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# Herbage accumulation, morphological composition, and nutritive value of *Paspalum notatum* cv. INIA Sepé

# Acumulación de forraje, composición morfológica y valor nutritivo de *Paspalum notatum* cv. INIA Sepé

# Acúmulo de forragem, composição morfológica e valor nutritivo de *Paspalum notatum* cv. INIA Sepé

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## Abstract

Defoliation strategies determine sward canopy structure and affect forage accumulation and nutritive value. The objective of this study was to determine forage accumulation, morphological composition and nutritive value of INIA Sepé subjected to combinations of three frequencies (defoliation at 90%, 95% and maximum canopy light interception during regrowth —$LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$), and two severities of defoliation (40 and 60% of the pre-cutting height). The experiment was carried out from November 15th, 2018 to March 31st, 2019 in Tacuarembó. Measurements of LI and canopy height, forage mass morphological composition and nutritional value were carried out. Forage mass was greater in Feb-March. The percentage of leaves was greater for the higher defoliation frequency treatment ($LI_{90\%}$). The percentage of stems did not vary among treatments (average of 23%). The percentage of dead material was greater for the lower defoliation frequency treatment ($LI_{Max}$) and 40% defoliation severity. Greater ADF and NDF values and smaller digestibility were recorded for $LI_{Max}$/40% combination. For $LI_{90\%}$, greater ADF and NDF, and smaller digestibility were recorded for the 60% defoliation severity (Feb-March). Forage accumulation was greater for $LI_{90\%}$ and $LI_{95\%}$. INIA Sepé shows large flexibility to defoliation management, and the optimal pre-cutting target should not exceed $LI_{95\%}$ (i.e. 30 cm of canopy height) in order to ensure production of high nutritive value forage and harvest efficiency.


**Keywords**: herbage accumulation, *Paspalum notatum*, nutritional value


## Resumen

El manejo de la defoliación es determinante de la estructura del dosel forrajero y afecta la acumulación de forraje y su valor nutricional. El objetivo de este trabajo fue determinar la acumulación de forraje, su composición morfológica y el valor nutritivo de INIA Sepé sometido a la combinación de tres frecuencias (defoliación a 90 %, 95 % y máxima interceptación de luz por el dosel forrajero durante el rebrote —$IL_{90\%}$, $IL_{95\%}$ e $IL_{MÁX}$) y dos severidades de defoliación (40 y 60 % de la altura precorte). El experimento fue realizado desde el 15 de noviembre de 2018 hasta el 31 de marzo de 2019 en Tacuarembó. Fueron realizadas evaluaciones de IL y altura del dosel forrajero, masa de forraje, composición morfológica y valor nutritivo del forraje. La masa de forraje fue mayor en Feb-Mar. El porcentaje de hojas fue mayor para la mayor frecuencia de defoliación ($IL_{90\%}$). El porcentaje de tallos no varió entre tratamientos (promedio de 23 %). El porcentaje de material muerto fue mayor para la menor frecuencia ($IL_{máx}$) y para la severidad 40 %. Mayores valores de FDA, FDN y menor digestibilidad fueron registrados para la combinación $IL_{máx}$/40 %. Para $IL_{90\%}$ mayor FDA y FDN y menor digestibilidad fueron registrados para la severidad 60 % (Feb-Mar). La acumulación de forraje fue mayor para $IL_{90\%}$ e $IL_{95\%}$. INIA Sepé posee gran flexibilidad de manejo, mientras que la meta precorte óptima no debe exceder 95 % de IL (30 cm de altura), como forma de asegurar producción de forraje con elevado valor nutritivo y elevada eficiencia de cosecha.


**Palabras clave**: acumulación de forraje, *Paspalum notatum*, valor nutritivo


## Resumo

O manejo da desfolhação é determinante da estrutura do dossel forrageiro e afeta a produção e o valor nutritivo da forragem. O objetivo deste trabalho foi determinar o acúmulo de forragem, a composição morfológica e o valor nutritivo de INIA Sepé submetido à combinação de três frequências (desfolhação aos 90%, 95% e máxima interceptação de luz pelo dossel forrageiro durante a rebrotação – IL90%, IL95% e ILMáx) e duas severidades de desfolhação (40 e 60% da altura pré-corte). O experimento foi realizado de 15 de novembro de 2018 a 31 de março de 2019, em Tacuarembó. Foram realizadas avaliações de IL e altura do dossel forrageiro, massa de forragem, composição morfológica e valor nutritivo da forragem. A massa de forragem foi maior em Fev-Mar. A porcentagem de folhas foi maior para a maior frequência de desfolhação (IL90%). A porcentagem de colmos não variou entre tratamentos (média de 23%). Por outro lado, a porcentagem de material morto foi maior para a menor frequência (ILMáx) e para a severidade 40%. Maiores valores de FDA e FDN assim como menores de digestibilidade foram registrados para a combinação ILMáx/40%. Para IL90% maior FDA, FDN e menor digestibilidade foram registrados para a severidade 60% (Fev-Mar). O acúmulo de forragem foi maior para IL90% e IL95%. INIA Sepé possui grande flexibilidade de manejo, sendo a meta pré-corte ótima não deve exceder 95% de IL (30 cm de altura) como forma de assegurar produção de forragem com elevado valor nutritivo e elevada eficiência de colheita.

