Revista Brasileira de Zootecnia
© 2012 Sociedade Brasileira de Zootecnia
ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.41, n.8, p.1848-1857, 2012

Frequencies and intensities of defoliation in Aruana guineagrass swards: morphogenetic and structural characteristics[1]

Guilherme Doneda Zanini[2], Gabriela Trevisan Santos[2], André Fischer Sbrissia[3]

[1] *Project funded by FAPESC – Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina.*
[2] *Programa de Pós-Graduação em Ciência Animal, UDESC/CAV, Lages-SC.*
[3] *Departamento de Produção Animal e Alimentos, Universidade do Estado de Santa Catarina (UDESC/CAV) – Avenida Luiz de Camões, 2090, 88520-000, Lages/SC.*

ABSTRACT - The objective of this study was to evaluate the morphogenetic and structural characteristics of Aruana guineagrass pastures (*Panicum maximum* cv. Aruana) subjected to rotational stocking by sheep. The treatments corresponded to grazing when swards reached 95 or 98% of interception of incident light (LI) until post-grazing heights of 10 and 15cm and were allocated to experimental units (plots of 196 m^2), according to a 2 × 2 factorial arrangement in a completely randomized design, with three replications, from January to May 2009. The morphogenetic assessments included: leaf appearance and elongation rates (LAR and LER), phyllochron (PHY) and leaf life span (LLS). Structural evaluations assessed the number of green leaves (NGL), dead leaves (NDL) and expanded leaves (NEL) per tiller, tiller population density (TPD) and final leaf length (FLL). The pre-grazing sward height relatively constant during the experimental period, with values ranging between 30 and 40 cm for treatments of 95 and 98% of LI, respectively, indicating potential for the development and use of management practices based on pasture conditions goals. The morphogenetic and structural characteristics were influenced by the frequency and intensity of grazing adopted, as well as by the seasons, implying that the capacity and speed for the recovery of Aruana grass pastures after grazing depend mainly on the management and edaphoclimatic conditions. The best grazing management for Aruana guineagrass is 95% canopy light interception, i.e., 30 cm pre-grazing height pastures interrupted when reaching 15 cm residue.

Key Words: grazing management, morphogenesis, *Panicum maximum*, sward height

Introduction

Animal husbandry on pastures in Brazil is recognized as the technical option that allows more flexibility when designing and planning competitive and economically viable systems, once the production costs are low and the animal product is said to be of better quality. In order to turn this into a competitive activity, it is really necessary to use the forage plant adequately, having comprehensive knowledge of its response in grazed environments. Lemaire & Chapman (1996) described the importance of morphogenesis (leaf appearance rate (LAR), leaf elongation rate (LER) and leaf life span (LLS)) as a key variable in the process of understanding the productive capacity of pastures. It is worth stressing that for tropical forage species, the stem elongation rate (SER) is also an important variable that causes morphogenetic changes in the sward structure and consequently on the leaf blade:stem ratio (LSR) (Sbrissia & Da Silva, 2001).

Although the morphogenic variables are genetically-determined characteristics, they can be influenced by environmental variables such as temperature (Duru & Ducrocq, 2000ab), light quality and intensity (Da Silva et al., 2009), water availability (Morales et al., 1997; Durand et al., 1997), nutrients and grazing effects (Barbosa et al., 2002), which define the rates and duration of the processes. The combination of these morphogenetic variables determines the main structural characteristics of tillers in pastures: final leaf length (FLL), tiller population density (TPD), number of green leaves per tiller (NGL) and leaf:stem ratio, which, in turn, directly influence the leaf area index (LAI) of the pasture (Da Silva et al., 2009).

The results available for Brazilian conditions, obtained in recent years for tropical forage plants, both under continuous (Mesquita et al., 2010; Pereira et al., 2010) and intermittent stocking conditions (Da Silva et al., 2009), in experiments characterized by strict control of the forage sward structure have shown high potential for forage production and animal performance. The objective of this experiment was to study the effects of different frequencies and intensities of grazing on the morphogenetic and structural characteristics of tillers on pastures of *Panicum*

Received October 18, 2010 and accepted November 25, 2011.
Corresponding author: a2afs@cav.udesc.br

maximum Jacq. cv. Aruana, grazed under rotational stocking, in order to understand and characterize their functional responses, which may contribute to planning grazing strategies and ensure productivity and longevity for these pastures.

Material and Methods

This study was performed between January and May 2009 at the Center of Agro-veterinary Sciences of Universidade Estadual de Santa Catarina (UDESC/CAV). The study site is located at an altitude of 913 m on approximately 27º47' Southern latitude and 50º18' Western longitude in Lages, Santa Catarina, Brazil. The geographical relief of the area is mildly to moderately undulated, and the soil is haplic cambisol (Embrapa, 2006). The chemical characteristics of the soil before the onset of the study were as follows: water pH - 5.2; P - 7.5 mg/dm^3; K - 164 mg/dm^3; Ca - 5.1 cmol$_c$/dm^3; Mg - 3.5 cmol$_c$/dm^3; H + Al - 6.7 cmol$_c$/dm^3 and Al - 0.3 cmol$_c$/dm^3.

The soil was prepared conventionally using plowing and harrowing at the beginning of September 2008. Seeds were cast by sowing during the second half of October with 10 kg/ha of seeds (cultural value = 32%), which were buried to 1 to 2 cm depth through harrowing, followed by a compaction roller. The regional climate is subtropical, without a dry season and with cool summers. The average temperature is between 9.2 to 10.8 ºC in the coldest months and 19.4 to 22.3 ºC in the warmest months (Braga & Ghellre, 1999). The climate data during this study were collected at the UDESC/CAV experimental meteorological station, which is located approximately 250 m from the study area (Figure 1).

