periods. Accordingly, Andrade et al. (2012) reported higher MM content in summer than in fall. Nonetheless, no seasonal effect on mineral composition was observed in 2020. Over the three-year period, most values in this study exceeded those reported by Taffarel et al. (2016).

Table 5
Mineral matter and total digestible nutrient contents and estimated digestibility of dry matter in Tifton 85 pasture according to the season and year of evaluation

Season	Year			Season average
	2019	2020	2021	
		Mineral matter (%)		
Summer	10.02 a	8.81 a	8.02 b	8.95 ab
Fall	10.10 a	8.58 a	7.36 b	8.68 b
Winter	8.84 b	9.22 a	7.59 b	8.55 b
Spring	9.78 a	9.26 a	9.46 a	9.50 a
Annual average	9.68 A	8.97 A	8.11 B	
		Total digestible nutrients (%)		
Summer	66.94 a	67.60 a	64.97 a	66.50 a
Fall	65.49 b	65.03 b	62.86 b	64.46 b
Winter	62.86 c	66.92 a	61.43 c	63.74 b
Spring	66.69 ab	66.86 a	65.66 a	66.40 a
Annual average	65.50 A	66.60 A	63.73 B	
		Estimated dry matter digestibility (%)		
Summer	64.97 a	66.38 a	63.45 a	64.93 a
Fall	64.03 a	63.52 b	61.09 b	62.88 b
Winter	61.10 b	65.62 a	59.51 b	62.07 b
Spring	65.36 a	65.55 a	64.21 a	65.04 a
Annual average	63.86 A	65.26 A	62.06 B	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly according to the Tukey's test at 5%.

Total digestible nutrient levels ranged from 61 to 68%, and EDMD ranged from 59 to 67% (Table 5). In all three years, spring and summer showed the highest values. Conversely, in the first and third years, winter had the lowest values ($P<0.05$), while in the second year, winter values were comparable to those of spring and summer. In contrast, Andrade et al. (2012) found higher TDN in fall than in summer, while Gonçalves et al. (2002) reported higher digestibility in fall and spring compared to summer and winter.

It is noteworthy that TDN and EDMD exhibited significant correlations ($P<0.05$) with the average maximum temperatures during the season (0.63 and 0.60, respectively). These two nutritional parameters are closely related and inversely associated with forage maturity. Thus, the more vigorous growth of Tifton 85 in warmer periods results in a higher proportion of immature tissues with lower fiber content, enhancing digestibility and increasing the amount of digestible nutrients.

Summer TDN values in this study exceeded those reported by Andrade et al. (2012), whereas fall values were lower. Across all seasons, TDN was markedly higher than values presented by Rezende et al. (2015). Regarding EDMD, summer, fall, and spring values were lower than those reported by Sanches et al. (2016) for the respective seasons. However, the overall data from the three-year period generally surpassed those of Rezende et al. (2015) and Taffarel et al. (2016), but were lower than those described by Sanches et al. (2015, 2017).

Results for net energy (for maintenance, lactation, and weight gain) followed the same pattern observed for TDN and EDMD: higher values in summer and spring across the three years, with statistical similarity to winter in the second year (Table 6). Four factors may explain this improved forage quality during the second winter:

In June, July, and August 2020, rainfall was exceptionally high, exceeding 200 mm per month 116% above the historical average for the period and 250 and 750% greater than in the winters of the other two years, respectively (Table 1). A second factor to consider is the proportion of days with minimum temperatures below 15 °C (Table 2). While this figure reached 70.6% in 2019 and 87.0% in 2021, it was only 54.3% in 2020. Therefore, a greater number of days in 2020 had conditions more favorable to summer-like forage development. The third factor is frost incidence. Although specific data for Campo Erê were unavailable, records from nearby municipalities indicated many more frost days in 2019 and 2021 (eight and ten, respectively) than in 2020, which registered only two (Instituto Nacional de Meteorologia, 2024). A fourth relevant point is the amount of forage produced. In 2020, dry matter accumulation over the three winter months was 8.9% lower than in the preceding year and 57% lower than in the following year. It is important to note that no nitrogen fertilizer was applied in 2020, which may have contributed to the lower forage yield.

Table 5
Net energy for maintenance, lactation, and weight gain on Tifton 85 pasture, according to season and year of evaluation

Season	Year			Season average
	2019	2020	2021	
Net energy for maintenance (Mcal/kg)				
Summer	1.66 a	1.67 a	1.60 a	1.64 a
Fall	1.61 b	1.60 b	1.54 b	1.58 b
Winter	1.54 c	1.65 a	1.50 c	1.56 b
Spring	1.65 a	1.65 a	1.62 a	1.64 a
Annual average	1.61 A	1.64 A	1.56 B	
Net energy for lactation (Mcal/kg)				
Summer	1.53 a	1.54 a	1.48 a	1.51 a
Fall	1.49 b	1.48 b	1.42 b	1.46 b
Winter	1.42 c	1.52 a	1.39 b	1.45 b
Spring	1.52 ab	1.52 a	1.50 a	1.51 a
Annual average	1.49 A	1.52 A	1.45 B	
Net energy for weight gain (Mcal/kg)				
Summer	0.93 a	0.95 a	0.88 a	0.92 a
Fall	0.89 b	0.88 b	0.82 b	0.86 b
Winter	0.81 c	0.93 a	0.78 c	0.84 b
Spring	0.92 ab	0.93 a	0.90 a	0.92 a
Annual average	0.89 A	0.92 A	0.84 B	

Means followed by the same lowercase letter in the column or uppercase letter in the row do not differ significantly according to the Tukey's test at 5%.

The abundance of water, the higher proportion of days with temperatures above the minimum threshold for growth, and the low incidence of frost led to reduced fiber content and increased levels of digestible compounds with energy potential compared to the other two winters. The limited forage production must also be considered, as it implies less mobilization of energy reserves for tissue formation. Together, these factors contributed to the higher digestibility and net energy values observed in the material.

Conclusions

The results confirmed the seasonal growth pattern of Tifton 85, with the influence of month and/or season being modulated by the year of evaluation, leading to a highly significant interaction between these factors. Summer pasture production (December to February) was greater in the first two years than in the third, while the opposite was observed for fall. Regarding the forage growth curve, the three-year evaluation indicates that approximately 63% of the annual yield occurred from November to March, highlighting the need for supplementary feeding strategies to mitigate the effects of forage seasonality on animal production. The chemical parameters were higher in summer and spring, but the values recorded in fall and winter were still adequate for a warm-season grass and suitable for animal categories with moderate nutritional demands.

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