doi: https://doi.org/10.36812/pag.202329116-31

ORIGINAL ARTICLE

Productivity and nutritional value of elephant grass BRS Kurumi subjected to different proportions of defoliation

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Abstract - The objective of this paper was to evaluate productivity, nutritional value of forage and tillering of elephant grass cv. BRS Kurumi under different pre-defoliation and post-defoliation canopy heights (residual height). The experimental design consisted in a randomized complete block design, with four replications. Treatments corresponded to the factorial combination of two pre-defoliation heights (60 and 80 cm) and three post-defoliation residue heights (10, 25 and 40 cm), combined in factorial design 2 x 3, being, respectively, 60 x 10 cm; 60 x 25 cm; 60 x 40 cm; 80 x 10 cm; 80 x 25 cm; 80 x 40 cm. Productive, bromatological, carbohydrate fractionation and *in situ* degradability characteristics were evaluated. Results indicated that if the objective is to seek short intervals between grazing, associated with higher forage quality, the 60 x 25, 60 x 40 and 80 x 40 managements are the most indicated ones. For maximum forage productivity, 80 x 10 and 80 x 25 are the most recommended ones. For tillering, a canopy height management of 80 cm is preferred, with 80 x 25 for aerial tillers and 80 x 40 for basal tillers.

Keywords: Tropical forage. Forage production. Tillering.

Produtividade e valor nutritivo do capim elefante BRS Kurumi sujeito a diferentes proporções de desfolhamento

Resumo - O objetivo do trabalho foi avaliar a produtividade, o valor nutricional da forragem e o perfilhamento do capim elefante cv. BRS Kurumi sob diferentes alturas de dossel pré e pós-desfolha (resíduo). Os tratamentos foram distribuídos em delineamento experimental de blocos completos ao acaso, com duas alturas de dossel pré-desfolha (60 e 80 cm) e três alturas de resíduo pós-desfolha (10, 25 e 40 cm), com quatro repetições, combinados em arranjo fatorial 2 x 3, sendo, respectivamente, de 60 x 10 cm; 60 x 25 cm; 60 x 40 cm; 80 x 10 cm; 80 x 25 cm; e 80 x 40 cm. Foram avaliadas as características produtivas, bromatológicas, fracionamento de carboidratos e degradabilidade *in situ.* Os resultados indicaram que se o objetivo for buscar curtos intervalos entre pastejos, associados a maior qualidade de forragem, os manejos 60 x 25, 60 x 40 e 80 x 40 são os mais indicados. Para máxima produtividade de forragem, 80 x 10 e 80 x 25 são os mais aconselhados. Para perfilhamento, manejos com altura de dossel de 80 cm são preferenciais, destacando-se 80 x 25 para perfilhos aéreos e 80 x 40 para perfilhos basais.

Palavras-chave: Forrageira tropical. Produção de forragem. Perfilhamento.

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ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

Introduction

Extensive and semi-intensive systems of milk and meat production depend on pasture as the main food source, and, in most cases, they make use of grasses with low nutritional value and degree of production, causing reduced production rates and unsatisfactory stocking rate (SAMPAIO *et al.*, 2017). As food is responsible for most of the production cost, it is essential to offer a food base from species that produce large volumes of forage with high levels of soluble nutrients and low fiber contents, providing high performance to animals (SANTOS *et al.*, 2013).

Elephant grass (*Pennisetum purpureum* Schumach) is a forage cultivated in tropical and subtropical regions of the world (ZAILAN *et al.*; 2016; RIGUEIRA *et al.*, 2018). Elephant grass species stands out for its high potential for biomass production, forage quality, palatability, vigor and persistence. It is mainly used for cutting and providing fresh fodder, being also used for silage or grazing (PEREIRA *et al.*, 2017). The use of elephant grass for grazing is limited due to the fast elongation of the internodes and premature maturation of stems, resulting in a size outside the reach of capture by animals. Thus, this forage needs frequent mowing to remove the fibrous material, stimulating the emergence of regrowth with better quality (PACIULLO *et al.*, 2015).

The use of low size or dwarf varieties, which have short internodes and a higher leaf/stem ratio, enables their implantation in grazing systems. Dwarf elephant grass has higher forage quality, facilitating the management of animals in rotational grazing because it presents a difference in stem growth in relation to that of high size (CHAVES *et al.*, 2013). In this scenario, the cultivar BRS Kurumi represents an alternative, with high forage yield, excellent pasture structure and good nutritional value.

Forage plants have their digestibility and nutritional value reduced due to increasing age or interval between leaves (VAN SOEST, 1994), especially C_4 plants. Thus, it is essential to choose the appropriate time for its use, maximizing its nutritional quality without affecting the productive capacity (PEREIRA *et al.*; 2017). Therefore, the objective of this study was to evaluate the effect of the pre-defoliation and post-defoliation canopy height on the productivity, nutritional value of forage and tillering of elephant grass cv. BRS Kurumi.

