

# THE MORPHOGENESIS OF MARANDU PALISADEGRASS AT FIXED OR VARIABLE HEIGHTS IN DIFFERENT SEASONS OF THE YEAR

## MORFOGÊNESE DO CAPIM-MARANDU EM ALTURAS FIXAS OU VARIÁVEIS NAS ESTAÇÕES DO ANO

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**ABSTRACT:** Height variations in a sward over the year may be efficient for increasing plant growth, compared with maintenance of the sward at a constant height. Thus, this experiment was conducted from February 2013 to May 2014 to characterise the development of *Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu (marandu palisadegrass), managed under three defoliation strategies: constant height (30 cm during the entire experimental period), increasing height (15 cm in the winter, 30 cm in the spring, and 45 cm in the summer), and decreasing height (45 cm in the winter, 30 cm in the spring, and 15 cm in the summer). The experimental design was completely randomised, in a split-plot arrangement, with four replicates. Phyllochron was higher in the winter, but leaf and stem elongation rates and the number of live leaves per tiller were lower compared with the spring and summer. In the summer, the swards under increasing height displayed a higher phyllochron than those under decreasing and constant height. When comparing seasons, the highest leaf senescence rate occurred in spring. In the winter, the sward with increasing height had shorter leaves and stems, in contrast to the summer. The sward under decreasing height showed a high stem elongation rate in the spring. Marandu palisadegrass has great flexibility in terms of defoliation management and a typical seasonal development pattern. Modifying the sward height results in a gradual change in the development of marandu palisadegrass and generates residual effects on the subsequent season.

**KEYWORDS:** *Brachiaria brizantha*. Defoliation. Development. Tiller.

### INTRODUCTION

In Brazil, forage plants of the genus *Urochloa* syn. *Brachiaria* are the most widely used for the formation of pastures (DA SILVA et al., 2013), representing a milestone in the national livestock activity. This genus occupies around 85% of the cultivated-pasture area; of this total, *U. brizantha* syn. *B. brizantha* cv. Marandu (marandu palisadegrass) has a remarkable contribution (MACEDO, 2004), as it is estimated that 60 million hectares of pasture are formed by marandu palisadegrass in Brazil, representing 65% of the planted area in the north region, and 50% in the central-west region (BARBOSA, 2006).

Evaluating growth, senescence and structural characteristics of pastures is essential for understanding the defoliation and climate effects on forage production by the pasture (DA SILVA et al., 2015). In this context, the study of the morphogenesis of forage plants provides knowledge of the dynamics of generation and expansion of the

plant's shape in space and time (CHAPMAN; LEMAIRE, 1993).

Under continuous stocking, pasture management strategies have been established for some tropical forage grasses (PAULA et al., 2012; DA SILVA et al., 2013). The results of some of these studies have revealed similar forage accumulation patterns to those described originally for perennial ryegrass (BIRCHAM; HODGSON, 1983). In general, in low pastures, forage accumulation is reduced due to the lower leaf production; in tall pastures, forage accumulation is also lower due to the high leaf mortality rate; and in intermediate pastures, accumulation is practically constant and close to maximum.

In this regard, in order to optimise forage accumulation in palisadegrass, the current recommendation is to maintain pastures under a continuous stocking rate, at a height of 20 to 40 cm (DA SILVA et al., 2013). However, one hypothesis is that the sward height should be flexible throughout the year (SANTOS; FONSECA;

GOMES, 2013; PESSOA et al., 2016). Increasing the height from winter to summer would increase plant growth and minimise the elongation of the stem compared with maintaining the sward at a constant height. In addition, to increase tiller density, marandu palisadegrass may be managed at 15 cm in the fall and winter, and 30 cm in the spring and summer (COSTA et al., 2016).

This study was conducted to understand the development of marandu palisadegrass managed under variable heights throughout the year.

