



## Morphogenesis of dwarf elephant grass clones in response to intensity and frequency of defoliation in dry and rainy seasons<sup>1</sup>

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**ABSTRACT** - The aim of this study was to evaluate during the dry and rainy seasons the morphogenesis traits of two clones of dwarf elephant grass under different management strategies. The study was conducted in a factorial  $2 \times 2 \times 3$  design, using two clones, one green and one purple, two residual heights, 25 and 45 cm, and three frequencies of defoliation according to the light interception of 90, 95 and 100%. The design was a randomized block with three replications. The variables were leaf elongation and leaf senescence rate, stem elongation rate and phyllochron. The leaf lifespan and the number of living leaves per tiller were also estimated. The clones presented low stem elongation rates, showing adaptation for grazing use. In the rainy season, the light interception of 100% promoted the highest stem elongation rate and increased the leaf senescence rate. In the dry season, the leaf elongation rate (LER) was higher for the purple clone than for the green one (23 vs 15 mm.tiller<sup>-1</sup>.day<sup>-1</sup>). In the rainy season, the LER of the green clone exceeded that of the purple one by 71% (149 vs. 87 mm.tiller<sup>-1</sup>.day<sup>-1</sup>). The phyllochron varied among clones only in the rainy season, when the value was 4.6 days.leaf<sup>-1</sup> for the green clone and 8.4 days.leaf<sup>-1</sup> for the purple one; both of these values are below the mean value observed during the drought (21,6 days.leaf<sup>-1</sup>). The residual heights did not affect, in an isolated way, any of the variables. The clones are well adapted to grazing, presenting low stem elongation rates. The interval between defoliations should consider the scope of light interception between 90 and 95%. The green clone, with a greater flow of biomass, requires handling with shorter defoliation intervals.

Key Words: leaf elongation, leaf senescence, light interception, *Pennisetum purpureum*, phyllochron, stem elongation

### Introduction

Elephant grass (*Pennisetum purpureum*) is one of the most productive nutritious value tropical grasses (Pereira & Ledo, 2008) however, its adoption for grazing use is hindered by its early stem elongation, which complicates management (Veiga, 1997). Grazing adaptation has been pursued in breeding programs incorporating short stature (Pereira, 2002).

The study of leaf emergence, leaf elongation and the leaf lifespan (Lemaire & Chapman, 1996) as well as stem elongation in tropical grasses (Sbrissa & da Silva, 2001), may help accelerate the selection of materials in breeding programs (Van Esbroeck et al., 1997) and determine the management of defoliation (Gomide et al., 2006). However, even cultivars of the same species have variations in their morphogenesis indices. Gomide & Gomide (2000) founded three live leaves in the *Panicum maximum* (Jacq.) cultivars Mombaça, Tanzânia, and Centenário with the senescence

process beginning 23 days after cutting. For the Vencedor cultivar, the number of living leaves was between five and six, and leaf death was apparent after the 37<sup>th</sup> day of regrowth.

According to Moser & Nelson (2003), differences in the morphology and tissue flow of tillers should be considered in adopting strategies for pasture management. In this sense, the number of leaves per tiller can be used as a criterion to establish the rest period under rotational stocking (Lemaire & Chapman, 1996; Gomide & Gomide, 2000). Candido et al. (2005) and Gomide et al. (2007) observed damage to the structural and productive characteristics of the pasture as the number of emerged leaves per tiller in Mombaça grass rose from 2.5 to 3.5 and/or 4.5 leaves per tiller.

Among management practices, the intensity and frequency of defoliation most influence the morphogenesis of grasses (Fulkerson & Slack, 1995),

affecting the canopy structure. Increases in leaf senescence and stem elongation have been related to conditions where the canopy exceeds the critical leaf area index, in which 95% of incident light is intercepted (Carnevali et al., 2006; Barbosa et al., 2007; Gomide et al., 2007). The height of stubble (residual height) is another important factor to ensure good sward structure (Carnevali et al., 2006; Barbosa et al., 2007; Casagrande et al., 2010).

The objective of this study was to evaluate the morphogenesis of dwarf elephant grass clones subjected to two residual heights combined with three frequencies of defoliation based on the light interception of the canopy.