**Palavras-chave**: acúmulo de forragem, *Paspalum notatum*, valor nutritivo

## 1. Introduction

*Paspalum notatum* is a summer perennial grass, type $C_4$, and one of the most common species in Uruguay's natural grassland. Taking into account *P. notatum*'s potential, and to capitalize Uruguayan genetic resources, a national collection of germplasm was held in 2006 to characterize, value and preserve genetic resources. The characterization and evaluation processes were developed between 2007 and 2012. The regional evaluation stage began in 2012 along with an increase of the seed clone TB42, which led to INIA Sepé cultivar; it belongs to the botanical variety *latiflorum*, it is tetraploid and its reproduction is apomictic(1). Once nutritional and water limiting factors are solved, and the productivity, quality and persistence of perennial pastures are determined, grazing management follows. Forage accumulation by forage crops subjected to intermittent cuttings or grazing was described as the result of the growth and senescence processes(2). Defoliation intensity in rotational grazing can be divided into frequency and severity, which are related to the interval between cuttings and tissue proportion (forage mass, height, LAI [Leaf Area Index]) removed in each cutting or grazing period. The timing in which the regrowth is interrupted is crucial as it determines the amount of accumulated forage, its nutritional value and the animals' ability to harvest it(3). Korte and others(4) postulated the concept of critical LAI as a determining criterion, which would correspond to the interception of 95% of the incident light by the forage canopy. Interrupting the regrowth after that point could result in forage accumulation reduction and a deterioration in pasture structure caused by an increase in stem proportion and senescence rates(5). Parsons and Penning(6) demonstrated that interruption of regrowth at the critical LAI results in maximum forage accumulation rate for perennial ryegrass, a condition in which the balance between growth and senescence processes would be maximum. Managing pastures with more than 95% of light interception during regrowth (LI) could result in a higher total accumulation. However, a significant proportion of stems and dead material would be present, resulting in a lower accumulation of dry leaf matter and forage of lower nutritive value(7). Although the concept of critical LAI was developed on temperate species, similar results were found on tropical and subtropical pastures through research that started in the early 2000s and continues to these days(8)(9)(10)(11). Relations were established between critical LAI and forage canopy heights associated with these studies, transforming the latter into a reliable and easy-to-apply tool in the field when setting management goals(5). To harvest better nutritive value forage at the expense of a possible loss of forage accumulation, studies were carried out evaluating targets of LI lower than critical LAI (90% vs 95% LI)(12), which indicated a decrease in forage and leaf accumulation in the growth process. Regarding defoliation severity, Parsons and others(13) demonstrated that the lower the residual LAI was, the longer the regrowth period had to be before reaching the maximum forage accumulation rate, which was unlikely to vary in an extensive range of defoliation regimes. Despite using the pre-set canopy height as a management criterion for temperate and tropical pastures, the use of flexible post-grazing (cutting) heights is more recent, mainly in tropical pastures, where most studies were carried out with fixed heights, generating variable defoliation severities that hinder the definition of a single goal for different forage crops. A recent improvement was the establishment of the defoliation ratio criterion based on the fact that severity greater than 50% of pre-grazing (cutting) height prevented maximizing intake in the short term(11)(14)(15), once leaves predominate in the upper half of the forage canopy(5). The need to evaluate different pre-grazing goals with defoliation severity that did not exceed 50% of the pre-grazing height was perceived in this way. Applying different managing intensities (combination of frequency and defoliation severity) determines the structure of the forage canopy, which modulates growth processes variation, forage accumulation and nutritive value. INIA Sepé cultivar, *Paspalum notatum*, has a high compensation capacity between number and size of tillers associated with tiller longevity, which ensures great flexibility to defoliation intensity(16). In this context, it is hypothesized that defoliation frequency has greater relative importance than defoliation severity, condition in which forage nutritive value would be determinant of the optimum harvest point. The goal of this study is to determine forage accumulation, its botanical and morphological composition, and the nutritional value of *Paspalum notatum* cv. INIA Sepé subjected to six defoliation regimes, product of the combination of three frequencies (90, 95, and maximum light interception during regrowth), and two severities of defoliation (40 and 60% of pre-cutting height).