## MATERIAL AND METHODS

The experiment was conducted from January 2013 to March 2014 in the Forage Section, on Experimental Farm Capim Branco, at the Faculty of the Federal University of Uberlândia (UFU), located in Uberlândia, MG, Brazil. The geographic coordinates of the experimental site are 18°53'19" South latitude and 48°20'57" West longitude (Greenwich), at an altitude of 776 m. The climate of Uberlândia is Aw, tropical savannah with a dry winter season (ALVARES et al., 2013). The average annual temperature is 22.3 °C, varying between 23.9 °C and 19.1 °C for the maximum and minimum means, respectively. The average annual precipitation is 1,584 mm. The climatic data during the entire experimental period were obtained at the meteorological station located approximately 200 m from the experimental area (Figures 1 and 2).

Before the experiment was implemented, soil samples were collected from the 0–10 cm layer for analysis, and the following chemical characteristics were found: pH H<sub>2</sub>O: 6.1; P: 9.4 mg/dm<sup>3</sup> (Mehlich-1); K<sup>+</sup>: 156 mg/dm<sup>3</sup>; Ca<sup>2+</sup>: 5.5 cmol/dm<sup>3</sup>; Mg<sup>2+</sup>: 1.7 cmol/dm<sup>3</sup>; Al<sup>3+</sup>: 0.0 cmol/dm<sup>3</sup> (KCl 1 mol/L); effective CEC: 7.6; CEC at pH 7.0: 10.3; and base saturation: 74%. Based on these results, 50 kg/ha of P<sub>2</sub>O<sub>5</sub>, 60 kg/ha of N, and 50 kg/ha of K<sub>2</sub>O were applied to all plots in the first week of January 2013. These same doses were applied again on 01/06/2014. Urea, single superphosphate, and potassium chloride were used as fertilisers.

The experimental area consisted of twelve plots (experimental units) with 6 m<sup>2</sup> each, delimited on a pasture established with marandu palisadegrass in 2000 and with no signs of degradation.

Three defoliation strategies were evaluated as follows: marandu palisadegrass kept at a constant height — 30 cm — during the entire experimental period (DA SILVA et al., 2013); marandu palisadegrass kept at a height of 15 cm in the fall and winter, 30 cm in the spring, and 45 cm during

the summer (increasing height throughout the seasons of the year); and marandu palisadegrass kept at 45 cm in the fall and winter, 30 cm in the spring, and 15 cm in the summer (decreasing height).

The grass maintained at 15 cm in the fall and winter took approximately one month to reach 30 cm in the spring. Likewise, the marandu palisadegrass was also left for around one month without being cut, until it reached 45 cm in the summer. In contrast, the grass kept at 45 cm in the fall and winter was cut to 30 cm at the beginning of spring (October 2013) and, later, to 15 cm in the early summer (January 2014). The plants managed at 30 cm in the fall and winter continued under the same management until the end of the experiment.

The seasons were comprised of the following months: winter (July, August and September 2013); spring (October, November and December 2013); and summer (January, February and March 2014).

From January 2013, cuts were made for the desired heights to be implemented in the fall and winter seasons, according to the treatments. The period from January to March 2013 was used for the acclimation of the plants to the heights. The heights were monitored once per week in the fall and winter and twice per week in the spring and summer. The sward height was measured at 10 points in each plot, using a graduated ruler. The excess forage was cut and removed manually after each cut.

Morphogenesis was evaluated in three periods during the experiment: winter (August to September), spring (November to December), and summer (January to February). The tillers were chosen with a 1 m-long wood stick graduated in 10 cm. In total, eight tillers located at the stick graduation marks were selected, spaced 10 cm apart, and were identified by a small numbered clip. In each season of the year, new groups with eight tillers were marked and evaluated per plot, in a data cycle of at least four weeks.

Using a ruler before the weekly cuts of the plants, the lengths of the leaf blades and stems of the tillers were measured. The expanded-leaf length was measured from the end of the leaf to its ligule. In the case of expanding leaves, the same procedure was adopted, but the ligule of the newest expanded leaf was considered as a reference for measurement. For the senescent leaf, the length corresponded to the distance between the point to which the senescence process had advanced and the leaf ligule. The size of the stem corresponded to the distance from the soil surface to the ligule of the youngest fully expanded leaf. Based on these pieces of