### Material and Methods

The experiment was conducted at Embrapa Gado de Leite, located in Coronel Pacheco, Minas Gerais. The geographic coordinates of the site are 21°33'22" south latitude, 43°06'15" west longitude and 410 m altitude. The climate according to Köppen is a Cwa (mesothermal), and the soil of the experimental area is a dystrophic clayey oxisol (Embrapa, 2006).

A soil analysis of the experimental area showed the following chemical characteristics: pH in water = 5.4, P = 5.2 mg.dm<sup>-3</sup>, K = 65 mg.dm<sup>-3</sup>, Ca = 2.1 cmolc.dm<sup>-3</sup>, Mg = 0.8 cmolc.dm<sup>-3</sup>, Al = 0.0 cmolc.dm<sup>-3</sup>, H + Al = 3.14 cmolc.dm<sup>-3</sup>, base sum = 3.07 cmolc.dm<sup>-3</sup>; cation exchange capacity (CEC) = 6.21 cmolc.dm<sup>-3</sup>, and V = 49%. In an attempt to raise the base saturation to 60% the equivalent of 0.68 t.ha<sup>-1</sup> of lime was applied on September 26, 2007.

Two clones of dwarf elephant grass (green = CNPGL 92-198-7 and purple = CNPGL 94-34-3), two residue heights (25 and 45 cm) and three frequencies of defoliation based on light interception (LI) (90, 95 and 100%) were tested in a factorial design with three repetitions. The experimental units of 5 × 4 m were arranged in a randomized block design.

The field was planted on October 22 and 100 kg/ha P<sub>2</sub>O<sub>5</sub> (derived from superphosphate) fertilizer was placed in the furrows. The planting furrows were spaced 80 cm apart and were approximately 15 cm deep. Mature husked stems (7-8 months) were distributed in double rows. The stems were chopped with a machete, leaving 3 to 4 knots at each stake. The equivalent of 50 kg.ha<sup>-1</sup> N (from ammonium sulfate) and K<sub>2</sub>O (from potassium chloride) were applied on November 20, 2007.

On December 14, 2007 the plots were first cut conditioning them to their respective residue heights. Afterwards, the defoliation interval was based on the LI for each proposed treatment. Throughout the rainy season, the

plots were fertilized after each harvest with the equivalent of 50 kg/ha of N and K<sub>2</sub>O using a 20-05-20 formulation. Thus, the dose of fertilizer varied with the speed of regrowth for each treatment to meet the rapid restoration of the canopy as described by Da Silva & Nascimento Júnior (2007). During the dry period no fertilizer was applied.

At the time of cutting based on LI the plants were cut to predetermined residual heights with a brushcutter, and harvested by hand.

The LI of the canopy was monitored with an LP80 (Accupar) canopy analyzer at four points per plot.

The average LI of three replicates was used to determine the time of cutting for each treatment. Thus, the evaluation period varied between treatments and between seasons (dry and wet) as the time required to reach the LI stipulated.

The dry season consisted of the months of April through September 2008, while the rainy season encompassed the months of November 2008 through March 2009. During the dry season, morphogenesis evaluations occurred from May to July 2008, allowing a period of regrowth for each treatment. In the rainy season, two regrowth periods for each treatment, occurring between January and March 2009, were considered. Thus, values of the rainy season correspond to the average of two regrowth periods.

Climatic data for the evaluation period, presented in Table 1, were collected from the meteorological station located about 1,000 m from the experimental area.

During the regrowth period the leaf length and the number of expanded leaves were evaluated weekly. After cutting were chosen and marked with colored rings, three tillers in each plot were used to represent the average condition of the canopy.

At the beginning and end of the assessment period, the height of the ligule of the youngest mature leaf was measured to estimate the stem elongation (SER). The estimates of the morphogenetic indices, such as leaf elongation rate (LER), leaf appearance rate (LAR), leaf senescence rate (LSR), phyllochron, which was defined as the time in days for the appearance of successive leaves (Gomide & Gomide, 2000; Wilhelm & McMaster, 1995), were estimated as follows:

LER = increase in the leaf length of the tiller/assessment period;

LAR = number of emerged leaves/assessment period;

LSR = increase in senescent leaf tissue/assessment period;

SER = increase in the ligule height of the last expanded leaf/assessment period;

Phyllochron = 1/LAR

We also estimated the number of living leaves per tiller (LLN) and the lifespan of the leaves (LSL), calculated

Table 1 - Maximum and minimum average temperatures and precipitation between May 2008 and March 2009

