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CROP PRODUCTION

Dynamics and stability of Marandu grass tillers in monocrop systems and babassu palm silvopastoral systems

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ABSTRACT. This study aimed to evaluate the dynamics, population density of tillers and stability index of *Urochloa brizantha* in silvopastoral systems composed of babassu palm trees in the Pre-Amazon region. Four systems consisting of different densities of palm trees (80, 131, and 160 palms ha^{-1}) and a monocrop were evaluated. The rates at which the basal tillers appeared in systems with 131 and 160 palms ha^{-1} were similar to each other and were slower compared to the monocrop pasture and the system with 80 palms ha^{-1}. Despite the variations, the stability index was always higher than 1.0, which infers a compensatory mechanism between tiller appearance and mortality rate, since monocrop pastures and systems with 80 palms ha^{-1} have a higher rate of tissue turnover with high rates of tiller appearance and mortality; in contrast, the system with 160 palms ha^{-1} presents high tiller survival rates. Both the 160 and 131 palms ha^{-1} systems indicate impaired canopy renewal, as seen in the low appearance rate of basal tillers due to shading. As such, the tillering dynamics of the systems vary according to the density of palm trees, and the smaller tree densities favor the tiller turnover in the first generations evaluated.

Keywords: tiller population density; continuous stocking; *Orbygnia phalerata* Martius; tillering; tillering rate.

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Introduction

Providing pasture to feed ruminants is the most economical way to maintain productive herds, and when well-managed, herds can remain productive for long periods provided that their physiological, nutritional and climatic requirements are met. However, due to inadequate management, pastures in Brazil are often degraded or present some degree of degradation, and the main consequence is the decrease in animal productivity, which requires the replacement and/or recovery of degraded pasture or even conversion new areas.

In this sense, integrated crop-livestock-forestry systems are viable alternatives for the advancement of a sustainable agriculture and livestock production given their positive influence on ecological and social processes. Silvopastoral systems are among these integrated systems and are characterized by managing animals in a silvo-agricultural consortium, with the purpose of providing shade to the animals, stabilizing forage, meat and/or milk production, and generating forestry products and other environmental services.

Depending on the characteristics of each ecosystem, native *forests* can be adapted to the natural silvopastoral systems, thus preserving the common and native trees of certain regions. One example can be seen in the Pre-Amazon region, where intercropping adult babassu palm trees (*Orbygnia phalerata* Mart.) with pastures is observed. This palm tree is noticeable in the dry forest of the Eastern Amazon, mainly in the State of Maranhão, where approximately 53% of the Brazilian babassu plantations are concentrated (Rodrigues et al., 2016).

Despite the great importance of the babassu palm tree, little is known about its influence on both native and cultivated pastures, as well as its effects on animal productivity. The expansion of cattle ranching in this and other ecosystems has led to a serious environmental problem with a loss of biodiversity and dramatic changes in ecosystems with consequent effects on climate, soil, water, land use and vegetation generating profound and irreversible social, economic and environmental impacts. It is worth mentioning that babassu palm silvopastoral systems promote positive effects on the chemical composition and behavior of grazing animals (Araújo et al., 2016a), although it may modify sward structure.

In this sense, knowledge of the basic unit of grass growth is of paramount importance for pasture management, since tillering is an important indicator of pasture persistence (Hodgson, 1990). Many factors affect the tillering of forage plants. According to Langer (1979), tiller production is controlled by temperature, the availability of water, light, and nutrients, mainly nitrogen, in addition to the stage of development of the plant (reproductive or vegetative).

The longevity of individual plants and consequently that of pasture depends on the replacement of dead tillers, which is also affected by the seasonal peaks of mortality and appearance, especially those associated with flowering events. If the tiller turnover fails, the plant dies. Additionally, if pasture is managed incorrectly and tiller mortality is consistently greater than appearance rate, the pasture begins to degrade (Marshall, 1987).

In this context, it should be expected that knowledge regarding the demography of tillering is essential to forage production. In the silvopastoral environment, there are no studies that have evaluated this variable. Thus, this study was carried out to evaluate the dynamics, the population density of tillers and the stability index in Marandu grass pastures in silvopastoral and monocrop systems in the Brazilian Pre-Amazon Region.

Material and methods

The study was conducted at Água Viva Farm (02°59’35” South and 45°06’25” West) in the municipality of Matinha, State of Maranhão, Brazil, from March 2012 to October 2013. The climate of the region is classified as Aw, according to Köppen, and the soil is classified as Plintissolo (Embrapa, 2006). The forage species used was *Urochloa brizantha* cv. Marandu, and the arboreal species was the babassu palm (*Orbygnia phalerata* Martius) already planted on the property.

The average annual rainfall is 2,000 mm, with the highest concentration occurring between March and June (INMET, 2014). Regarding the temperature of this region, during the experimental period, the maximum and minimum values were approximately 32 and 25°C, respectively.

Four systems were evaluated: one monocrop of Marandu grass and three different densities of babassu palms with Marandu grass at 80, 131 and 160 palms ha^{-1}. We adopted a completely randomized split-plot design, with the densities of palm trees assigned to the plots and the rainy and dry seasons to the subplots. The total area used was eight hectares, subdivided into four plots of two hectares each (experimental units), managed under continuous stocking, with five Nelore x Guzerá crossbred cattle with an initial age between 8 and 10 months and a body weight of 180 ± 15 kg, per experimental unit. Over time, regulatory animals were placed and removed from each paddock, according to the forage allowance.