Material and Methods

The experiment was conducted according to the ethical standards in animal experimentation and was approved by the CEEAs of the Universidade Federal de Pelotas and the Empresa Brasileira de Pesquisa Agropecuária (Embrapa Clima Temperado), under registration number CEEA 1933/2015.

It was developed in Sistema de Pesquisa e Desenvolvimento em Pecuária Leiteira – SISPEL, of the Estação Experimental Terras Baixas (EETB) da EMBRAPA Clima Temperado (31º45'S; 52º21'W; altitude of 13.2 m), Capão do Leão – RS – Brazil. The climate of the region is humid subtropical (Cfa, according to Köeppen's classification) (MORENO, 1961), with an annual precipitation of 1,366.9 mm, relative humidity of 80.7 %, average minimum temperatures of 13.8 °C and average maximum temperatures of 22.9 ºC, according to data from the agroclimatological station of Pelotas (Capão do Leão). Climatic information that occurred

ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

during the experimental period is described in Figure 1.

The soil of the experimental area is characterized as hydromorphic, classified as Solodic Eutrophic Haplic Plane soil, belonging to the Pelotas mapping unit (STRECK *et al.*, 2008). The soil presented: pH in H_2O: 5.8; organic matter: 2.35 %; SMP index: 6.3; P: 135.0 $mg.dm^{-3}$; K: 205.5 $mg.dm^{-3}$; Ca: 3.4 $cmol_c.dm^{-3}$; Mg: 1.9 $cmol_c.dm^{-3}$; H+Al: 3.4 $cmol_c$ $.dm^{-3}$; SB: 64 %; CTCe: 5.8 $cmol_c.dm^{-3}$; pH: 7 9.2. The fertilization consisted of 400 $kg.ha^{-1}$ of the 05-30-15 formula of NPK applied to pitch and incorporated at the time of the preparation of the soil, done by harrowing. During the experimental period, 400 kg/ha of N were applied in the form of urea, divided into four applications (12/21/2016, 02/01/2017, 02/21/2017 and 04/10/2017).

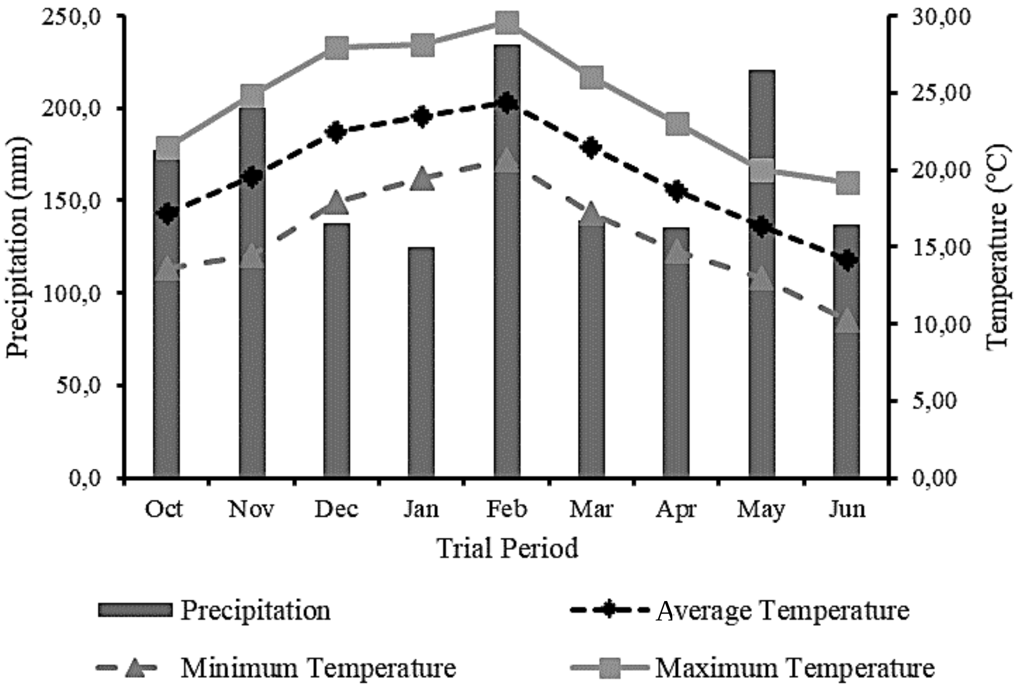

Figure 1. Climatic data during the experimental period. Source: Estação Agroclimatológica de Pelotas (EAP).