information, the following variables were calculated: phyllochron – the number of leaves per tiller emerged divided by the number of days of the trial period; leaf elongation rate (LER) – the sum of all leaf blades per tiller divided by the number of evaluation days; stem elongation rate (SER) – the growth of the stem divided by the number of evaluation days; leaf senescence rate (LSR) – the senescence of the leaf blades divided by the number of evaluation days; leaf lifespan – the number of live leaves per tiller at the end of the evaluation multiplied by the phyllochron; the number of live leaves (NLL) – the number of leaf blades with more than 50% of their length showing no senescence at the end of the evaluation; final leaf blade length (FLL) – the average of the lengths of the expanded leaf blades without senescence; and final stem length (FSL) – measured at the end of the evaluation period.

The data were analysed using the MIXED (mixed models) procedure of the SAS® (Statistical Analysis System) version 9.2 program. Initially, the

dataset was analysed to check whether it met the assumptions of variance analysis (normality and homogeneity). For the statistical assumptions to be met, the response-variable stem elongation rate had its data transformed using the base-10 logarithm. The variance and co-variance matrix was chosen using Akaike's Information Criterion (WOLFINGER, 1993). Treatment means were estimated using the LSMEANS option and compared by Student's t test at 5% probability.

## RESULTS

The phyllochron of the marandu palisadegrass was influenced by the interaction between defoliation strategy and the season of the year. In the winter, phyllochron was higher than in the spring and summer. Concerning height, in the summer the swards under increasing height displayed a higher phyllochron in relation to those under decreasing and constant height (Table 1).

**Table 1.** Morphogenetic and structural characteristics of marandu palisadegrass with variable heights during the seasons of the year

Height	Season of the year			Average
	Winter	Spring	Summer	
Phyllochron (day)				
Increasing	40.3Aa	16.6Ca	20.7Ba	23.6
Constant	42.0Aa	15.6Ba	16.7Bb	24.8
Decreasing	42.0Aa	15.6Ba	13.1Bb	25.8
Average	41.4	15.9	16.8	SEM=1.27
Stem elongation rate (cm/tiller.day)				
Increasing	0.02Ba	0.11Aa	0.12Aa	0.08
Constant	0.02Ba	0.07Ab	0.07Ab	0.05
Decreasing	0.03Ba	0.10Aab	0.04Bc	0.05
Average	0.02	0.09	0.08	SEM=0.011
Leaf elongation rate (cm/tiller.day)				
Increasing	0.12Ca	1.57Aa	1.02Bb	0.90
Constant	0.14Ca	1.46Aa	0.80Bb	0.80
Decreasing	0.18Ba	1.55Aa	1.34Aa	1.02
Average	0.14	1.53	1.05	SEM=0.086
Leaf senescence rate (cm/tiller.day)				
Increasing	0.29Ba	0.59Ab	0.57Aa	0.48
Constant	0.28Ba	0.99Aa	0.38Ba	0.55
Decreasing	0.36Ba	0.83Aab	0.45Ba	0.54
Average	0.31	0.81	0.46	SEM=0.089
Leaf lifespan (day)				
Increasing	127Aa	75Ba	99Aa	100
Constant	145Aa	67Ba	81Ba	97
Decreasing	151Aa	74Ba	58Cb	94

Average	141	72	79	SEM=6.57
Leaf blade length (cm)				
Increasing	11.3Bb	17.7Aa	15.5Aa	14.8
Constant	14.1Ba	17.8Aa	9.1Cb	13.7
Decreasing	15.6Ba	19.7Aa	13.3Ba	16.3
Average	13.7	18.4	12.6	SEM=0.939
Stem length (cm)				
Increasing	10.3Cc	15.0Bb	28.9Aa	18.1
Constant	24.5ABb	20.9Ba	26.4Aa	23.9
Decreasing	33.2Aa	24.3Ba	7.5Cb	21.6
Average	22.6	20.1	20.9	SEM=1.667

Decreasing: sward with a height of 45 cm in the fall and winter, 30 cm in the spring, and 15 in the summer; Constant: sward with a height of 30 cm during the entire experimental period; Increasing: sward with a height of 15 cm in the fall and winter, 30 cm in the spring, and 45 cm in the summer; SEM: standard error of the mean. For each characteristic, means followed by the same lowercase letter in the column and uppercase letter in the row do not differ ( $P>0.05$ ).