Month/year	Tmax (°C)	Tmin (°C)	Precipitation (mm)
May/2008	25.6	13.1	13.2
June/2008	26.3	10.0	5.0
July/2008	27.0	9.5	0.0
August/2008	28.8	12.7	6.0
September/2008	27.2	12.7	65.1
October/2008	28.8	18.2	175.3
November/2008	27.7	17.7	195.8
December/2008	30.0	20.0	200.0
January/2009	30.2	20.6	278.7
February/2009	29.1	19.7	105.1
March/2009	32.1	21.4	179.2

as the product of the phyllochron and the number of green leaves per tiller (Lemaire & Chapman, 1996).

The data were grouped into seasons and subjected to analysis of variance and the treatment means were compared at 10% probability by the Tukey test.

## Results and Discussion

In the dry season, the LER was influenced ( $P < 0.10$ ) only by the clones, with the highest value the in purple clone (Table 2), and no interaction between factors. The residual heights and frequencies of defoliation did not change the LER ( $P > 0.10$ ). The literature suggests that there is a reduction in the LER as the intensity of defoliation increases (Gomide et al., 2006); however, Carvalho et al. (2005) found no effect of grazing residues of 50 and 100 cm on the morphogenetic traits of Napier elephant grass. Likewise, Casagrande et al. (2010) evaluated four herbage allowances in Marandugrass and observed no change in the LER.

The stem elongation rate (SER) was not influenced by any of the factors studied ( $P > 0.10$ , Table 2). It is possible that the high coefficient of variation (176.5%) compromised the detection of significant differences. Thus, although the observed value for the purple clone was three times that of the green clone, these values were not statistically different. At any rate, because these values were measured during the dry season, with longer intervals between cuts, they are much lower than those found by Carvalho et al. (2005) for the elephant grass cultivar Napier and by Rezende et al. (2008) for the cultivar Cameroon, showing the effective control of stem elongation in the short stature materials in this study.

The LSR responded to the interactions between the clone and residue height and between the residue height

and LI (Table 3). A higher LSR was observed in the green clone with a 25 cm residue, while the lowest value was obtained in the purple clone with a 25 cm residue. One possible explanation for these results is that the morphological difference between the clones causes the green clone to present a higher residual mass of green leaves (Gomide et al., 2010), resulting in potentially greater leaf length to senesce. For the residue of 45 cm there was no difference between clones. The association of higher LER (Table 2) and lower LSR (Table 3), especially for the 25 cm residue shows more favorable characteristics for the purple clone in the dry season. However, it is important to consider the tiller density to confirm this indication (Sbrissa & Da Silva, 2008; Gomide et al., 2006).

The LSR increased with LI only for the residue height of 45 cm ( $P < 0.10$ ) (Table 3). Longer defoliation intervals represent a greater chance for senescence occur. Moreover, with increased LI, the leaves in the lower strata of the canopy are more shaded, increasing the rate of leaf senescence. Carnevali et al. (2006) and Barbosa et al. (2007) found a marked increase in the accumulation of dead leaves for Mombaça grass and Tanzania grass, respectively, when the intervals between grazing were increased to 100% LI by the canopy during the pre-grazing period.

The residual heights differed only under 90% LI, with a lower rate of senescence under the 45 cm residue condition. The evaluations so far conducted with these materials have shown that there are more leaves under lower residue conditions, mainly in the green clone (Gomide et al., 2010). This fact, combined with the shortest interval between cuts at 90% LI, explains the lower value of the LSR in the treatment where a 45 cm residue and cutting took place at 90% LI.

The height of the residue did not affect the LSR consistently (Table 3), taking into account the clones of elephant grass and LI. This result, coupled with a lack of effect of the height of residue on the SER, caused some surprise, as grazing intensity and grazing intervals have been indicated as factors to control the structure of the pasture in terms of their leaf/stem ratio and percentage of dead material (Gomide et al., 2006; Da Silva & Nascimento Júnior, 2007).

The phyllochron, the leaf lifespan (LLS) and the number of living leaves per tiller (LLN) varied between clones and with the interaction between residue height and LI (Table 4). Higher phyllochron value (29.5 vs. 17.2 days.leaf<sup>-1</sup>) and a longer leaf lifespan (96.9 vs. 66.4 days) were observed in the purple clone, while the largest number of green leaves was observed in the green clone (4.0 vs. 3.5 living leaves).