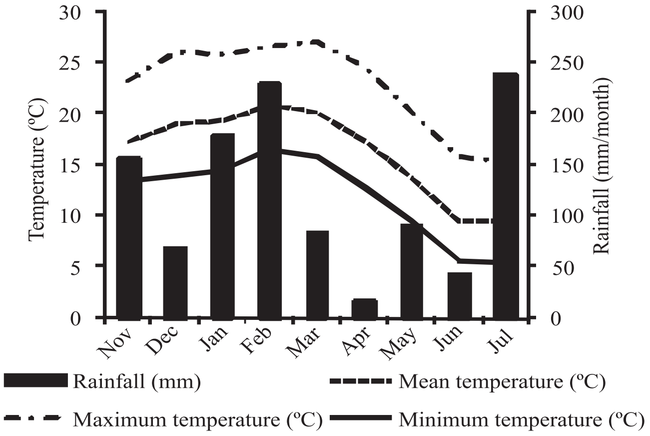


Figure 1 - Mean temperature (minimum, mean and maximum) and mean rainfall during the experimental period.

The experiment was fully randomized with 2 × 2 factorial design and was replicated three times. Thus, there was a total of 12 experimental units measuring 196 m^2 each. Treatments consisted of two frequencies (time needed for the sward to attain 95 to 98% light interception during regrowth) and two defoliation intensities (10 and 15 cm post-grazing heights).

Prior to establishing the treatments, no grazing occurred, and the grass was mowed to approximately 15 cm in height. This was performed first at the end of December 2008 and again at the beginning of January 2009, when treatments reached the desired light interception level. The treatments were maintained until the second half of May, permitting measurements to be made in two different seasons (summer and fall). Texel sheep (live weight of approximately 30 kg, provided by the UDESC/CAV Animal and Food Production Department) were used as the grazers. The number of animals used in each grazing cycle was calculated so that grass grazing down would last no longer than one day by the mob-grazing technique (Gildersleeve et al., 1987). Animals merely served as defoliating agents, and they were not subjected to any assessments. Grasses received 150 kg/ha N from urea in fractions corresponding to each grazing cycle throughout the study.

Light interception (LI) was measured twice each week at the onset of the regrowth period and every two days after reaching 90% LI until achieving the 95 and 98% LI goals. In each experimental unit, an ACCUPAR® model LP 80 (Decagon Devices, USA) sward analyzer was used to perform readings at six random points that were representative of the average state of the grasses at the time of sampling. One reading was performed above the sward, and five were performed at ground level at each sampling site. Sward height was measured in the same frequency as the LI assessments. Fifty readings per unit were taken during each assessment session using a sward stick (Barthram, 1985) along five transects (10 points per transect) following a zigzag pattern.

For the assessment of morphogenetic and structural characteristics, two points representing the average height of pasture in each experimental unit were chosen, where 2 m long metal bars, graduated every 20 cm were allocated since the beginning of the assessment (pre and post-grazing). In these locations, 10 tillers per bar were selected and numbered using adhesive tape. On these tillers, leaves were numbered and classified as: intact or defoliated; expanding leaves (no visible ligule); expanded leaves (visible ligule) or leaves that did not show any growth (sometimes the ligule was positioned into the sheath, making visualization difficult) and senescent leaves (when some portion of the leaf is starting the process of senescence). Leaves with more than 50% of the leaf blade compromised by senescence were considered dead leaves. For expanding leaves the procedure was similar, but the framework of the measure became the ligule of the last expanded leaf (Duru & Ducrocq, 2000b). For senescence leaves, the leaf blade was considered from the ligule to the point where the senescence process had advanced. The stem length (stem + sheaths) was measured from between the ground level to the ligule of the last expanded leaf.

The tiller population density (TPD) was determined by counting the total number of existing tillers within two 38 cm^2 diameter metal frames, placed at points representing the average condition of the pastures at the moment of the assessment. These countings were systematically performed pre-grazing, just before the entry of animals in the paddocks. After counting, the tillers were cut (common scissors) at ground level, packed in paper bags, taken to forced-ventilation oven at 65 °C for 48 hours and then they were weighed to determine dry matter weight (kg DM/ha).

The data were analyzed using the procedure MIXED of the statistical package SAS® (Statistical Analysis System, version 8.02). Covariance matrix selection was made according to the Akaike information criterion (AIC) (Wolfinger, 1993). Thus, there was the possibility to detect the effects of the main causes of variation (LI, post-grazing height and time of year, and the interactions between them). T-tests were used to compare means between treatments at the 5% significance level.

Results and Discussion

Triple interaction was not observed for any of the variables. The intervals between grazing were variable and, as a result, it also occurred for the number of grazing cycles. Thus, more frequent (95% of LI) and less severe (after-grazing height of 15 cm) grazing provided five grazing cycles. More frequent (95% of LI) and more severe (10 cm) grazing provided four grazing cycles, as well as less frequent (98% of LI) and less severe (15 cm) grazing. Less frequent (98% of LI) and more severe (10 cm) grazing, in turn, provided only three grazing cycles.

Pre-grazing sward height values were quite uniform when pastures were grazed at 95% of LI. The same pattern of response was not observed when the pastures were managed at 98% of LI. Sward height was influenced by the LI ($P<0.05$), post-grazing height ($P<0.05$), season of the year ($P<0.05$), LI × post-grazing height interaction ($P<0.05$) and LI × season of the year interaction ($P<0.05$). Pastures grazed at 95% of LI showed an average height of 31 cm. But for less frequent grazing (98% of LI) there were height variations with the highest values observed in pastures grazed at 98% of LI and post-grazing heights of 10 cm (Table 1). Higher pre-grazing heights were recorded for pastures grazed at 98% of LI in the two periods evaluated (summer and fall).