The stem (SER) and leaf (LER) elongation rates were influenced by the interaction between defoliation strategy and time of the year. In the swards under constant and increasing height, SER was lower in the winter compared with the spring and summer. The same response pattern occurred for LER in all swards.

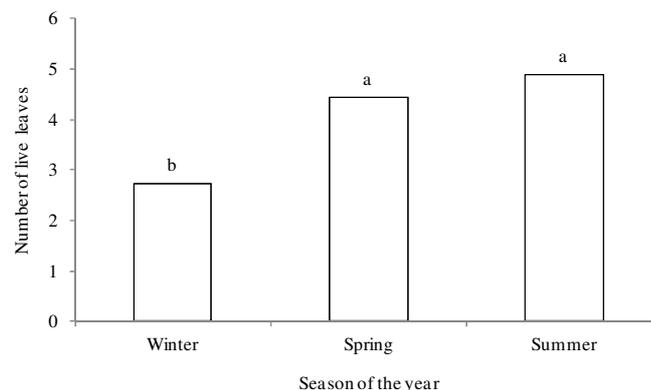
Regarding the defoliation strategy, the sward under increasing height displayed a higher SER than the others. Leaf elongation rate was higher only in the summer and in the sward with decreasing height, compared with the other swards.

Compared with the spring, the lowest leaf senescence rate (LSR) occurred in the winter, and did not vary with the defoliation strategies evaluated. In the summer, LSR decreased in relation to spring in the plants with constant and decreasing heights. In the winter, leaf lifespan (LLS) was

longer compared with the spring and summer. Only in the summer was the LLS shorter in the decreasing sward compared with the others.

In the winter, final leaf blade length (FLL) and final stem length (FSL) were lower in the swards with increasing height. In the spring, no difference was found in FLL between the studied defoliation strategies, but FSL was lower in the grass under constant height. In the summer, however, FLL and FSL were lower in the grass under constant and decreasing heights, respectively.

No interaction was detected between the season of the year and defoliation strategy for the number of live leaves (NLL) in the marandu palisadegrass. The NLL was influenced only by the season of the year, so that the NLL was lower in the winter (2.73) than in the spring (4.43) and summer (4.89) (Figure 3).



**Figure 3.** Number of live leaves of marandu palisadegrass with variable heights during the seasons of the year.

## DISCUSSION

Phyllochron, the interval between the appearance of two consecutive leaves on the same

tiller, was higher in the winter than in the spring and summer, due to the adverse climatic conditions during the winter, including lower temperature, rainfall, and reduced isolation, compared with the

other seasons (Figures 1 and 2). The climate that was unfavourable to plant growth in the winter also resulted in a lower stem elongation rate in the swards under increasing and constant height and reduced the leaf elongation rate in all swards. The ideal temperature for the growth of grasses in a tropical climate ranges from 30 to 35 °C, while growth was practically zero from 10 to 15 °C (MENDONÇA; RASSINI, 2006). Thus, when the night temperature is below 15 °C, tissue formation in the shoots of tropical forages is impaired.

On the other hand, in the winter, the leaf lifespan (LLS) was longer and leaf senescence rates were low compared with those of the other seasons of the year. The longer LLS in the winter might have been a response to the decreased availability of nutrients to the forage plant, resulting mainly from the water deficit that occurred at that time of the year, which limits nutrient absorption by the plant (NOVAES; SMYTH, 1999). In this condition, the longer LLS would contribute to increasing the average time of permanence of the nutrients in the plant. Moreover, the increase in LLS in the winter offsets the reduction in leaf appearance and elongation at this time of the year. In this way, the sward partially avoids marked reductions in leaf area index, a relevant characteristic to light interception and thus to photosynthesis and plant growth (LARA; PEDREIRA, 2011).

In the winter, the plants went through intense water scarcity and a low minimum temperature (Figures 1 and 2). Thus, the grass prioritised the maintenance of younger leaves because they had greater photosynthetic ability and were located at the upper layers of the tillers (PEDREIRA et al., 2015), which led to the higher mortality of old leaves located at the base of the tillers. Therefore, the winter had the lowest number of live leaves per tiller (Figure 3).