Seeking a practical application of the morphogenesis study, Gomide et al. (2006) suggested the lifespan of the leaves as a determinant for the range of grazing. Thus, these results suggest that the interval between grazings/defoliations during the dry season might be approximately 95 days for the purple clone, while for the green clone 65 days would suffice. These intervals are quite long, but they serve to show that the definition of the interval between defoliations, which is shorter during the rainy season and longer during the dry season, must be based on technical criteria rather than empirical or subjective criteria that would pose risks to the productivity and sustainability of the pasture.

Analyzing the interaction of the variables “height of residue” and “light interception”, we noted that 95 and 100% LI promoted higher phyllochron values in the residue of 45 cm (Table 4). Under 90% of LI, however, the largest phyllochron was observed with a residue of 25 cm. The literature states that short swards have a higher density of smaller tillers (Sbrissa & Da Silva, 2008) and higher LARs (Skinner & Nelson, 1995). However, Rezende et al. (2008) also observed, in Cameroon grass pasture, no change in LAR of basal tillers as the stocking rate increased, despite the linear increase in the number of basal tillers. Also Neto et al. (2002), in a study with Mombacagrass, and Carvalho et al. (2005), with Napier grass, found no effect of grazing residues on the main morphogenetic traits evaluated.

In the residue of 25 cm, the phyllochron decreased with increased LI. This behavior could be explained by the elevation of the apical meristem, which accelerates leaf appearance. There was no effect of LI on the SER (Table 2).

The number of living leaves increased as LI increased in the 25 cm residue condition, but the opposite effect was seen in the 45 cm residue treatment. Possibly, the lower penetration of light into the canopy at the highest residue limited the survival of the leaves. Shading is one of the main factors affecting the metabolism of leaves and, consequently, their senescence (Gan & Amasino, 1997). Changes in canopy structure with consequent influence on light penetration were reported in Tanzaniagrass under three residues (Mello & Pedreira, 2004) and in Mombacagrass pasture under three grazing intervals (Gomide et al., 2007).

Under the 25 cm of residual height, the lifespan of the leaves decreased significantly with increasing LI, from 101.5 to 41.1 days, for 90 and 100% of LI, respectively. These two variables are interdependent, since the lifespan of the leaves is calculated by the product of the number of green leaves per tiller and the phyllochron (Lemaire & Chapman, 1996). Thus, the decrease in the lifespan of the leaves was related to the reduction in phyllochron under 25 cm of residue, while the number of green leaves had a little variation (Table 4). For the residue of 45 cm, the behavior was inconsistent, increasing between 90 and 95% LI and decreasing with 100% LI.

In the residue height comparison, the leaf lifespan differed only under the 90% LI condition, with lower values observed for the 45 cm residue.

As in the dry season, the LER was affected only by the clones (Table 5), and it was 71% higher in the green clone than in purple clone. In the dry season the LER was superior to the purple clone (Table 2), although the magnitude of difference was smaller.

Although there was no comparison between seasons, the effect of the season on morphogenesis is striking. For example, the reduction in the LER during the dry season compared with rainy season was 84% (1.9 vs. 11.8 cm/tiller.day). Paciullo et al. (2008) found a 72% reduction in LER of signal grass in full sun in winter compared with winter. However, Rezende et al. (2008) found no great variation in the LER of Cameroon elephant grass between the dry and rainy seasons. The monthly precipitation observed in that work, even under drought conditions, were always more than 100 mm, whereas in this study, the monthly precipitation was less than 10 mm (Table 1), which helps to understand this response. In fact, the rate of elongation is highly susceptible to weather conditions, especially water availability (Ludlow & Ng, 1977).

The LER is an important feature when associated with tiller density, due to its high correlation with herbage mass (Horst et al., 1978). Thus, the biomass flow, represented on the tiller by the balance between the rates of elongation and leaf senescence, allows estimation of biomass flow from the pasture when one considers the number of tillers (Sbrissa & Da Silva, 2008; Gomide et al., 2006).

Table 2 - Leaf elongation rate (LER) and stem elongation rate (SER) of elephant grass clones during the dry season

	Clone		Residue		Light interception			CV
	Green	Purple	25 cm	45 cm	90%	95%	100%	
	mm.tiller <sup>-1</sup> .day							
LER	15.7b	22.6a	19.8a	18.1a	17.6a	18.8a	20.5a	31.7%
SER	0.07a	0.22a	0.19a	0.10a	0.13a	0.20a	0.07a	176.5%

Means followed by the same letter do not differ (P>0.10) by Tukey test. CV = coefficient of variation.