The seedlings of the dwarf elephant grass cultivar *Pennisetum purpureum* (Schumach) cv. BRS Kurumi were prepared in 500 mL, in round bottom plastic disposable cups, by making use a node for each seedling. Seedlings were kept in a greenhouse until they reached 50 cm in height and, subsequently, were transplanted to the experimental area on 11/29/2016, with a spacing of 80 cm between the plants and between rows.

The experimental design consisted in randomized blocks, with four replications. In each block, six plots of 4 x 4.8 m were demarcated, each containing five rows of six plants. The useful area of each plot was composed of three lines and four central plants. The treatments were randomized in the plots, contemplating, in a 2 x 3 factorial arrangement with two pre-defoliation canopy heights (60 and 80 cm) and three heights of post-defoliation residue (10, 25 and 40 cm), forming these combinations: 60 x 10 cm, 60 x 25 cm, 60 x 40 cm, 80 x 10 cm, 80 x 2 cm and 80 x 40 cm. Each block had water tightness meters in the Watermark soil®, and watering was performed when the readings reached 60 kPa. Watering was done with manual watering cans and maximum volumes of 5 mm/m^2 per operation.

ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

Four plants, from each plot, were cut where the production of green matter was determined by direct weighing. To determine the structural components, two plants were separated into leaf blade, stem with sheath and dead material (senescent). To estimate the productivity, it has been considered a spacing, between plants, of 80 cm in the planting, which establishes an area of 0.64 m²/plant or 15,625 plants/ha. The forage accumulation rate was considered only from the cut portion, taking into account the accumulated dry matter when the plants reached the stipulated canopy heights, divided by the number of days between the cuts. On the day after the cutting of the four plants per plot, the tillers had been counted and classified as basal (those that emerged near the surface of the soil) and aerial (those that emerged in the buds of the upper part of the plant).

After harvesting green forage and separating the leaf, stems and senescent material, the fractions were dried, in a greenhouse, with forced air circulation, at 55 ºC, until constant weight, to determine the dry matter content. Subsequently, they were ground in a *Wiley* mill, with 1 mm sieves, and analyzed for: Organic Matter (OM), Crude Protein (CP) and Ethereal Extract (EE), according to AOAC (1996, methods 967.03, 942.05, 954.05 and 920.39, respectively); neutral detergent insoluble fiber (NDF) and acid detergent insoluble fiber (ADF), according to Van Soest *et al*. (1991); and adaptations to autoclave, as described by Senger *et al.* (2008), as well as lignin in acid detergent (LDA), according to Van Soest *et al*. (1991). Cellulose, hemicellulose and silica were determined by difference, and NDF, FDA and LDA were performed sequentially.

Carbohydrates fraction was determined as follows: the fractions "A+B1", corresponding to soluble carbohydrates (Fraction "A" – readily fermented in the rumen), starch and pectin (fraction "B1" – intermediate rate of degradation) were estimated from non-fibrous carbohydrates (NFC), according to the equation described by Hall (2003). Fraction "C" was estimated by the indigestible NDF after 240 hours of *in situ* incubation, and fraction "B2" (cellulose and hemicellulose), which corresponds to the slow and potentially digestible degradation fraction of the fiber, was obtained by the difference between the protein-corrected neutral detergent fiber (NDFcp) and the "C" fraction.

In situ degradability was determined by making use of four Jersey cows, with ruminal cannulas fed with forage and mineral salt *ad libitum*. One gram of partially dried sample (ground at 2 mm) was incubated in polyester bags (5 x 5 cm and porosity of 50 µm). The samples were incubated for 24 and 48 hours. Post-incubation residues were washed in running water until water flowed clear and kept in a solution, for bacteria dissociation, for 15 minutes, according to Whitehouse *et al.* (1994). After that, they were dried in a greenhouse at 105 °C, for 8 hours, and weighed. Subsequently, they were submitted to neutral detergent solubilization to predict the total digestibility of this technique.

Data analysis was performed using the mixed model procedure (PROC MIXED), where canopy height and residue heigh were considered as a fixed effect and the cut as a random effect, following the following model Yijk is the plant's response about Canopy height i on residue height j in repetition k; µ is the overall mean; αi is the fixed effect of canopy height i; βj is the fixed effect of residue heigh j; (αβ) effect of interaction among canopy height and residue height in k repetition; eijk is the random error associated canopy

PESQ. AGROP. GAÚCHA, V.29, N.1, P. 16-31, 2023.
ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

height i, on residue height j and repetition k. The means were compared using the Tukey-Kramer test (P = 0.05). The software used was SAS University Edition.

Results and Discussion

Green forage mass and dry forage mass were significantly different between treatments (P < 0.05). Treatments of 80 cm of canopy height associated with residue of 10 cm had higher yield by defoliation, resulting from the largest portion that has been harvested (70 cm) (Table 1). In turn, at a canopy height of 60 cm, associated with 40 cm of residue (smallest extract harvested being of 20 cm) lower forage production occurred. At these productivity extremes, the 80 x 10 treatment suffered three defoliations; and the 60 x 40, eleven, with the interval between them of 41 and 11 days, respectively.