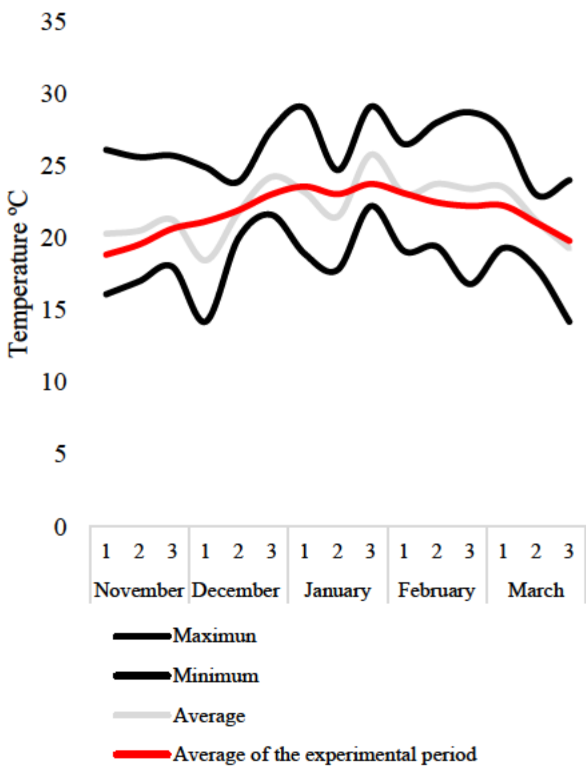
## 2. Materials and methods

The experiment was carried out from November 15, 2018, to March 31, 2019, at Campo Experimental Tambores, dependent on INIA Tacuarembó, in the department of Tacuarembó, Uruguay: latitude 31º54'41.15"S, longitude 56º13'39.35"W and altitude 253 meters.

The climate of this region of Uruguay is of Cfa type according to Köppen classification, with an average temperature of 18.5 °C and average annual rainfall of 1294 mm(17). In order to maintain an adequate soil water level above 50% of available water, spray irrigation was used throughout the experiment period. The application was made according to water balance carried out daily and considering the soil physics data of the site such as water retention capacity (80 mm), infiltration speed, effective depth of root exploration (40 cm), and daily climatic variables such as potential evapotranspiration and daily rainfall, as well as applied irrigation. Climate data were collected with a Davies Pro-2 Plus meteorological station (Davis, USA) located 30 meters from the experiment within the experimental site (Figure 1).

Water balance was completed daily from Monday to Friday, and irrigation was carried out in 10 to 30 mm doses, so as to prevent depletion of available soil water below 50% and losses by surface runoff.

Figure 1. Average decadal temperature evolution of the experimental period, and average, minimum, and maximum of the historical series (1986-2019) of INIA Tacuarembó climate records




Source: INIA GRAS(18)

The experimental area was sown in November 2015, with a Semeato drill seeder, consisting of 13 lines separated by 17 cm at a density of 15 kg ha$^{-1}$, to place 150 viable seeds per square meter. The pasture was considered adequately established after a series of 3 cuttings made at 4.9 cm from the ground on 1/15/2016, 9/19/2016 and 10/3/2016. The soil of the experimental site is a Typic Eutric Vertisol (Hapluderts Typic), belonging to the Soil Unit Coneat Itapebí Tres Árboles, with 39% clay, 31% sand and 30% silt content. The chemical characteristics were those observed in Table 1.

Table 1. Result of soil chemical analysis used in experiment II

| Depth cm | Organic C % | pH (H20) | N-NO3 µg N/g | P (Citric Acid) µg P/g | K meq/100g | S-SO4 µg S/g | Ca meq/100g | Mg meq/100g | Zn mg/kg | B mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| 0-7.5 | 5.41 | 5.9 | 6.1 | 10.5 | 0.44 | 12.2 | 19.8 | 8.9 | 2.06 | 1.57 |
| 7.5-15 | 3.88 | 6.0 | 4.5 | 3.4 | 0.39 | 9.0 | 20.7 | 9.3 | 1.09 | 0.63 |

Source: La Estanzuela INIA's Analysis Laboratory.

Initial fertilization consisted of locating all experimental units at soil phosphorus sufficiency levels (minimum of 30 ppm) by applying differential doses of triple Superphosphate according to soil phosphorus level, measured with the Citric Acid method. Nitrogen fertilization was performed by applying granular urea, manually distributed in each experimental unit after each cutting and before irrigation at an equivalent dose of 1 kg of nitrogen per hectare per day of regrowth.

The experimental design was completely randomized, with 4 replications. As experimental units, 24 plots of 10×16 m were used. The treatments corresponded to all combinations between three cutting frequencies determined by the incident light interception percentage during regrowth (90%, 95% and maximum LI, the latter being defined when similar values were obtained in two consecutive measures —$LI_{90\%}$, $LI_{95\%}$ and $LI_{max}$, respectively), and cutting severity corresponding to 40 and 60% of the canopy height at cutting time (60 and 40% removal of pre-cutting height corresponding to LI targets). Treatment application was performed using a Honda HRX217 propeller cutter, removing the cut forage.