The pre-grazing heights of canopies were also stable in experiments conducted by Da Silva et al. (2009) with Mombaça grass. For pastures grazed at 95 and 100% of LI, the pre-grazing heights were 90 and 115 cm, respectively, indicating potential for the development and use of management practices based on pasture condition targets. Hack et al. (2007) compared, under intermittent stocking management pastures of Mombasa grass using two pre-grazing heights, 90 and 140 cm, and two post-grazing heights, 30 and 50 cm. The authors showed that lower pre-grazing height had a favorable effect on sward characteristics and milk production of cows kept exclusively under grazing. Consistent results about pre-grazing heights observed for Aruana grass point to a very promising way for the possibility of using sward height for pre-grazing as a practical, easy and reliable guide showing great uniformity and consistency regardless of season, post-grazing height and phenological stage of plant (Sbrissia & Da Silva, 2001; Vilela et al., 2005; Pereira et al., 2010). However, it is important to emphasize that height determination should be associated

Table 1 - Pre-grazing sward surface height (cm) in Aruana guineagrass pastures subjected to grazing frequencies and intensities in two seasons of the year

	Sward light interception (%)	
Post grazing sward height	95	98
10 cm	32.4Ba (0.65)	45.2Aa (0.73)
15 cm	30.7Ba (0.65)	39.3Ab (0.65)
	Sward light interception (%)	
Season of the year	95	98
Summer	32.9Ba (0.65)	47.1Aa (0.65)
Fall	30.0Ba (0.65)	37.4Ab (0.73)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$). Numbers in parentheses correspond to the standard error of the mean.

with grazing physiological and ecophysiological parameters to be valid as a management tool.

The time to remove the animals was determined by post-grazing height of pastures in order to maintain the control over the structure of the forage sward. The post-grazing height was influenced by LI ($P<0.05$), post-grazing height ($P<0.05$), season of the year ($P<0.05$), LI × season of the year interaction ($P<0.05$) and post-grazing height × season of the year interaction ($P<0.05$). Overall, the goal of keeping post-grazing height was achieved only when pastures were grazed at 95% of LI and post-grazing height of 15 cm (Table 2). There was an increase in post-grazing height from summer to fall for pastures grazed at 98% of LI (Table 2).

Maintenance of post-grazing conditions was reached during the two growing seasons with post-grazing height of 15 cm (Table 2). The same response was not observed for most of the severe grazing (10 cm), in which the increase in post-grazing height from summer to fall was observed (Table 2). These results are in agreement with the data presented by Zanini et al. (2012), which showed that around 90% of the whole stem in forages subjected to rotational stocking is at heights lower than 50% of the pre grazing height, making the process of seizing and ingesting forage more difficult.

Lemaire & Chapman (1996) observed that LAR is considered the main feature of morphogenesis because of its influence on the three main components of the sward structure: final leaf length (FLL), tiller population density (TPD) and number of live leaves per tiller (NGL), determining the leaf area index (LAI) of the pasture. There were only season effects ($P<0.05$) for this variable (Figure 2) and the highest values were observed in the summer and the lowest in the fall.

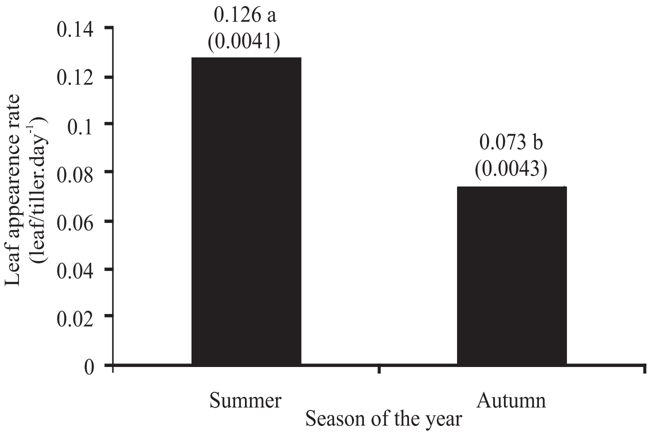
The highest values for LAR were observed in the summer, 42% higher than in the fall. Gastal et al. (1992) showed that LAR and LER generally tend to increase with increasing temperature. Therefore, the FLL, determined by the relationship between leaf elongation rate and leaf appearance rate increases according to the temperature. As a result of shorter interval between the appearance of leaves (Figure 2), tillers which had grown in the summer showed larger number of leaves (Figure 5) but with smaller sizes (Table 7). On the other hand, leaves which had grown in the summer, under high temperatures (Figure 1), showed greater length mainly due to higher LER (Table 4).

The phyllochron (PHY) in grasses results from the inverse of the LAR and is related to the time interval between the appearance of two consecutive leaves in tillers. There was effect of the season of the year ($P<0.05$) and LI × post-grazing height interaction ($P<0.05$) for this variable. Throughout the growing seasons, the lowest values were recorded in the summer (8.30 days/leaf) and the highest in the fall (15.3 days/leaf). The values observed in this study were similar to those found by Pena et al. (2009) working with Tanzania grass subjected to two heights and three cutting intervals (7.5 and 17.9 days/leaf) and by Santos et al. (2011), working on signalgrass pastures varying on height (7.9 and 12.3 days/leaf). The interaction between LI × post-grazing height showed that there was an increase in the

Table 2 - Post-grazing sward height (cm) in Aruana guineagrass pastures subjected to grazing frequencies and intensities in two seasons of the year

	Sward light interception (%)	
Season of the year	95	98
Summer	14.4Ba (0.43)	18.0Ab (0.43)
Fall	15.2Ba (0.43)	20.9Aa (0.4842)
	Post grazing height (cm)	
Season of the year	10	15
Summer	14.5 Bb (0.43)	17.1Aa (0.43)
Fall	17.8Aa (0.48)	17.7Aa (0.43)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$).
Numbers in parentheses correspond to the standard error of the mean.



Numbers in parentheses correspond to the standard error of the mean.

Figure 2 - Leaf appearance rate (leaf/tiller.day^{-1}) in Aruana guineagrass pastures in two seasons of the year.

Table 3 - Phyllochron (days.leaf^{-1}) in Aruana guineagrass pastures subjected to grazing frequencies and intensities

	Sward light interception (%)	
Post grazing height	95	98
10 cm	11.83Aa (0.436)	12.89Aa (0.488)
15 cm	10.43Bb (0.436)	12.12Aa (0.436)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$).
Numbers in parentheses correspond to the standard error of the mean.

phyllochron when pastures were grazed from 95 to 98% LI, with more pronounced effects on pastures grazed at 98% of LI and post-grazing height of 15 cm (Table 3).