It is noteworthy that neither the residue height nor the defoliation frequency affected the LER (Table 5). Even under frequent defoliations (IL = 90%), the LER remained high, showing no signs of depletion of the plant. However, the decrease in cutting frequency, represented by the higher LI at the time of cutting, increased the LSR and SER, showing its deleterious effect on the structure. Similar results were observed in studies with Mombaça grass (Carnevali et al., 2006; Gomide et al., 2007) and Tanzania grass (Barbosa et al., 2007).

The green clone showed a lower LSR, but a higher rate of stem elongation in relation to the purple clone. However, the SER was low, even with longer cutting intervals (IL = 100%), especially when compared with the figures reported by Resende et al. (2008) in Cameroon grass (up to 20 mm/tiller.day) and Carvalho et al. (2005) in Napier grass (15 mm/tiller.day). Again, this feature indicates a good adaptation of these clones for grazing use.

In the rainy season the three factors studied interacted to produce effects on the phyllochron, the number of leaves per tiller and the leaf lifespan (Table 6).

The phyllochron was higher for the purple clone at both residue heights, but only under 100% LI. The comparison at the highest LI is more reliable, because during the rainy season, the rapid growth of the grasses shortened the cutting intervals, particularly for the green clone under 90 and 95% LI. The defoliation intervals for the green clone were 16 and 20 days at 90 and 95% LI, respectively. Thus, analyzing the 100% LI condition, the green clone had higher leaf emission. This characteristic is important both for the formation of photosynthetic tissue and for its relationship to the tillering potential (Davies, 1971).

As expected, the phyllochron decreased during the rainy season when compared with the dry season (Table 4).

For the green clone, the phyllochron varied with residue only under the 90% LI condition, whereas for the

purple clone, it varied with residue under the 90 and 95% LI treatment. In both cases, the highest value was observed with the higher residue.

In general, LI increase did not affect the phyllochron. We expected that extending the cut intervals (increase in LI) would reduce the phyllochron because the stem elongation raises the apical meristem ever closer to the point of emergence of the leaves, reducing the time between leaf appearances (Skinner & Nelson, 1995). However, despite of the effect of LI, the SER (Table 5) was low. Two factors may be account for this response: (1) the short interval between cuts during the rainy season, especially for the green clone, along with (2) effective control of stem elongation of these dwarf varieties (Pereira & Ledo, 2008).

The number of green leaves varied among the clones only under the 45 cm residue and 90 and 95% LI condition (Table 6), with lower values for the purple clone. The effect of residues heights was found only for the green clone under 100% LI, when the 45 cm residue showed 5.6 leaves per tiller compared with 7.6 leaves per tiller for the 25 cm residue. An increase in the defoliation intensity can result in canopies with a higher number of short tillers, which, in turn, tend to have many small leaves (Grant et al., 1981) however, the lack of a similar effect under other light interceptions makes it hard to develop a consistent explanation for this fact. The leaf number per tiller is, in part, genetically determined, but it also responds to environmental changes and management practices (Lemaire & Chapman, 1996).

The increase in the cutting interval, promoted by increasing LI, resulted in a higher number of green leaves, except for the green clone under the 45 cm residue condition, for which there was no significant difference. This finding might suggest that cuts made at an LI close to 100% provide

Table 3 - Leaf senescence rate (mm.tiller<sup>-1</sup>.day) of elephant grass clones managed under two residue heights and three levels of light interception at the time of cutting

Clone	Residual height (cm)	
	25	45
Green	8,6aA	5,9aB
Purple	1,8bB	5,4aA
Light interception		
90%	4,4aA	1,3cB
95%	6,4aA	5,8bA
100%	8,0aA	9,9aA
CV (%)	42,3	

Means followed by the same letter, uppercase in the row and lowercase in the column, do not differ (P>0.1) by the Tukey test.