Before the start of the study, the experimental area was prepared and subjected to an adaptation period to experimental treatments and conditions. During the growth season between October 2016 and May 2017, the preparation of the experimental area began through a series of cuttings made on 10/24/2016, 1/3/2017 and 3/1/2017, at an average height of 6.5 cm with an average interval between cuttings of 49.6 + 14.9 days. On September 29, 2017, a homogenization cutting was carried out at 8.5 cm from the ground, and the control of the experimental conditions and treatment imposition were initiated throughout the growing season between October 2017 and May 2018. The effective experimental period corresponded to the following growth season, from November 2018 to March 2019.

### 2.1 Light interception (%) and forage canopy height (cm)

Light interception monitoring (LI) by the forage canopy was performed using the LAI-2000 Li-Cor equipment (LI-COR, USA), every 10 days on average, monitoring weekly on plots exceeding 85% of LI. Three measurements were taken on each plot at dawn (due to the need to measure under diffuse light condition). Each consisted of an above-canopy measurement recording incident photosynthetically active radiation (iPAR), and 5 consecutive measurements under the canopy, recording transmitted photosynthetically active radiation (tPAR) at ground level.

Canopy height (in centimeters) was determined at pre and post-cutting using a ruler, considering the highest sheet density point, registering 10 randomly chosen points per plot; the average of these observations being the average height of the plots.

### 2.2 Forage mass (DM kg.ha$^{-1}$), morphological and botanical composition (%), and nutritive value

The evaluation of forage mass, botanical and morphological composition and nutritive value in pre-cutting and post-cutting was carried out by extracting 3 samples per plot, cut at ground level with electric scissors powered by an internal battery and a rectangular steel frame of 35x70 cm. Once extracted, samples were conditioned in plastic bags, adding distilled water with a sprinkler and taken to a cold chamber until processing. This procedure was performed so as to minimize respiration and perspiration processes. All material was taken to the laboratory and stored in a cold chamber for further processing. The fresh weight of the entire sample was registered. Subsequently, subsamples were separated for botanical and morphological analysis. The remaining material was weighed for fresh weight and taken to the oven to dry for 48 hours at 65 °C. Finally, it was weighted once more in order to obtain the total dry matter percentage and total dry matter amount by relating this percentage to the total fresh weight of the sample. The subsamples selected for botanical and morphological composition analysis were weighted in fresh and then manually fractioned into weeds, dead material and *Paspalum notatum* (leaf, stem and inflorescence). Each fraction was sent to the oven to dry for 72 hours at 60 °C. Dried material was weighted, and the results used to calculate total dry matter percentage and total dry matter amount from each of the fractions. The results were expressed as percentage of the total dry matter. Once dry, the material obtained from the leaf fraction was ground and subsequently sent to the laboratory to determine: dry matter content (DM), crude protein (CP), acid and neutral detergent fiber (ADF and NDF), by using the equipment NIR PERTEN DA7250 (Perten, USA). The digestibility of the forage dry matter was estimated through the formula:

DMD(%) = 88.9 – (0.779×ADF%)[19]

### 2.3 Forage accumulation (kg DM.ha$^{-1}$) and daily rates of forage accumulation (kg DM.ha$^{-1}$.day$^{-1}$)

During the pre-cutting evaluation period, sampling was carried out to evaluate the total forage mass accumulation by using a HRX217 Honda propeller cutter with forage collector, where the 0.52 m wide and 8 m long central plot surface was harvested, thus avoiding the effect of the edges. For each sampling, the residual height was determined according to the height set in each treatment for the corresponding severity.

The daily forage accumulation rate was calculated by dividing the total harvested forage mass between the days of duration of the regrowth period, then a daily weighed average was calculated for each plot corresponding to each period.

### 2.4 Statistical analysis

The basic prerogatives of the analysis of variance (normality of the data and homogeneity of variance) were tested and the model additivity and independence of errors were assumed. When necessary, data were transformed before the analysis of variance. ANOVA was performed using the Mixed Models package of the Infostat software[20]. The results were analyzed considering the periods of greatest growth activity (November to March), which determined two periods (Period 1: from November 15, 2018, to January 31, 2019; Period 2: from February 1 to March 31, 2019). Frequency and severity of defoliation were considered as fixed effects, while period as a random effect. The comparison of means, when necessary, was carried out through the Tukey test ($P<0.05$).

### 2.5 Transparency of data

Data not available: The data set that supports the results of this study is not publicly available.

## 3. Results

### 3.1 Experimental control

In general, LI pre-cutting values were close to those proposed and on average corresponded to 92.9, 96.1 and 97.8 for treatments with $LI_{90\%}$, $LI_{95\%}$, and $LI_{Max}$, respectively.