To Fournier et al. (2005), the time interval necessary for the appearance of two consecutive leaves is directly connected to the duration of leaf elongation, i.e., an increase in sheath length results in increase of phyllochron (Skinner & Nelson, 1995). The functional relation between LER and PHY (Sbrissia, 2004) can explain the data obtained. This is an exponential relation, so in Brachiaria pastures, for instance, leaf elongation rates above 1.3 cm/tiller.day^{-1} tend to be settled at around 9-12 days/leaf, showing that the values found are within those already reported in the literature.

Leaf elongation rate showed to be the morphogenetic variable that best directly correlates with forage dry matter (Horst et al., 1978) and it was affected by environmental and grazing factors in this study. Effects caused by season of the year ($P<0.05$) and the LI × post grazing height interaction ($P<0.05$) were observed. The highest LER were recorded in the summer (2.29 cm/tiller.day^{-1}) and the lowest in the fall (1.02 cm/tiller.day^{-1}). Barbosa et al. (2011), studying Tanzania grass subjected to three frequencies and two defoliation intensities found values around 4.16 and 1.16 cm/tiller.day^{-1} for the LER in the summer and winter, respectively. The increase in these values, according to the authors, is mainly due to increased availability of nutrients and growth factors such as water, light and temperature during the summer. The LI × post-grazing height interaction showed that LER increased in pastures grazed from 95 to 98% of LI, with more pronounced effects in pastures grazed at 98% of LI and post-grazing height of 10 cm (Table 4).

The increase in the length of the leaf sheath results in higher values of PHY (Skinner & Nelson, 1995), since the time required to visualize the emerging new leaf can be delayed, based on a basic relation established by the length of the sheaths that surround the apical meristem and leaf elongation rate. According to Duru & Drucrocq (2000a), the fact that the leaf travels a greater path between its connection point to the meristem and the end of the pseudostem formed by sheaths of older leaves can explain the greater LER found in pastures grazed at 98% of LI and post-grazing height of 10 cm.

Table 4 - Leaf elongation rate (cm/tiller.day^{-1}) in Aruana guineagrass pastures subjected to grazing frequencies and intensities

	Sward light interception (%)	
Post grazing height	95	98
10 cm	1.42Bb (0.127)	1.89Aa (0.142)
15 cm	1.69Aa (0.127)	1.71Aa (0.127)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$). Numbers in parentheses correspond to the standard error of the mean.

Stem elongation rate (SER) directly affects TPD and FLL and it can also be used as an indicator of control or not of the accumulation of this component by grazing management (Da Silva et al., 2009), whose growth is unfavorable for the pasture production system, since it represents a physical barrier to the voluntary intake of grazing animals, affecting the ability to grasp forage (Hodgson, 1990). The SER varied according to the LI ($P<0.05$), LI × post-grazing height ($P<0.05$), LI × season of the year ($P<0.05$) and post-grazing height × season of the year interactions($P<0.05$) (Table 5).

Greater SER was observed in pastures grazed at 98% of LI and post-grazing height of 10 cm and 15 cm (Table 5). When pastures were managed at 95% of LI associated with post-grazing height of 15 cm, there was increase in SER (Table 5). Overall, more frequent grazing (95% of LI) showed more control of the stem elongation, and pastures grazed at 95% of LI and post-grazing height of 10 cm were the ones that showed the lowest SER (Table 5). Cândido et al. (2005) observed increased stem elongation from the point at which the sward intercepted 95% of photosynthetically active radiation in Mombaça grass pastures subjected to intermittent grazing regime. Likewise, Da Silva et al. (2009), in a study with Mombaça grass pastures under different defoliation regimes, observed that when the rest period was extended until 100% of LI, the stem elongation was greater than in pastures where the rest period was interrupted when the sward reached 95% of LI. Greater stem elongation in pastures grazed at 98% of LI can be justified by greater

Table 5 - Stem elongation rate (cm/tiller.day^{-1}) in Aruana guineagrass pastures subjected to grazing frequencies and intensities in two seasons of the year

	Sward light interception (%)	
Post grazing height	95	98
10 cm	0.009Bb (0.0133)	0.246Aa (0.0148)
15 cm	0.099Ba (0.0133)	0.205Aa (0.0133)
	Sward light interception (%)	
Season of the year	95	98
Summer	0.085Ba (0.0133)	0.216Aa (0.0133)
Fall	0.022Bb (0.0133)	0.235Aa (0.0148)
	Post grazing height (cm)	
Season of the year	10	15
Summer	0.112Bb (0.0133)	0.189Aa (0.0133)
Fall	0.142Aa (0.0148)	0.116Bb (0.0133)

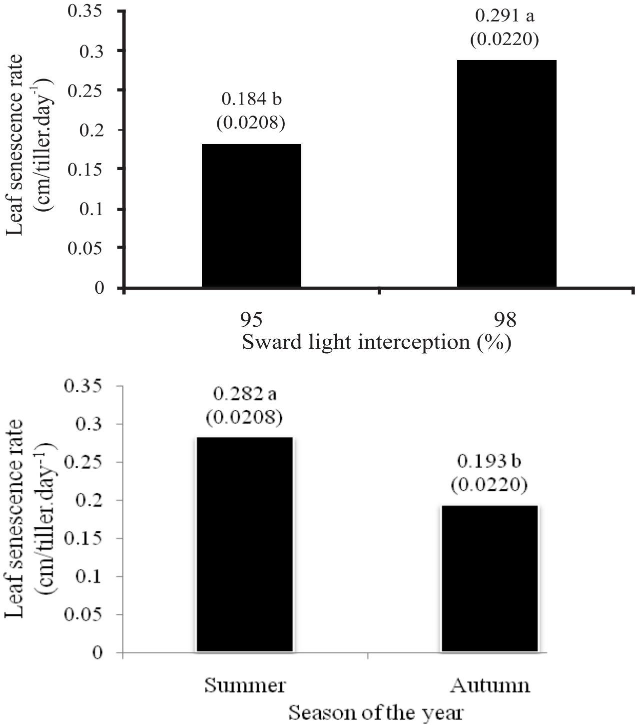
Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$). Numbers in parentheses correspond to the standard error of the mean.