Rupollo *et al.* (2013), by making use of cv. Mott in the third year of production, found out a yield between 5,450 and 3,958 kg/ha from the first to the third defoliation, respectively. Paciullo *et al.* (2015), when studying the cultivars BRS Kurumi, CNPGL-00-1-3 and Napier, found out, in BRS Kurumi, dry forage yield ranging from 6,300 kg/ha (1^{st} defoliation) to 5,500 kg/ha (5^{th} defoliation), with superiority over other cultivars.

Percentage of leaves showed a maximum value in the 60 x 40 (P < 0.05) treatment without stem participation in the harvested stratum. This management provided 11 defoliations, with 11 days of average defoliation interval, and, thus, successive regrowth with the production of new leaves. In turn, with 41 days of interval and only three defoliations, the forage produced in the 80 x 10 management contained high stem participation and lower leaf participation among the proposed treatments (Table 1). That is, in cv. BRS Kurumi, the elevation in pre-defoliation height increases the participation of stems, while the increase in residue height increases the participation of leaves in the harvested forage. In this regard, by comparing different elephant grass genotypes, Gomide *et al*. (2011) associated the high production of leaf from cv. BRS Kurumi with lower plant management heights.

The percentage of senescent material was higher (P < 0.05) at the canopy height of 80 cm when compared to 60 cm, a result that is in line with that cited by Silva and Nascimento Júnior (2007). According to these authors, higher managed pastures provide shading at the base of the canopy, increasing the incidence of senescent material. The highest percentage of senescent material was observed in the 80 x 10 treatment due to the fact that this management present higher harvested extract (70 cm), and, thus, require more time (41 days) to reach the desired defoliation height again. As a result, the first leaves to appear during growth reach their leaf lifespam and begin senescence.

The accumulation rate showed significant results between the pre-defoliation canopy heights (P < 0.05), with higher daily production at the height of 80 cm. Araújo *et al.* (2011), when studying different elephant grass genotypes, found out values similar to those of this study regarding the accumulation rate of cv. BRS Kurumi, with 94.5 kg/ha/day at an interval of 41 days between defoliations. According to Costa *et al.* (2016), the highest values in the accumulation rate are reached when canopy reaches 95 % of light interception.

ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

Table 1. Effect of pre-defoliation canopy height and post-defoliation residue on the productive characteristics of dwarf elephant grass cv. BRS Kurumi subjected to different managements.

Canopy height	Residue height			Mean
	10 cm	25 cm	40 cm	
		Green Fodder (ton/ha)		
60 cm	15247 ± 1264 Ba	10933 ± 1094 Bb	5424.4 ± 863 Bc	**10535 ± 845**
80 cm	36350 ± 1399 Aa	27612 ± 1264 Ab	17348 ± 1168 Ac	**27103 ± 988**
Mean	**25798 ± 1108**	**19273 ± 995**	**11386 ± 863**	-
		Dry Fodder (kg of MS/ha)		
60 cm	1430.81 ± 143 Ba	1133.11 ± 120 Bb	641.93 ± 91Bc	**1068.61 ± 84**
80 cm	3755.08 ± 161 Aa	3092.15 ± 143 Ab	1993.91 ± 130 Ac	**2947.04 ± 102**
Mean	**2592.94 ± 120**	**2112.63 ± 104**	**1317.92 ± 88**	
		Percentage of Leaves		
60 cm	76.67 ± 1 Ac	91.78 ± 0.9 Ab	100.0 ± 0.7Aa	**89.48 ± 0.8**
80 cm	66.36 ± 1.1 Bc	78.92 ± 1 Bb	91.28 ± 0.9 Ba	**78.85 ± 0.9**
Mean	**71.51 ± 1**	**85.35 ± 0.9**	**96.04 ± 0.8**	-
		Percentage of Stem		
60 cm	23.01 ± 1 Ba	8.21 ± 0.8 Bb	0±0.7 Bc	**10.41±0.6**
80 cm	30.65 ± 1.1 Aa	19.38 ± 1 Ab	7.83±0.9 Ac	**19.20±0.7**
Mean	**26.83 ± 0.8**	**13.80 ± 0.7**	**3.91±0.6**	-
		Percentage of Senescent Material		
60 cm	0.28 ± 0.3 Ba	0 ± 0.2 Ba	0 ± 0.2 Ba	**0.09 ± 0.1**
80 cm	2.92 ± 0.3 Aa	1.66 ± 0.3 Ab	0.87 ± 0.2 Ac	**1.82 ± 0.2**
Mean	**1.60 ± 0.2**	**0.83 ± 0.2**	**0.43 ± 0.1**	
		Accumulation rate (kg/ha/day)		
60 cm	65.45 ± 9.5	66.90 ± 8.7	61.44 ± 7.7	**64.60 ± 7.7B**
80 cm	94.64 ± 10	101.12 ± 9.5	116.42 ± 9	**104.06 ± 8.3A**
Mean	**80.05 ± 8.8**	**84.01 ± 8.3**	**88.93 ± 7.7**	-
		Number of Basal Tillers (m²)		
60 cm	25.41 ± 2.1 Bb	34.91 ± 1.7 Aab	38.85 ± 1.3 Ba	**33.06 ± 1.1**
80 cm	44.33 ± 2.4 Ab	32.78 ± 2.1Ac	52.15 ± 1.8 Aa	**43.09 ± 1.4**
Mean	**34.87 ± 1.7**	**33.84 ± 1.4**	**45.50 ± 1.2**	
		Number of Air Tillers (m²)		
60 cm	125.95 ± 20.7 Ba	95.87 ± 19.7 Bab	58.88±18.4 Bc	**93.56±18.4**
80 cm	161.46 ± 21.5 Ab	200.60 ± 20.7 Aa	148.33±20.1 Ab	**170.13±19.2**
Mean	**143.70 ± 19.8**	**148.24 ± 19.2**	**103.61±18.4**	-