Pre-cutting height varied ($p<0.05$) with defoliation frequency, severity and the interaction frequency × severity × growing period. In general, higher values of pre-cutting height were found in lower defoliation frequencies. Regarding defoliation severity, there were no differences between severity, except in the treatment $LI_{Max}$ during period 2, where the highest value was recorded for the defoliation severity of 60% (Table 2).

Table 2. Pre-cutting height (cm) for *Paspalum notatum* cv. INIA Sepé subjected to intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity | Frequency (% LI during regrow) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| pre-cutting height % | 90 | | 95 | | Max | | Means | | SE |
| | | | (Height in cm) | | | | | | |
| | | | Period 1: | | | | | | |
| 40 | 28.8 | Ab | 29.0 | Ab | 37.3 | Aa | 31.7 | A | 1.21 |
| 60 | 26.0 | Ab | 32.5 | Aa | 36.2 | Aa | 31.6 | A | 1.65 |
| Means | 27.4 | b | 30.8 | b | 36.7 | a | | | |
| SE | 1.10 | | 2.22 | | 1.21 | | | | |
| | | | Period 2: | | | | | | |
| 40 | 26.9 | Ab | 32.9 | Aa | 32.4 | Ba | 30.7 | B | 1.02 |
| 60 | 29.6 | Ab | 32.3 | Ab | 40.3 | Aa | 34.1 | A | 1.30 |
| Means | 28.2 | c | 32.6 | b | 36.4 | a | | | |
| SE | 1.10 | | 1.19 | | 1.56 | | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different (p>0.05). SE indicates the standard error of the variable.

Post-cutting height varied (p<0.05) with frequency, defoliation severity, growth period and the interaction frequency × severity × growing period. In general, higher values were registered in lower frequency treatments and lower defoliation severity (Table 3).

Table 3. Post-cutting height (cm) for *Paspalum notatum* cv. INIA Sepé subjected to intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity | Frequency (% LI during regrow) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pre-cutting height % | 90 | | 95 | | Max | | Means | | SE |
| | | | (Height in cm) | | | | | | |
| | | | Period 1: | | | | | | |
| 40 | 10.9 | Bb | 11.4 | Bb | 14.2 | Ba | 12.2 | B | 0.44 |
| 60 | 15.0 | Ab | 19.6 | Aa | 20.5 | Aa | 18.4 | A | 0.91 |
| Means | 13.0 | b | 15.5 | a | 17.4 | a | | | |
| SE | 0.68 | | 0.82 | | 0.72 | | | | |
| | | | Period 2: | | | | | | |
| 40 | 10.7 | Bc | 12.2 | Bb | 14.1 | Ba | 12.3 | B | 0.32 |
| 60 | 16.9 | Ab | 18.7 | Ab | 24.6 | Aa | 20.1 | A | 0.59 |
| Means | 13.8 | c | 15.5 | b | 19.3 | a | | | |
| SE | 0.52 | | 0.52 | | 0.75 | | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different (p> 0.05). SE indicates the standard error of the variable.

Post-cutting height values expressed as a percentage of the pre-cutting height were close to those proposed and corresponded, on average, to 40.7 and 58.4 for severity treatments of 40 and 60%, respectively.

The interval, in days, of each cycle, was greater for the less frequent ($LI_{Max}$) and more severe (post-cutting height equivalent to 40% of the pre-cutting height) treatments.

### 3.2 Forage mass (kg DM.ha$^{-1}$), botanical/morphological composition (%) and nutritive value of harvested forage at pre-cutting

Forage mass at pre-cutting varied ($p<0.05$) with growing period and the frequency × severity × growing period interaction. In general, forage mass was higher in Period 2 than in Period 1. While there were no differences between treatments in period 1, in period 2 a difference was found between levels of defoliation severity for the $LI_{90\%}$ treatment (higher values for 60% relative to 40%), and between targets of LI for the severity level of 40% (higher values for $LI_{95\%}$ relative to $LI_{90\%}$, with intermediate values for $LI_{Max}$) (Table 4).

Table 4. Pre-cutting forage mass (kg DM.ha$^{-1}$) in *Paspalum notatum* cv. INIA Sepé subjected to different intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity | Frequency (LI % during regrow) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pre-cutting height % | 90 | | 95 | | Max | | Means | SE |
| | | | (kg dm.ha$^{-1}$) | | | | | |
| | | | Period 1: | | | | | |
| 40 | 6910 | Aa | 5960 | Aa | 6000 | Aa | 6290 | 678 |
| 60 | 6180 | Aa | 6780 | Aa | 7650 | Aa | 6870 | 651 |
| Means | 6540 | | 6370 | | 6830 | | | |
| SE | 661 | | 344 | | 825 | | | |
| | | | Period 2: | | | | - - | |
| 40 | 5280 | Bb | 9640 | Aa | 7560 | Aab | 7490 | 730 |
| 60 | 7420 | Aa | 7480 | Aa | 8270 | Aa | 7720 | 569 |
| Means | 6350 | | 8560 | | 7920 | | | |
| SE | 381 | | 1294 | | 586 | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different ($p>0.05$). SE indicates the standard error of the variable.