sward height (Table 1), causing mutual shading of tillers and severe competition for light. The LI × season of the year interaction showed that there was an increase in SER in the summer when pastures began to be grazed at 98% of LI (Table 5). There was SER reduction from the summer to the fall when pastures were grazed at 95% of LI. The same response was not observed for pastures grazed at 98% of LI (Table 5). The increased availability of growth factors such as water, light and temperature during the summer (Figure 1) may explain the increased stem elongation in pastures grazed at 95% of LI. The post-grazing height × season of the year relation showed that there was a SER increase in the summer when pastures were grazed at post-grazing height of 15 cm (Table 5). There was a SER reduction from summer to fall when pastures were grazed at a post-grazing height of 15 cm. The same behavior was not observed in pastures grazed at a post-grazing height of 10 cm (Table 5). Variations of temperature or quality of light can bring about changes in appearance and elongation rates of leaves and stems, in the leaf area index (LAI), in the FLL, in the number of leaves per tiller and in tiller population density, as shown by Lemaire & Agnusdei (2000). Thus, the differences in stem elongation between the grazing frequencies tested (95 or 98% of LI), correspond to plastic responses of plants to the post-grazing height used (10 or 15 cm) and to the season (summer or fall).

The leaf senescence rate (LSR) was influenced by LI (P<0.05) and season (P<0.05). For pre-grazing sward light interception, the highest rates were observed in pastures grazed at 98% of LI (Figure 3A) and in the summer there were greater rates compared with the fall (Figure 3B).

Da Silva et al. (2009) showed the increased accumulation of dead material after the sward intercepted 95% of the photosynthetically active radiation (PAR). Pedreira et al. (2009), in a study with Xaraés grass at a post-grazing height of 15 cm, observed that after the rest period of about 22 days (time for the sward intercept 95% of PAR), it also showed increased accumulation of dead material. The highest leaf senescence rate in pastures grazed at 98% of LI can be attributed to greater competition for light and hence to lower tissue replacement in these pastures. According to Moreira et al. (2009), a possible explanation for higher rates of senescence in the summer may be the accumulation of this component in the pasture since the beginning of the experiment (January). Moreover, during hot and wet periods (summer), tissue turnover is enhanced and both tiller survival and mortality are accelerated. So, rest periods longer than the leaf lifespan result in huge losses due to senescence.

The longevity or leaf lifespan (days/leaf) is an important feature for determining tissue stream at individual tillers level (Lemaire & Chapman, 1996). Leaf lifespan (LLS), in turn, was affected by LI (P<0.05), season of the year (P<0.05) and LI × post-grazing height (P<0.05). In the fall, higher LLS was found (50.7 days.leaf^{-1}), compared with the summer (32.8 days.leaf^{-1}). The LI × season of the year interaction showed that there was LLS increase from summer to fall in pastures grazed at 95 and 98% of LI, and those of least frequent grazing (98% of LI) were the ones that showed the highest values (Table 6).



Numbers in parentheses correspond to the standard error of the mean.

Figure 3 - Leaf senescence rate (cm/tiller.day^{-1}) in Aruana guineagrass pastures subjected to grazing frequencies (A) and seasons of the year (B).

Table 6 - Leaf lifespan (days.leaf^{-1}) in Aruana guineagrass pastures subjected to grazing frequencies and intensities

	Sward light interception (%)	
Season of the year	95	98
Summer	32.9Ab (1.31)	32.7Ab (1.31)
Fall	46.3Ba (1.31)	55.0Aa (1.47)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different (P>0.05). Numbers in parentheses correspond to the standard error of the mean.

The longer LLS recorded during the fall suggests some adaptation of the plant to maintain its leaf area in the balance between growth and senescence processes (Nabinger, 1997). In the fall it took almost eight days more than in the summer (Table 6) for the emergence of a new leaf. The LLS and LAR are associated to each other, as higher LAR determines lower LLS (Sbrissia & Da Silva, 2001; Barbosa et al., 2011).

The final length of the leaves (FLL) is determined by the relation between LAR and LER since, for a particular genotype, the expanding period of a leaf is a constant fraction of the interval between the appearance of successive leaves (Dale, 1982). There were effects caused by LI ($P<0.05$), season of the year ($P<0.05$), LI × post-grazing height interaction ($P<0.05$) and LI × season interaction ($P<0.05$). There was an increase in the final length of leaves for more frequent grazing (95% of LI), with more pronounced effects when the pastures were grazed at 15 cm post-grazing height (Table 7). The same behavior was not observed in less frequent grazing (98% of LI), and the highest values were found in the most severe grazing (10 cm post-grazing) (Table 7). The LI × season of the year interaction showed that FLL was lower from summer to fall in pastures grazed at 98% of LI (Table 7). In pastures grazed at 95% of LI, although no difference was found, the FLL showed a slight increase from summer to fall (Table 7).

According to Gomide & Gomide (2000), FLL is affected mainly by the length of the pseudostem (sheath wrap). Thus, the greater the pseudostem, the larger the space to be covered by leaves in order to start and complete their emergence to achieve expansion, determining therefore the greater length. So it is possible to explain the results obtained for FLL, which were higher in pastures grazed at 98% of LI and post-grazing height of 10 cm and in pastures grazed at 98% of LI in the summer (Table 7). It is noteworthy that the elongation of stems in a grazing cycle is reflected in the length of pseudostem in the next cycle, since the largest SER were observed in less frequent (98% of LI) and more severe (10 cm post-grazing height) grazing (Table 5). The same explanation can be used to discuss the higher values of FLL in pastures grazed at 98% of LI in the summer, since the higher grazing interval (98% of LI) and the better growth conditions (light, water temperature) during the summer influenced the FLL (Table 7) and SER (Table 5).