The higher leaf senescence rate in the spring was accompanied by a lower phyllochron and higher leaf elongation rate, which caused NLL per tiller in the marandu palisadegrass to increase in this season of the year compared with the previous one. The occurrence of a constant NLL per tiller in the spring and summer indicates that it is a genetically stable characteristic, and thus not deeply affected by management. In this regard, in a study conducted by Paula et al. (2012), with marandu palisadegrass managed at 15, 30, and 45 cm under continuous grazing, the average NLL per tiller (3.9) was similar to that observed in this study.

When conditions favourable to plant growth are re-established, the stem and leaf elongation rates usually reach higher values in the spring. However,

the leaf elongation rate decreased in the summer in the swards with increasing and constant height, and, likewise, the stem elongation rate was reduced in the sward with decreasing height. This might have been a result of the dry spell in the summer months, which reduced the availability of water in the soil (Figures 1 and 2). In fact, the leaf growth depends on the growth of each cell, which, in turn, depends on the increase in volume, mainly caused by the physical action of the water entry, causing a great expansion of the plant structures (TAIZ; ZEIGER, 2012).

Among the seasons of the year, the highest leaf senescence rates were found in the spring, which may be related to the longer lifespan of the leaves recorded during the winter, which senesced during the spring. Moreover, it is possible that, in the spring, as the temperature, solar radiation, and soil moisture increased (Figures 1 and 2), leaves underwent senescence to provide nutrients and help with the expansion of new leaves. Indeed, the highest leaf elongation rates of marandu palisadegrass start in the spring. There is a possibility that 50% of the carbon and 80% of the nitrogen will be recycled from the senescent leaves and utilised by the plant for the synthesis of leaf tissues (LEMAIRE; AGNUSDEI, 2000). The leaf is genetically programmed to die, and, during senescence, hydrolytic enzymes decompose many proteins, carbohydrates, and nucleic acids. Sugars, nucleosides, and amino acids, in addition to many minerals, are then transported via the phloem to other plant organs, where they will be reused in synthesis processes (TAIZ; ZEIGER, 2012).

With regard to the defoliation strategies, there was no effect on the development of the marandu palisadegrass during the winter, because the climatic conditions that restrict growth in that season (Figures 1 and 2) limited the variations in phyllochron, leaf elongation, stem elongation, senescence and leaf lifespan. However, in the winter, stem length was lower in the sward under increasing height than in the others, due to the lower height (15 cm) at which it was kept. Thus, the leaf blade under development might have travelled a smaller distance within the pseudostem until its exposure at the tiller, because, in shorter swards, the distance between the apical meristem and the tiller apex is smaller (SKINNER; NELSON, 1995). Therefore, in the winter, the leaf length was also lower in the sward kept under increasing height compared with the other swards.

In the spring and in comparison with the other defoliation strategies, plants managed under an increasing height, which ranged from 15 cm

(winter) to 30 cm (spring), displayed a higher SER, and consequently longer stems, probably due to the greater shading within the sward, as reported in research studies with tropical forage grasses (CARNEVALLI et al., 2006; PEDREIRA et al., 2007). However, in the spring, a lower LSR occurred in the sward with increasing height, compared with the other evaluated heights, which was unexpected.

Despite having its height reduced from 45 to 30 cm from winter to spring, the sward under decreasing height retained a high SER in the spring, which is a typical response pattern of taller plants. It is possible that plants were still acclimatising to the new defoliation environment, which was characterised by the reduction in height. Thus, they expressed a residual effect, characterised by greater stem lengths. The change in the structure of a plant in response to a new defoliation environment is gradual; it is possible that the effects of a previous defoliation management subsist for some time before a new pasture structure is established. This may be related to the fact that, during defoliation, some young leaves were already under cell division inside the remaining pseudostem, since the multiplication and a good portion of the cell elongation may occur from 2 to 3 cm of the base of the leaf (SCHNYDER; RADEMACHER; KÜHBAUCH, 1990). Thus, during cell expansion and differentiation after defoliation, these leaves might have already been determined morphogenetically by the previous sward condition.