Leaf percentage in the pre-cutting forage mass varied ($p<0.05$) with defoliation frequency. Greater values were registered for $LI_{90\%}$ relative to $LI_{Max}$, with similar intermediate values for $LI_{95\%}$ (48.3, 45.5 and 42.3 $\pm$ 1.41% for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively). Stem percentage in the pre-cutting forage mass did not vary between treatments, its mean value being 22.8 $\pm$ 0.96%. Dead material percentage in the pre-cutting forage mass varied ($p<0.05$) with defoliation frequency and with the frequency × defoliation severity interaction. No difference was found between LI targets for the severity of 60%, while for 40% severity, higher values were recorded for $LI_{Max}$ relative to $LI_{95\%}$ with intermediate values for $LI_{90\%}$. There was a difference between levels of defoliation severity only for $LI_{Max}$, with higher values recorded for the 40% relative to 60% treatments (Table 5).

Table 5. Dead material percentage in pre-cutting forage mass (kg dm.ha-1 ) in *Paspalum notatum* cv. INIA Sepé subjected to different intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity | Frequency (LI % during regrow) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Pre-cutting height % | 90 | | 95 | | Max | | Means | SE |
| | | | (%) | | | | | |
| 40 | 12.0 | Aab | 8.6 | Ab | 17.8 | Aa | 12.8 | 1.91 |
| 60 | 12.2 | Aa | 9,0 | Aa | 10.9 | Ba | 10.7 | 1.28 |
| Means | 12.1 | ab | 8.8 | b | 14.3 | a | | |
| SE | 1.42 | | 1.77 | | 1.67 | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different (p> 0.05). SE indicates the standard error of the variable.

Weed percentage in the pre-cutting forage mass varied ($p<0.05$) only with growth period, with greater values recorded during Period 1 relative to Period 2 (18.6, 14.0 ± 1.43% for Period 1 and 2, respectively). Inflorescence percentage in the pre-cutting forage mass did not vary between treatments, its mean value being 3.0 ± 0.33%.

Crude protein percentage in the forage varied ($p<0.05$) with defoliation frequency. Higher values were recorded for the $LI_{90\%}$ relative to $LI_{Max}$ treatments (13.0, 12.7 and 12.1 ± 0.25% for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively). ADF percentage varied ($p<0.05$) with defoliation severity and with the frequency × defoliation severity interaction. No difference was found between LI targets for the 60% severity, while for 40% severity, higher values were recorded for $LI_{Max}$ relative to $LI_{90\%}$, with intermediate values for $LI_{95\%}$. There was difference between levels of defoliation severity only for the $LI_{90\%}$ treatments, with higher values recorded for the 60% relative to 40% treatments (Table 6).

Table 6. ADF percentage in forage in *Paspalum notatum* cv. INIA Sepé subjected to different intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity | Frequency (LI % during regrow) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pre-cutting height % | 90 | | 95 | | Max | | Means | | SE |
| | | | (%) | | | | | | |
| 40 | 37.4 | Bb | 38.5 | Aab | 39.0 | Aa | 38.3 | B | 0.36 |
| 60 | 39.4 | Aa | 39.7 | Aa | 38.6 | Aa | 39.2 | A | 0.44 |
| Means | 38.4 | | 39.1 | | 38.8 | | | | |
| SE | 0.38 | | 0.37 | | 0.44 | | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different (p> 0.05). SE indicates the standard error of the variable.

The percentage of NDF in the forage varied ($p<0.05$) with the frequency × defoliation severity interaction and with the growth period × frequency × defoliation severity interaction. No difference between treatments was observed in period 1. In period 2, no difference was found between LI targets for the 60% severity, while for the 40% severity, higher values were recorded for $LI_{Max}$ relative to $LI_{90\%}$ with intermediate values for $LI_{95\%}$. Differences in levels of defoliation severity were recorded only during period 2 for the $LI_{90\%}$ treatments, with higher values recorded for 60% severity (Table 7).