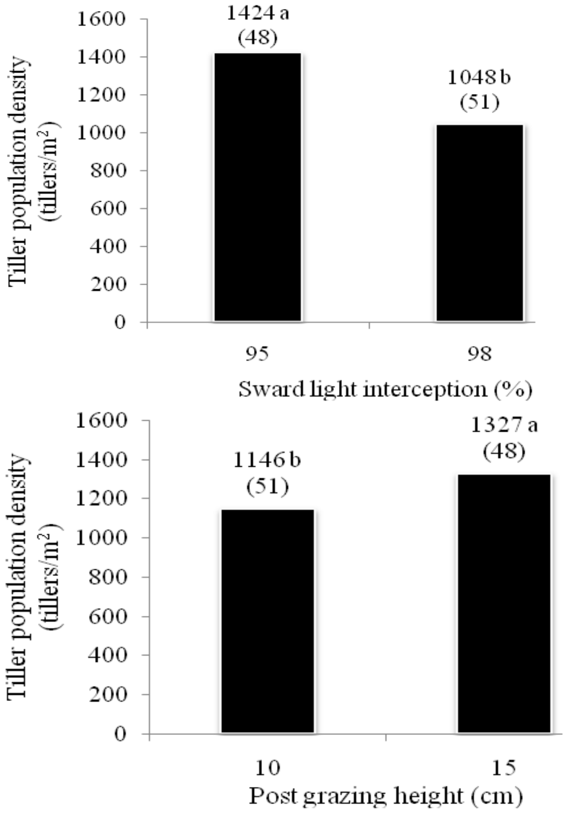
Table 7 - Final leaf lenght (cm) in Aruana guineagrass pastures subjected to frequencies and intensities of grazing in two season of the year

	Sward light interception (%)	
Post grazing height	95	98
10 cm	11.5Bb (0.30)	13.3Aa (0.33)
15 cm	12.6Aa (0.30)	12.2Ab (0.30)
	Sward light interception (%)	
Season of the year	95	98
Summer	12.0Ba (0.30)	13.7Aa (0.30)
Fall	12.2Aa (0.30)	11.7Ab (0.33)

Means followed by the same lowercase letter in columns and upper case letters in the rows are not different ($P>0.05$). Numbers in parentheses correspond to the standard error of the mean.

The tiller population density (TPD) is the component of the LAI that allows greatest adjusting flexibility by the plant to different plant defoliation regimes (Sbrissia & Da Silva, 2001). Effects caused by LI ($P<0.05$) and post-grazing height ($P<0.05$) were observed and the highest values were observed in pastures grazed at 95% of LI and the lowest in pastures grazed at 98% of LI (Figure 4A). The lowest TPD were observed in more severe grazing (10 cm post-grazing height) and the highest in pastures grazed at 15 cm post-grazing height (Figure 4B).

The first effect of defoliation is a plastic response of plants to adapt to changes in their environment (Lemaire & Agnusdei, 2000). Tillering is fostered, among other factors, by the quantity and quality of solar radiation that reaches the soil. Pastures exposed to high grazing pressure are characterized by numerous small tillers, while the presence



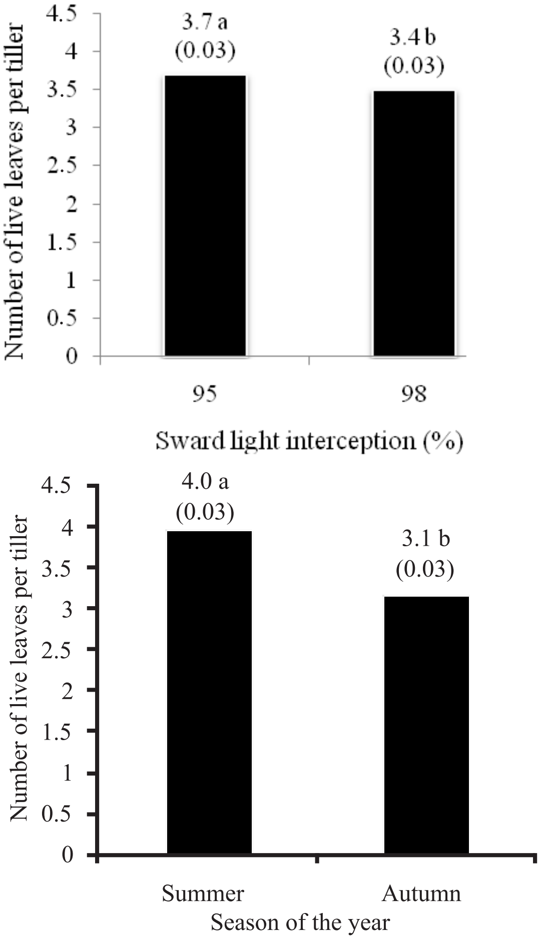
Numbers in parentheses correspond to the standard error of the mean.

Figure 4 - Tiller population density (tillers/m^2) in Aruana guineagrass pastures subjected to grazing frequencies (A) and intensities (B).

of large tillers in small numbers is a characteristic of less frequent grazing (Grant et al., 1988). The lower TPD in pastures grazed at 98% of LI can be attributed to higher sward height (Table 1), more severe light interception by the sward and the consequent impairment of the tillering process by low severity and quality of light at the base of the sward (Chapman & Lemaire, 1993). These data corroborate the findings of Skinner & Nelson (1992), that tillering in very shaded swards (98% of LI) is inferior to the potential determined by LAR, due to the effect of strong competition between individuals for light. The defoliation management induces changes in the quality and quantity of light that reaches the leaves closer to the ground (Deregibus et al., 1985), determining variations in the tillering (Lemaire & Agnusdei, 2000). In this experiment, post-grazing height of 15 cm provided plants with better solar radiation quality on the leaves close to the ground, thus activating the dormant buds and increasing the appearance of new tillers.

The number of leaves per tiller (NGL) is a relatively constant value for a given genotype. This characteristic remains constant after the pasture reaches an equilibrium condition in which the processes of emergence and death of leaves are synchronized (Lemaire & Chapman, 1996). Effects caused by LI ($P<0.05$) and season of the year ($P<0.05$) were observed for this variable. Pastures that were grazed at 95% of LI showed higher values compared with pastures grazed at 98% of LI (Figure 5A). In the summer, higher NGL values were recorded compared with the fall (Figure 5B).