Means followed by the same uppercase letters in the columns and lowercase in the rows do not statistically differ from the 5 % probability of error by the Tukey's test. ± EPM (standard error of the mean).

PESQ. AGROP. GAÚCHA, V.29, N.1, P. 16-31, 2023.
ISSN: 0104-907. ISSN ONLINE: 2595-7686.
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When it comes to the counting basal tillers, except for the 80 x 25 combination, the canopy height of 80 cm ($P < 0.05$) provided better results, having its maximum value when it was associated with the residue of 40 cm (80 x 40). The microclimate of the interior of the canopy, associated with low luminosity, may have influenced this result, because, according to Silva *et al*. (2017), tillers follow a "reproductive mechanism", and its renewal is associated with the death of some of them for the emergence of new tillers. Similarly, the aerial tillers also presented a higher number when the canopy was managed at 80 cm. However, the highest production rate in these tillers occurred when the residue was at 25 cm due to the higher luminosity input in the canopy, thus allowing greater light capture by the new tillers and subsequent development. BRS Kurumi presented high tillering rates in warmer months, from January to March (Figure 1) for being a perennial hot season plant. Fernandes *et al.* (2011), when studying two varieties of dwarf elephant grass, observed values of 51.6 basal tillers/m² for BRS Kurumi and 49.2 basal tillers/m² for CNPGL 00-1-3, values that are in agreement with this study.

The dry matter content presented a higher value ($P < 0.05$) in the residue of 40 cm, regardless of the height of the canopy in the pre-defoliation (Table 2). The highest organic matter contents were analyzed at canopy heights with 60 cm and residue height of 40 cm. For ash, the highest values were obtained at the canopy height of 80 cm and in the residue of 10 cm, following the largest extract collected and the highest percentages of stem and senescent material. Higher crude protein (CP) values were found at canopy height of 60 cm and in 40 cm residue, with the lowest residue value of 10 cm ($P < 0.05$), that is, older plants have lower protein content, as well as smaller post-defoliation residues due to reduced leaf share and higher proportion of stems in forage.

The ethereal extract content (Table 2), neutral detergent insoluble fiber (NDF) and acid detergent insoluble fiber (ADF) (Table 3) did not present significant differences between treatments ($P > 0.05$), indicating that, within the height intervals studied, cv. BRS Kurumi may be indicated for grazing. Its growth characteristics allow management flexibility regarding the time required for the entry (canopy height) and output (post-defoliation residue) of grazing animals.

The contents of cellulose and hemicellulose showed higher values in the canopy with 80 cm ($P < 0.05$), regardless of the height of the residues, which can be justified by the greater participation of stems in this treatment. Stem usually presents higher levels of structural carbohydrates when compared to other parts of the plant because it is the component of the plant that requires greater support structure. These contents are close to those found by Morenz *et al.* (2017), who managed elephant grass of the dwarf group with a defoliation height of 75 cm, having obtained cellulose contents of 32.5 % and hemicellulose contents of 23.8 %. Increases in cellulose and hemicellulose contents with increased maturity of the plant are expected due to the need of more time to reach the highest canopy height, given that, because of aging, forages tend to have its constituents of cell wall increased.

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Table 2. Effect of pre-defoliation canopy height and post-defoliation residue on the bromatological characteristics of dwarf elephant grass cv. BRS Kurumi subjected to different managements.