Table 7. NDF percentage in forage in *Paspalum notatum* cv. INIA Sepé subjected to different intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity<br>Pre-cutting height % | Frequency (% LI during regrow)<br>90 | | 95 | | Max | | Means | SE |
|---|---|---|---|---|---|---|---|---|
| | | | (%) | | | | | |
| | | | Period 1: | | | | | |
| 40 | 62.7 | Aa | 63.1 | Aa | 62.8 | Aa | 62.9 | 0.98 |
| 60 | 63.8 | Aa | 62.0 | Aa | 63.6 | Aa | 63.1 | 0.91 |
| Means | 63.3 | | 64.1 | | 63.2 | | | |
| SE | 0.93 | | 0.77 | | 1.14 | | | |
| | | | Period 2: | | | | | |
| 40 | 60.2 | Bb | 63.0 | Aab | 65.1 | Aa | 62,8 | 0.73 |
| 60 | 65.5 | Aa | 63.5 | Aa | 61.5 | Aa | 63.5 | 1.19 |
| Means | 62.8 | | 63.2 | | 63.3 | | | |
| SE | 0.75 | | 1.07 | | 1.14 | | | |

Means with the same uppercase in the column or lowercase in the row are not significantly different (p> 0.05). SE indicates the standard error of the variable.

Dry matter digestibility varied ($p<0.05$) with the frequency × defoliation severity interaction. No difference was found between LI targets for the 60% severity, while for the 40% severity, higher values were recorded for the $LI_{90\%}$ relative to $LI_{Max}$ with intermediate values for $LI_{95\%}$ treatments. There was difference between levels of defoliation severity for the $LI_{90\%}$ treatments, with higher values recorded for 40% (Table 8).

Table 8. Dry matter digestibility (%) in *Paspalum notatum* cv. INIA Sepé subjected to different intermittent defoliation strategies from November 15, 2018, to March 31, 2019

| Severity<br>Pre-cutting height % | Frequency (% LI during regrow)<br>90 | | 95 | | Max | | Means | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | | | (%) | | | | | | |
| 40 | 59.8 | Aa | 58.9 | Aab | 58.5 | Ab | 59.1 | A | 0.26 |
| 60 | 58.2 | Ba | 58.0 | Aa | 58.8 | Aa | 58.3 | B | 0.35 |
| Means | 59.0 | | 58.7 | | 58.6 | | | | |
| SE | 0.29 | | 0.29 | | 0.35 | | | | |

Means with the same uppercase in the column and lowercase in the row are not significantly different (p> 0.05). SE indicates the standard error of the variable.

### 3.3 Forage mass (kg DM.ha$^{-1}$) and botanical/morphological composition (%) at post-cutting

Forage mass at post-cutting varied ($p<0.05$) with frequency, defoliation severity and growing period. For the LI targets, higher values were recorded for $LI_{Max}$ relative to $LI_{90\%}$ (3370, 3770 and 3920 $\pm$ 131 kg DM.ha$^{-1}$ for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively). Regarding defoliation severity, higher values were recorded for the 60% severity (3190 and 4190 $\pm$ 107 kg DM.ha$^{-1}$ for treatments 40 and 60%, respectively). During the experimental period, higher values were recorded during period 2 (3490 and 3880

± 107 kg DM.ha$^{-1}$ for growth periods 1 and 2, respectively).

Leaf percentage in the forage mass at post-cutting varied ($p<0.05$) with defoliation severity, with higher values recorded for the 60% severity (33.1 and 41.4 ± 1.73% for treatments 40 and 60% respectively). Stem percentage varied ($p<0.05$) with defoliation frequency. Higher values were registered for $LI_{95\%}$ relative to $LI_{90\%}$ and $LI_{Max}$ (27.8, 32.8 y 27.8 ± 1.38% for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively).

Dead material percentage varied ($p<0.05$) with defoliation severity, with higher values recorded for the 40% severity (22.8 y 15.4 ± 1.27% for treatments 40 and 60%, respectively). Inflorescence percentage did not exceed 0.5% in all treatments.

### 3.4 Daily rates of forage accumulation (kg DM.ha$^{-1}$.day$^{-1}$) and total forage accumulation (kg DM.ha$^{-1}$)

The daily rate of forage accumulation varied ($p<0.05$) with frequency and defoliation severity. Higher values were recorded for $LI_{90\%}$ and $LI_{95\%}$ compared to $LI_{Max}$ treatments (66.0, 62.7 and 45.1 ± 4.27 kg DM.ha$^{-1}$.day$^{-1}$ for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively), and higher values were recorded for the 40% severity compared to 60% (64.7 and 51.1 ± 3.48 kg DM.ha$^{-1}$.day$^{-1}$ for treatments 40 and 60%, respectively). Forage accumulation varied ($p<0.05$) with defoliation frequency, with higher values recorded for treatments $LI_{90\%}$, $LI_{95\%}$ relative to $LI_{Max}$ (7870, 7760 and 5450 ± 625 kg DM.ha$^{-1}$ for treatments $LI_{90\%}$, $LI_{95\%}$ and $LI_{Max}$, respectively).