For the number of expanding leaves (NEL), only season of the year ($P<0.05$) effects were observed and the highest values were recorded in the summer (1.1 leaves/tiller) and the lowest in the fall (0.9 leaves/tiller). The number of senescent leaves (NSL) was affected by LI ($P<0.05$) and season of the year ($P<0.05$). Overall, pastures grazed at 95% LI had the lowest values of NSL (0.23 leaves/tiller) compared with pastures grazed at 98% LI (0.29 leaves/tiller). In the summer, higher NSL values were recorded (0.34 leaves/tiller); and lower values were found in the fall (0.18 leaves/tiller). The number of green leaves is relatively constant for each genotype, i.e., when a leaf reaches maturity, a new leaf appears in the same tiller (Hodgson, 1990) provided that the tiller is not in initial growth. In this case, the expanded number of leaves is equal to the number of green leaves; however, when the process of leaf senescence starts, the total number of expanded leaves is gradually larger than the number of green leaves, which tends to be constant. (Gomide & Gomide, 2000). From these results, it can be concluded that Aruana grass pastures grazed at 95% of LI and post-grazing height of 15 cm promoted more efficient use of pastures, as it allowed greater tissue renewal, lower senescence of leaves (Figure 3) and stem elongation (Table 5), in addition to increasing tiller density (Figure 4), suggesting higher accumulation of leaves.



Numbers in parentheses correspond to the standard error of the mean.

Figure 5 - Number of live leaves per tiller in Aruana guineagrass pastures subjected to grazing frequencies (A) and seasons of the year (B).

Conclusions

The morphogenetic and structural characteristics were strongly influenced by the frequency and severity of defoliation and season. The pre-grazing height of the grass showed to be a good indicator for pasture management, since it varied little and showed great consistency throughout the experimental period for the LI goals practiced. The most efficient use of Aruana grass is achieved when the pasture is grazed at post-grazing height of 15cm, combined with more frequent grazing (95% of light interception or 30 cm). Thus, higher number of tillers and renewal of tissues, coupled with lower rates of stem elongation and leaf senescence suggest greater leaf contribution to the forage accumulated.

References

BARBOSA, R.A.; NASCIMENTO JÚNIOR, D.; EUCLIDES, V.P.B. et al. Características Morfogênicas e acúmulo de forragem do capim-tanzânia (*Panicum maximum* Jacq. cv. Tanzânia) em dois resíduos forrageiros pós-pastejo. **Revista Brasileira de Zootecnia**, v.31, n.2, p.583-593, 2002.

BARBOSA, R.A.; NASCIMENTO JÚNIOR, D.; EUCLIDES, V.P.B. et al. Morphogenic and structural characteristics of guinea grass pastures submitted to three frequencies and two defoliation severities. **Revista Brasileira de Zootecnia,** v.40, n.5, p.947-954, 2011.

BARTHRAM, G.T. Experimental techniques: the HFRO sward stick. In: **The Hill Farming Research Organization Biennial Report 1984/1985**. Penicuik: HFRO, 1985. p.29-30.

BRAGA, H.J.; GHELLRE, R. Proposta de diferenciação climática para o Estado de Santa Catarina. In: CONGRESSO BRASILEIRO DE AGROMETEOROLOGIA, 11., E REUNIÃO LATINO-AMERICANA DE AGROMETEOROLOGIA, 2., 1999. Florianópolis. **Anais...** Florianópolis: SBA, 1999. (CD-ROM).

CÂNDIDO, M.J.D.; GOMIDE, C.A.M.; ALEXANDRINO, E. et al. Morfofisiologia do dossel de *Panicum maximum* cv. Mombaça sob lotação intermitente com três períodos de descanso. **Revista Brasileira de Zootecnia**, v.34, n.5, p.406-415, 2005.

CHAPMAN, D.F.; LEMAIRE, G. Morphogenetic and structural determinants of plant regrowth after defoliation. In: INTERNATIONAL GRASSLAND CONGRESS, 17., 1993, Australia. **Proceedings...** Australia, 1993. p.95-104.

DALE, J.E. **The growth of leaves**. London: Edward Arnold, 1982. 60p. (Studies in biology, 137).

DA SILVA, S.C.; BUENO, A.A.O.; CARNEVALLI, R.A. et al. Sward structural characteristics and herbage accumulation of *Panicum maximum* cv. Mombaça subjected to rotational stoking managements. **Scientia Agricola** (Piracicaba, Brazil), v.66, n.1, p.8-19, 2009.

DEREGIBUS, V.A.; SANSHEZ, R.A.; CASAL, J.J. et al. Tillering responses to enrichment of red light beneath the canopy in humid natural grassland. **Journal of Applied Ecology**, v.22, p.199-206, 1985.

DURAND, J.L.; GASTAL, F.; ETCHEBEST, S. et al. Interespecific variability of plant water status and leaf morphogenesis in temperate forage grasses under summer water deficit. **European Journal of Agronomy**, v.7, p.99-107, 1997.

DURU, M.; DUCROCQ, H. Growth and senescence of the successive leaves on a Cocksfoot tiller. Effect of nitrogen and cutting regime. **Annals of Botany**, v.85, p.645-653, 2000a.

DURU, M.; DUCROCQ, H. Growth and senescence of the successive grass leaves on a tiller. Ontogenic development and effect of temperature. **Annals of Botany**, v.85, p.635-643, 2000b.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. **Sistema brasileiro de classificação de solos**. 2.ed. Rio de Janeiro: Embrapa Solos, 2006. 306p.

FOURNIER, C.; DURAND, J.L.; LJUTOVAC, S. et al. A functional-structural model of elongation of the grass leaf and its relationships with the phyllochron. **New Phytologist**, v.166, p.881-894, 2005.

GASTAL, F.; BÉLANGER, G.; LEMAIRE, G. A model of the leaf extension rate of tall fescue in response to nitrogen and temperature. **Annals of Botany**, v.70, n.2, p.437-442, 1992.