Canopy height	Residue height			Mean
	10	25	40	
		Dry matter (% DM)		
60	8.62 ± 0.5	10.05 ± 0.5	11.89 ± 0.4	**10.19 ± 0.4**
80	9.49 ± 0.6	10.31 ± 0.5	10.89 ± 0.5	**10.24 ± 0.5**
Mean	**9.06 ± 0.5 c**	**10.18 ± 0.5 b**	**11.40 ± 0.4a**	
		Organic matter (% DM)		
60	82.89 ± 0.3	84.73 ± 0.3	86.34 ± 0.2	**84.66 ± 0.2 A**
80	83.00 ± 0.3	83.97 ± 0.3	85.44 ± 0.3	**84.14 ± 0.3 B**
Mean	**82.95 ± 0.3 c**	**84.35 ± 0.3 b**	**85.89 ± 0.2 a**	
		Ash (% DM)		
60	17.10 ± 0.3	15.27 ± 0.3	13.65 ± 0.28	**15.33 ± 0.2 B**
80	16.99 ± 0.3	16.03 ± 0.3	14.56 ± 0.3	**15.86 ± 0.3 A**
Mean	**17.04 ± 0.3 a**	**15.65 ± 0.3 b**	**14.10 ± 0.2 c**	
		Crude Protein (% DM)		
60	17.87 ± 0.5	18.95 ± 0.4	21.14 ± 0.3	**19.31 ± 0.4 A**
80	14.94 ± 0.6	16.65 ± 0.5	17.76 ± 0.5	**16.44 ± 0.5 B**
Mean	**16.40 ± 0.4 c**	**17.79 ± 0.4 b**	**19.44 ± 0.3 a**	
		Ethereal Extract (% DM)		
60	2.45 ± 0.6	2.54 ± 0.5	2.52 ± 0.3	**2.50 ± 0.3**
80	2.50 ± 0.6	2.48 ± 0.6	2.38 ± 0.5	**2.45 ± 0.4**
Mean	**2.47 ± 0.5**	**2.51 ± 0.4**	**2.45 ± 0.3**	

DM – Dry Matter; Means followed by lowercase letters in the row and uppercase in the column differ by Tukey's test at 5 % probability of error. ± EPM (standard error of the mean).

Higher lignin content was attributed to the canopy height of 80 cm, associated with the residue of 10 cm and 25 cm ($P < 0.05$). Lignin values close to those in this study were reported by Araújo *et al.* (2011). These authors observed an increase in lignin due to maturity, with values of 4.2 and 5.1 % in cv. BRS Kurumi, and of 4.5 and 4.6 % in cv. CNPGL 00-1-3, at 28 and 42 days of regrowth, respectively. According to Pereira, Lédo, and Machado (2017), the decline in nutritional value of forage, with an increase in age, results in a decrease in leaf/stem ratio, combined with increasing lignification of cell wall. In this sense, there is reduction

ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

in cell content and an increase in wall constituents, such as cellulose, hemicelluloses and lignin, resulting in cell wall thickening (MINSON, 1990; VAN SOEST, 1994).

Table 3. Effect of pre-defoliation canopy height and post-defoliation residue on the structural carbohydrates content of dwarf elephant grass cv. BRS Kurumi subjected to different managements.

Canopy (cm)	**Residue height**			**Mean**
	10	25	40	
		Neutral detergent fiber (% MS)		
60	57.59 ± 0.7	58.37 ± 0.7	58.47 ± 0.6	**58.14 ± 0.6**
80	59.02 ± 0.8	58.94 ± 0.7	58.52 ± 0.7	**58.83 ± 0.6**
Mean	**58.31 ± 0.7**	**58.65 ± 0.6**	**58.49 ± 0.6**	
		Acid detergent fiber (% MS)		
60	36.34	36.70	36.26	**36.43 ± 0.4**
80	36.94	35.40	36.40	**36.24 ± 0.4**
Mean	**36.64 ± 0.5**	**36.05 ± 0.4**	**36.33 ± 0.4**	
		Cellulose (% MS)		
60	30.43 ± 0.5	30.53 ± 0.4	31.51 ± 0.3	**30.82 ± 0.3B**
80	32.93 ± 0.6	3218 ± 0.5	32.05 ± 0.5	**32.38 ± 0.3A**
Mean	**31.68 ± 0.4**	**31.35 ± 0.4**	**31.78 ± 0.3**	
		Hemicellulose (% MS)		
60	21.49 ± 0.6	21.73 ± 0.5	22.21 ± 0.4	**21.81 ± 0.3 B**
80	22.40 ± 0.6	23.78 ± 0.6	22.30 ± 0.5	**22.82 ± 0.4A**
Mean	**21.95 ± 0.5**	**22.76 ± 0.4**	**22.25 ± 0.3**	
		Lignin (% MS)		
60	4.10 ± 0.2Ba	3.32 ± 0.2 Bb	4.37 ± 0.1 Aa	**3.93 ± 0.1**
80	6.02 ± 0.3Aa	6.11 ± 0.2Aa	4.75 ± 0.2Ab	**5.63 ± 0.1**
Mean	**5.06 ± 0.2**	**4.72 ± 0.1**	**4.56 ± 0.1**	
		Silica (% MS)		
60	1.78 ± 0.1	1.77 ± 0.1	1.84 ± 0.08	**1.80 ± 0.07**
80	2.12 ± 0.1	1.87 ± 0.1	1.82 ± 0.1	**1.94 ± 0.09**
Mean	**1.96 ± 0.1**	**1.82 ± 0.1**	**1.83 ± 0.08**	