## 4. Discussion

In general, experimental conditions were adequately controlled, with pre-cutting LI values close to the pre-established targets, ensuring the planned contrasts between defoliation regimes. Forage mass recorded values were generally high and within the range found for *Paspalum notatum* in other countries, such as Japan[21] and USA[22], reaffirming this species' potential as a forage source during summer. Higher values were recorded in period 2 compared to period 1. This result could be related to the effect of leaf area recovery in period 1, since during the previous winter and due to frosts, plots did not have live (green) material above ground. Leaf percentage at pre-cutting was higher for the higher defoliation frequency ($LI_{90\%}$). This is a relevant aspect considering the importance the leaf component has for the plant regarding both its photosynthetic apparatus and effect on forage production; and for the grazing animal, given its preference for this type of plant structure and the associated benefits to animal performance[11]. Stem percentage did not vary between treatments and its average value was close to 23%, a result that is inconsistent with what happened in evaluations of other tropical pastures such as *Panicum maximum*, *Pennisetum purpureum* and *Brachiaria brizantha*, where stem percentage rapidly increased after the $LI_{95\%}$ condition[5]. This aspect generates greater management flexibility given that there is no increase in stem percentage in forage mass with higher levels of LI, generating benefits in terms of both herbage production and intake.

On the other hand, dead material percentage (Table 5) was higher for the lower frequency (treatments of 40% defoliation severity), an aspect that could be due to the longer interval between cuttings, which explains the greater accumulation of senescent and dead material under those circumstances[5][11]. Although stem percentage is relatively stable in the range of the defoliation frequencies studied, the increase in dead material with greater intervals between cuttings indicates greater losses due to senescence and nutritive value deterioration (reduction in CP and digestibility and increase in NDF and ADF). The recorded CP values are within the existing range in bibliography[21][22] (between 10-15%), variable according to leaf age, time of year, cutting frequency and level of nitrogenous fertilization. Regarding ADF (Table 6) and NDF (Table 7), the highest values were recorded for the combination $LI_{Max}$/40%, indicating a greater presence of structural tissue in the leaves which is consistent with larger leaves due to the greater intervals between cuttings. These values of fiber and dead material determined a lower dry matter digestibility (Table 8) for this treatment, indicating that the $LI_{95\%}$ condition during regrowth should not be exceeded, even if there is no increase in stem percentage in the forage mass.

In general, the values obtained for leaf dry matter digestibility were similar to those obtained for the species in previous studies, varying between 55 and

65% for green leaves during summer[23] and within the range found in experimental studies[22]. In turn, for $LI_{90\%}$, ADF and NDF values (in period 2) were higher for the 60% severity level, resulting in lower digestibility values. This result is expected since lower tissue renewal caused by lower defoliation severity generates leaves with greater structural tissues accumulation[24].

Values of forage mass at post-cutting, as described for pre-cutting, were higher in period 2, while highest values were registered for defoliation severity of 60%, a predictable outcome given the lower severity applied to treatments that had similar pre-cutting mass values. Furthermore, higher forage mass values for lower defoliation frequencies are a consequence of greater intervals between cuttings and higher pre-cutting forage mass, a common behavior in this type of study[7]. Leaf percentage at post-cutting was higher for the 60% severity, an expected result since less severe harvests do not reach the bottom half strata where a higher proportion of stems and dead material is normally accumulated. As expected, the percentage of inflorescences in the post-cutting forage mass was extremely low, not exceeding 0.5%.

The values recorded for both total forage accumulation and daily rates of forage accumulation are within the range of those observed by Hirata and others[20] in a review of experiments carried out with *Paspalum notatum* in Japan. Forage accumulation rate, as well as total accumulation during the experiment, was higher for higher the defoliation frequency treatments ($LI_{90\%}$ and $LI_{95\%}$), probably as a result of greater shading and lower photosynthetic efficiency associated with greater cutting intervals for the $LI_{Max}$ treatments, which determine greater senescence and therefore higher dead material percentage in the pre-cutting forage mass. Overall, the results indicate greater production of high nutritive value forage in *Paspalum notatum* cv. INIA Sepé if the defoliation frequency used does not exceed the critical LAI (95% LI). This is an analogous result to that reported for other tropical forage grasses such as *Panicum maximum*, *Pennisetum purpureum*, and *Brachiaria brizantha*. The difference relies on the fact that the restriction not to exceed 95% of LI would not be an increase in stem accumulation, but in dead material instead, with consequent reduction in harvest efficiency and nutritive value of produced forage.

## 5. Conclusions

*Paspalum notatum* cv. INIA Sepé has large flexibility of defoliation management, and optimal pre-cutting condition should not exceed 95% of LI (about 30 cm of canopy height) as a way to ensure high nutritive value and forage production.

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### Author contribution statement

DG: collected and analyzed the data, interpreted the results, and wrote the article; AS: contributed to the conceptualization of the experiment, in the analysis of the data and the editing of the article; SDS: performed the conceptualization of the experiment, experimental design, data analysis, interpretation of results and edited the article.

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