GILDERSLEEVE, R.R.; OCUMPAUGH, W.R.; QUESENBERRY, K.H. et al. Mob-grazing of morphologically different *Aeschynomene* species. **Tropical Grasslands**, v.21, p.123-132, 1987.

GOMIDE, C.A.M.; GOMIDE, J.A. Morfogênese de cultivares de *Panicum maximum* Jacq. **Revista Brasileira de Zootecnia**, v.29, n.2, p.341-348, 2000.

GRANT, S.A.; BARTHRAM, G.T.; TORVELL, L. et al. Comparison of herbage production under continuous stocking and intermittent grazing. **Grass and Forage Science**, v.43, p.29-39, 1988.

HACK, E.C.; FILHO, A.B.; DE MORAES, A. et al. Características estruturais e produção de leite em pastos de capim-Mombaça (*Panicum maximum* Jacq.) submetidos a diferentes alturas de pastejo. **Ciência Rural**, v.37, p.218-222, 2007.

HODGSON, J. **Grazing management**: science into practice. New York: John Wiley & Sons, 1990. 203p.

HORST, G.L.; NELSON, C.J.; ASAY, K.H. Relationship of leaf elongation to forage yield of tall fescue genotypes. **Crop Science**, v.18, n.5, p.715-719, 1978.

LEMAIRE, G.; AGNUSDEI, M. Leaf tissue turn-over and efficiency of herbage utilization. In: LEMAIRE, G.; HODGSON, J.; MORAES, A. et al. (Eds.) **Grassland ecophysiology and grazing ecology**. Wallingford: CAB International, 2000. p.265-288.

LEMAIRE, G.; CHAPMAN, D. Tissue flows in grazed plant communities. In: HODGSON, J.; ILLIUS, A.W. (Eds.) **The ecology and management of grazing systems**. Cabi International, 1996. Chap. 1, p.3-36.

MESQUITA, P.; DA SILVA, S.C.; PAIVA, A.J. et al. Structural characteristics of marandu palisade grass swards subjected to continuous stocking and contrasting rhythms of growth. **Scientia Agricola**, v.67, n.1, p.23-30, 2010.

MORALES, A.S.; NABINGER, C.; MARASCHIN, G.E. et al. Efeito da disponibilidade hídrica sobre a morfogênese e a repartição de assimilados em *L. corniculatus* L. cv. São Gabriel. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 34., 1997, Juiz de Fora. **Anais...** Juiz de Fora: SBZ, 1997. p.124-126.

MOREIRA, L.M.; MARTUSCELLO, J.A.; DA FONSECA, D.M. et al. Perfilhamento, acúmulo de forragem e composição bromatológica do capim-braquiária adubado com nitrogênio. **Revista Brasileira de Zootecnia**, v.38, n.9, p.1675-1684, 2009.

NABINGER, C. Eficiência do uso de pastagens: disponibilidade e perdas de forragem. In: SIMPÓSIO SOBRE MANEJO DE PASTAGENS, 14., 1997, Piracicaba. **Anais...** Piracicaba: FEALQ, 1997. p.213-251.

PEDREIRA, B.C.; PEDREIRA, C.G.S.; DA SILVA, S.C. Acúmulo de forragem durante a rebrotação do capim-Xaraés submetido a três estratégias de desfolhação. **Revista Brasileira de Zootecnia**, v.38, n.4, p.618-625, 2009.

PENA, K.S.; NASCIMENTO JÚNIOR, D.; DA SILVA, S.C. et al. Características morfogênicas, estruturais e acúmulo de forragem do capim-Tanzânia submetido a duas alturas e três intervalos de corte. **Revista Brasileira de Zootecnia**, v.38, n.11, p.2127-2136, 2009.

PEREIRA, L.E.T.; PAIVA, A.J.; DA SILVA, S.C. et al. Sward structure of marandu palisade grass subjected to continuous stocking and nitrogen-induced rhythms of growth. **Scientia Agricola**, (Piracicaba, Brazil), v.67, n.5, p.531-539, 2010.

SANTOS, M.E.R.; DA FONSECA, D.M.; BRAZ, T.G.S. et al. Características morfogênicas e estruturais de perfilhos de capim-braquiária em locais do pasto com alturas variáveis. **Revista Brasileira de Zootecnia**, v.40, n.3, p.535-542, 2011.

SBRISSIA, A.F.; DA SILVA, S.C. O ecossistema de pastagens e a produção animal In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 38., 2001, Piracicaba. **Anais...** Piracicaba: SBZ, 2001. p.731-754.

SBRISSIA, A.F. **Morfogênese, dinâmica do perfilhamento e do acúmulo de forragem em pastos de capim-Marandu sob lotação contínua**. 2004. 171f. Tese (Doutorado em Ciência Animal e Pastagens) - Universidade de São Paulo/Escola Superior de Agricultura "Luiz de Queiroz", Piracicaba.

SKINNER, R.H.; NELSON, C.J. Estimation of potential tiller production and site usage during tall fescue canopy development. **Annals of Botany**, v.70, p.493-499, 1992.

SKINNER, R.H.; NELSON, C.J. Elongation of the grass leaf and its relationship to the phyllochron. **Crop Science,** v.35, n.1, p.4-10, 1995.

VILELA, D.; PAIVA, P.C.A.; LIMA, J.A. et al. Morfogênese e acúmulo de forragem em pastagem de *Cynodon dactylon* cv. *coastcross* em diferentes estações de crescimento. **Revista Brasileira de Zootecnia**, v.34, n.6, p.1891-1896, 2005.

WOLFINGER, R.D. Covariance structure selection in general mixed models. **Communications in Statistics Simulation and Computation**, v.22, n.4, p.1079-1106, 1993.

ZANINI, G.D.; SANTOS, G.T.; SCHMITT, D. et al. Distribuição de colmo na estrutura vertical de pastos de capim Aruana e azevém anual submetidos a pastejo intermitente por ovinos. **Ciência Rural**, v.42, n.5, p.882-887, 2012.