In the summer, the marandu palisadegrass with decreasing height (15 cm in the summer) had a low SER and lower final stem length, probably as a result of the greater incidence of light within the sward and the possible improvement in the quality of this light. The better luminous environment within the sward might have minimised the competition for light among the tillers, which led to less stem elongation. In contrast, in the sward with a height of 45 cm in the summer (increasing height), the opposite response pattern might have happened, explaining its higher SER and greater stem length. In the summer, the longer stem, which increases the distance covered by the leaf inside the pseudostem to its emergence on the tiller (SKINNER; NELSON, 1995), could have been responsible for the lower phyllochron observed in the sward managed under increasing height.

By the end of the summer, the high SER rate in the swards with increasing and constant height appears to have been a consequence of the flowering of marandu palisadegrass being concentrated in this summer (PAULA et al., 2012).

In the sward managed under constant height, FLL was lower in the summer compared with the other defoliation strategies studied. This may be related to the low leaf elongation of this sward during the summer. The maintenance of a constant height throughout the experimental period was unlikely to cause variations in the microclimate within the sward, and did not stimulate the appearance of new tillers. On the other hand, this change in microclimate might have occurred in the swards under increasing and decreasing height, stimulating the appearance of young tillers, which have greater leaf elongation (PAIVA et al., 2011) and longer leaves (BARBOSA et al., 2012).

The results of this study indicate the great flexibility in adapting to defoliation by marandu palisadegrass, through different morphogenetic adjustments to the seasonal variation in sward height. It is possible that the decreasing height promotes the accumulation of reserve compounds in the winter, even with little growth, which might favour regrowth in the spring through the mobilisation of these reserves (THORNTON et al., 2000), associated with medium defoliation (30 cm). Moreover, the grass lowering in the summer to 15 cm re-establishes the tissue-flow potential under favourable environmental conditions. Additionally, when the marandu palisadegrass has its height changed throughout the year, residual effects may occur, such as greater elongation and size of stems, which are expected when the sward height is greater in previous seasons.

## CONCLUSIONS

*Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu has great flexibility in terms of defoliation management and a typical seasonal development pattern.

In the winter, variations in sward height do not result in alterations in the development of marandu palisadegrass.

Alterations in the sward height change the development of marandu palisadegrass and generate residual effects on the subsequent season.

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**RESUMO:** As variações de altura em um pasto ao longo do ano podem ser eficientes em aumentar o crescimento das plantas, em comparação com a manutenção do pasto a uma altura constante. Assim, este experimento foi conduzido de fevereiro de 2013 a maio de 2014 para caracterizar o desenvolvimento de

*Urochloa brizantha* syn. *Brachiaria brizantha* cv. Marandu (capim-marandu) manejado com três estratégias de desfolhação: altura constante (30 cm durante todo o período experimental), altura crescente (15 cm no inverno, 30 cm na primavera e 45 cm no verão) e altura decrescente (45 cm no inverno, 30 cm na primavera e 15 cm no verão). O delineamento experimental foi inteiramente casualizado, em esquema de parcelas subdivididas, com quatro repetições. O filocrono foi maior no inverno, mas as taxas de alongamento de folhas e caules e o número de folhas vivas por perfilho foram menores em comparação com a primavera e o verão. No verão, o relvado em altura crescente apresentou filocrono maior do que em altura decrescente e constante. Entre as estações, a maior taxa de senescência foliar ocorreu na primavera. No inverno, o pasto com o aumento da altura apresentava folhas e caules mais curtos, ao contrário do verão. O relvado em altura decrescente apresentou alta taxa de alongamento na primavera. O capim-marandu possui grande flexibilidade em termos de manejo de desfolha e um padrão típico de desenvolvimento sazonal. A modificação da altura do pasto resulta em uma mudança gradual no desenvolvimento do capim-marandu e gera efeitos residuais na estação subsequente.

**PALAVRAS-CHAVE:** *Brachiaria brizantha*. Desfolhação. Desenvolvimento. Perfilho.

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