Table 4 - Phyllochron, number of living leaves per tiller and leaf life span of elephant grass clones according two residue heights and three levels of light interception at the defoliation during the dry season

Residue (cm)	Light interception (%)			CV (%)
	90	95	100	
	Phyllochron (days.leaf <sup>-1</sup> .tiller)			
25	30,6aA	19,4bAB	9,4bB	47,2
45	15,1bB	37,5aA	18,0AB	
	Number of living leaves per tiller			
25	3,5bB	4,1aAB	4,5aA	14,6
45	4,1aA	3,2bB	3,8aAB	
	Leaf lifespan (days)			
25	101,5aA	77,6aAB	41,1aB	50,5
45	60,2bB	115,3aA	66,8aAB	

Means followed by the same letter, uppercase in the rows and lowercase in the column, do not differ (P>0.1) by the Tukey test.

higher yields; however, other characteristics such as the LSR and SER should be considered for this definition.

Comparing the number of green leaves between the dry (Table 4) and rainy seasons (Table 6), we found that this parameter was less affected than either the phyllochron or the leaf lifespan.

Under management with defoliation interval between 90 and 95% LI, the green clone had 5-6 green leaves per tiller, while the purple clone had 4 to 5 leaves per tiller. This characteristic has been presented as a practical criterion for interrupting the rest period under intermittent stocking (Gomide et al., 2006, Fulkerson & Slack, 1995).

The leaf lifespan varied inconsistently with interactions between the experimental factors. Differences between clones were observed for both residue heights, but only when cutting occurred at 100% LI. Under this condition, the green clone had lower leaf lifespan than the purple

Table 5 - Leaf and stem elongation rates and leaf senescence rate in response to intensities and frequencies of defoliation during the rainy season

Clones		Residue		Light interception (%)			CV
Green	Purple	25	45	90	95	100	(%)
Leaf elongation rate (mm.tiller <sup>-1</sup> .day)							
149a	87b	128a	108a	126a	111a	118a	24.8
Leaf senescence rate (mm.tiller <sup>-1</sup> .day)							
0.33b	11.1a	7.0a	8.1a	0.8b	16b	192a	167.0
Stem elongation rate (mm.tiller <sup>-1</sup> .day)							
3.6a	0.5b	1.7a	2.4a	1.6b	1.4b	3.2a	76.1

Means followed by the same letter do not differ (P>0.1) by Tukey test.

Table 6 - Phyllochron, number of living leaves per tiller and leaf lifespan in response to both intensities and frequencies of defoliation during the rainy season

Clone	Residue (cm)	Light interception (%)		
		90	95	100
Phyllochron, days (CV = 30.3%)				
Green	25	6.5aAX	4.8aAX	3.6bAX
	45	2.7bBX	4.3bAX	5.8bAX
Purple	25	5.8aBXY	5.1aBY	8.9aAX
	45	10.8aAX	10.5aAX	9.3aAX
Number of living leaves per tiller (CV = 15.9%)				
Green	25	5.0aAY	5.3aAY	7.6aAX
	45	6.0aAX	6.0aAX	5.6aBX
Purple	25	5.6aAY	5.0aAY	7.3aAX
	45	4.6bAY	4.3bAY	6.6aAX
Leaf lifespan (CV = 26.9%)				
Green	25	31.6aAX	23.8aAX	26.3bAX
	45	15.4bBY	24.9bAXY	32.9bAX
Purple	25	30.4aBY	23.4aBY	57.7aAX
	45	47.7aAX	43.8aAX	57.9aAX

a>b compares clones within the combination residue/frequency; A>B compares residues within the combination clone/frequency; X>Y compares frequencies within the combination clone/residue by Tukey test at 10% probability.

one, which is consistent with its lower phyllochron. In fact, the green clone was characterized by having a greater biomass flow and a shorter interval between cuts. On average, the plots of the green clone were cut every 26 days, versus every 47 days for the purple clone. In this sense, it is noteworthy that the increase in LI reflected an increased in the leaf lifespan for purple clone.

## Conclusions

The increase in LI at the time of cutting increases the rate of leaf senescence and reduces the phyllochron. The residue heights do not affect the leaf elongation rate and stem elongation rate. During the dry season, the phyllochron increases and the LER decreases for both clones and the leaf lifespan increases concomitantly. The green clone has a higher biomass flow, represented by higher rates of elongation and leaf senescence, and smaller values of phyllochron and leaf lifespan. When choosing the interval between defoliations the appearance of 4 to 5 leaves in the green clone and 5 to 6 leaves in the purple clone should be considered.

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