DM – Dry Matter; Means followed by lowercase letters in the row and uppercase in the column differ by Tukey's test at 5 % probability of error. ± EPM (standard error of the mean).

Total carbohydrate (TC) content was higher at the height of 80 cm ($P < 0.05$) (Table 4). Older plants presented lower crude protein content, which contributed to these TC results. According to Sniffen *et al.* (1992), TC values are strongly influenced by crude protein levels, given the use of this variable to determine TC.

Regarding the A+B1 fraction of carbohydrates, there was also a significant superiority ($P < 0.05$) for the canopy height of 80 cm. Lima *et al.* (2017), when evaluating tall elephant grass, with an age of

PESQ. AGROP. GAÚCHA, V.29, N.1, P. 16-31, 2023.
ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

approximately 60 days, verified 4.47 % of fraction A+B1, which is lower than that presented in the study. This is a fact that is associated with the height of plant at the time of cutting, since the author obtained plants with approximately 2.27 m, which contributed to the increase of constituents of cell wall and the low value of soluble fraction. Elephant grass is described as containing low concentrations of soluble carbohydrates, representatives of fraction "A". However, new cultivars have presented higher levels than those normally found, reaching 20 % of fraction A in MS (SCHEIBLER, 2018).

Table 4. Effect of pre-defoliation canopy height and post-defoliation residue on the fractionation of carbohydrates from dwarf elephant grass cv. BRS Kurumi subjected to different managements.

Canopy (cm)	**Residue height**			**Mean**
	10	25	40	
		TC (% MS)		
60	62.74 ± 0.7	63.48 ± 0.6	62.69 ± 0.4	**62.97 ± 0.4B**
80	65.75 ± 0.8	65.01 ± 0.7	65.50 ± 0.6	**65.42 ± 0.5A**
Mean	**64.24 ± 0.6**	**64.24 ± 0.5**	**64.09 ± 0.4**	
		A + B1 (% TC)		
60	12.09 ± 1.1	12.15 ± 0.9	10.97 ± 0.8	**11.74 ± 0.7B**
80	14.35 ± 1.2	13.15 ± 1.1	14.51 ± 1	**14.00 ± 0.9A**
Mean	**13.22 ± 1**	**12.65 ± 0.9**	**12.74 ± 0.8**	
		B2 (% TC)		
60	72.13 ± 1.2	73.58 ± 1.1	74.86 ± 0.9	**73.52 ± 0.9A**
80	67.59 ± 1.4	69.22 ± 1.2	70.47 ± 1.2	**69.23 ± 1B**
Mean	**69.86 ± 1b**	**71.60 ± 1 ab**	**72.67 ± 0.9 a**	
		C (% TC)		
60	15.51 ± 0.4	14.06 ± 0.3	14.17 ± 0.2	**14.58 ± 0.2B**
80	17.72 ± 0.5	16.96 ± 0.4	14.76 ± 0.4	**16.49 ± 0.3A**
Mean	**16.62 ± 0.3a**	**15.52 ± 0.3b**	**14.47 ± 0.2c**	

DM – Dry Matter; TC – Total Carbohydrates; A + B; B2 -; C - means followed by lowercase letters in the row and uppercase in the column differ by Tukey's test at 5 % probability of error. ± EPM (standard error of the mean).

In fraction B2, a superiority ($P < 0.05$) was observed for the canopy height of 60 cm and for residue heights of 25 and 40 cm (Table 4). These results follow the variation in lignin contents of this study. Fraction "B2" represents potentially degradable carbohydrates (cellulose and hemicellulose), but shows slow degradation in most tropical fodder. Values of fraction B2 of this study are within the expected for plants grown in tropical regions and are close to those found by Valadares Filho *et al* (2016), who, when evaluating cv. Mott, found out 69.31 % of their carbohydrates as fraction B2.

In fraction C, there was a significant superiority ($P < 0.05$) for the canopy height of 80 cm and residue of 10 cm. These results derive from the higher aging of the harvested plants with height of 80 cm, the higher proportion of forage stems harvested at 10 cm and the combination of these factors. According to Caballero *et*

ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

al. (2001), the unavailable fraction (C) is dependent on lignin content; therefore, plants with a more advanced physiological age have higher levels of this fraction. Thus, the increase in fraction C promotes reduction of the potentially degradable fraction (B2). Cabral *et al.* (2000), when evaluating elephant grass cv. Cameroon, found out 24 % of the fraction “C” at 42 days and 25 % of the fraction “C” at 63 days. These results are higher than those of this study due to the difference in size of the dwarf group in comparison with the high size group, in which there is an elevation of stems and, consequently, a cell wall with more rigid and linear structure. All fractions above mentioned and their interrelations determined the digestibility coefficients of DM and NDF observed in Table 5.

Table 5. Effect of pre-defoliation canopy height and post-defoliation residue on in situ digestibility of dry matter and insoluble fiber in neutral detergent of dwarf elephant grass cv. BRS Kurumi subjected to different managements.

Canopy (cm)	Residue (cm)			Mean
	10	25	40	
dry matter *in situ* digestibility 24 hours (%)				
60	77.93 ± 1.5	77.12 ± 0.9	75.46 ± 0.7	**76.84 ± 0.6 A**
80	69.24 ± 0.3	72.20 ± 1.1	70.92 ± 1	**70.79 ± 0.7 B**
Mean	**73.59 ± 0.9**	**74.66 ± 0.7**	**73.19 ± 0.6**	
dry matter *in situ* digestibility 48 hours (%)				
60	84.83 ± 0.7	85.71 ± 0.6	85.45 ± 0.4	**85.33 ± 0.4 A**
80	82.15 ± 0.8	83.39 ± 0.7	84.44 ± 0.6	**83.32 ± 0.5 B**
Mean	**83.49 ± 0.6**	**84.55 ± 0.5**	**84.95 ± 0.4**	
in situ digestibility of fiber insoluble in neutral detergent 24 hours (%)				
60	62.09 ± 1.7	60.93 ± 1.4	58.04 ± 1	**60.36 ± 0.8 A**
80	49.16 ± 2	53.41 ± 1.7	50.62 ± 1.5	**51.06 ± 1 B**
Mean	**55.63 ± 1.3**	**57.17 ± 1.1**	**54.32 ± 0.9**	
in situ digestibility of fiber insoluble in neutral detergent 48 hours (%)				
60	73.76 ± 1.2	75.64 ± 0.9	75.11 ± 0.7	**74.84 ± 0.6 A**
80	70.03 ± 1.3	72.08 ± 1.2	73.56 ± 1	**71.89 ± 0.7 B**
Mean	**71.90 ± 0.9**	**73.86 ± 0.8**	**74.34 ± 0.7**	

Mean followed by lowercase letters in the row and uppercase in the column differ by Tukey’s test at 5 % probability of error. ± (SEM) (standard error of the mean).

The digestibility of dry matter and insoluble fiber in neutral detergent, at 24 and 48 hours, showed similar behavior, being significantly higher ($P < 0.05$) for the canopy height of 60 cm (Table 5). Plants that needed to reach 80 cm were older, and, thus, with less digestibility due to an increase in fraction C and the higher values of cellulose and lignin. The age of the plant contributes to speed the cell wall degradation. In young plants, a higher fraction of compounds is degraded in the first 24 hours, not occurring in older plants. Morenz *et al.* (2017), when evaluating elephant grass, found out values for in vitro digestibility of DM of 70 and 69.4 %, respectively, for the BRS Kurumi and the clone CNPGL 00-1-3. Madeiro *et al.* (2010), when studying BRS Kurumi, also observed high digestibility rates for DM (72.7 %).

In the use of elephant grass cv. BRS Kurumi, if the objective is to seek short intervals between grazing associated with higher forage quality, the managements of 60 cm of canopy height and 25 cm of residue height (60 x 25), 60 cm of canopy and 40 cm of residue (60 x 40), as well as 80 cm of canopy and 40 cm of residue (80 x 40) are the most indicated ones. When the objective is to achieve maximum dry matter yield, the managements of 80 cm of canopy and 10 cm of residue (80 x 10) and 80 cm of canopy and 25 cm of residue (80 x 25) are the most recommended ones. For tillering, a canopy-height management of 80 cm is preferred, with 80 x 25 for aerial tillers and 80 x 40 for basal tillers.

Acknowledgements

This study was partially financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. We would like to thank EMBRAPA for the resources and infrastructure provided.

Conflict of Interest

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical Statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

The experiment was evaluated and approved by the Animal Experimentation Ethics Committee of the Federal University of Pelotas, under registration number CEEA 1933/2015.

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ISSN: 0104-907. ISSN ONLINE: 2595-7686.
Received on 28 Jun. 2022. Accepted on 07 Oct 2022.

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