Before the experiment, soil samples were taken at the 0 - 20 cm layer for soil fertility analysis. As shown in Table 1, all experimental units had moderate soil fertility, and, regardless of treatment, soil acidity was corrected by increasing base saturation.

Table 1. Soil chemical composition prior to the beginning of experiments in the four pasture systems evaluated.

Systems (palms ha^{-1})	pH	M.O	P	K	Ca	Mg	H+Al	Al	B	CTC
		g dm^{-3} [(1)]		mmol$_c$ dm^{-3} [(1)]						
Monocrop	4.8	23	21	32	17	6	42	2	19	68
80	5.2	23	9	40	21	9	27	1	20	61
131	5.0	22	23	26	22	10	42	2	20	77
160	4.8	23	11	37	20	7	44	1	28	75

Systems (palms ha^{-1})	V	S	Cu	Fe	Zn	Mn	B
	%	mg dm^{-3} [(1)]					
Monocrop	38	5	0.4	104	4.4	47.3	0.19
80	56	7	0.4	149	4.2	33.6	0.20
131	45	6	0.4	61	4.6	54	0.20
160	41	10	0.4	105	4.1	44	0.28

The experimental units were fertilized with nitrogen (N) as urea at 150 kg ha^{-1} year^{-1}, phosphorus (P_2O_5) as single superphosphate at 150 kg ha^{-1} year^{-1}, and potassium chloride (KCl) at 60 kg ha^{-1} year^{-1}. Finally, depending on the silvopastoral system, dolomitic lime was added at 550, 135, 775, and 630 kg ha^{-1} to the palisade grass monocrop and the three palm-tree densities (80, 131, and 160 palms ha^{-1}), respectively.

Ten clumps were marked per system in representative areas of pasture. The first evaluation of the tillers was carried out in April, when all the tillers were marked with a color-coded wire and named generation one (G1).

At each new evaluation, all the marked tillers were counted, new tillers were marked with a different color from the previous markings, and the wires marking the dead tillers were collected. The tillers that had disappeared, dried, or were at an advanced stage of senescence were considered dead. Thus, the tillers belonging to all the evaluated generations were always recounted at each new evaluation, and the new tillers were marked with a new color, characterizing a new generation. The interval between evaluations was 28 days, and at the end of the experimental period, five generations of tillers (G1 to G5) were identified.

The tiller appearance, tiller mortality and tiller survival rates were calculated by the following equations: tiller appearance rate = number of new tillers (last generation marked) x 100/total number of existing tillers (generations marked previously); tiller mortality rate = [total number of tillers marked in the previous generations minus the total number of surviving tillers (last marking)] x 100/total number of tillers marked in the previous generations (Carvalho et al., 2000); and tiller survival rate = 100 multiplied by the tiller mortality rate. The balance was obtained by subtracting the tiller appearance rate from the tiller mortality rate (Santos et al., 2011).

Tiller population stability index was calculated by the following equation: P1/P0 = tiller survival rate (1 + tiller appearance rate), where P1/P0 is the proportion between the existing population of tillers at month 1 and the existing population at month 0 in a given period of evaluation (Bahmani, Thom, Matthew, Hooper, & Lemaire, 2003; Sbrissia et al., 2010).

Tiller density was determined in three areas per experimental unit. All tillers within a 0.25 m^2 quadrat were collected at the ground level, and only live tillers were quantified.

Population estimates of basal tillers were obtained independently from those obtained with tillering demography by counting the total number of tillers contained within a with 0.25 m^2 (0.50 x 0.50 m) PVC frame, which was placed over ten clumps in each system at random every 28 days.

Data were initially subjected to normality tests (Shapiro - Wilks) and homoscedasticity tests (Levene's) and later to an analysis of variance using the F test after the assumptions were met, using the following model: $Yijk = \mu + \propto i + \beta j + (\propto\beta)ij + eijk$. Where Yijk is the dependent variable corresponding to the experimental observation; μ is the overall mean; αi is the fixed effect of the systems; βj is the fixed effect of the season; (αβ)ij is the interaction effect; and eijk is the random error, assuming an independent normal distribution. Statistical analyses were performed using the GLM procedure of the SAS software version 9.3 (SAS, 2002).

The analysis for the comparison test of the linear regression parameters was performed using a regression for each repetition according to the generations, and the parameters A and B of the regression were tabulated after the procedure was done in all the repetitions of each evaluated system, a comparison of means of the parameters was performed through analysis of variance, and whenever significant, subjected to Tukey's test to compare means using SAS 9.0 statistical software.

Results

Tiller population density was influenced ($p < 0.001$) by both season and palm density (Table 2). A higher tiller population density was observed in the rainy season; between systems, tiller population density was highest for the system with 80 palms ha^{-1}, there was no significant difference between the 131 and 160 palms ha^{-1} systems, and the 131 and 160 palms ha^{-1} systems did not differ from the monocrop, which had the lowest tiller population density.

There was interaction ($p < 0.001$) between the seasons and systems for the appearance rate of basal tillers. In the rainy season, the highest appearance rate of basal tillers was found in the system with 80 palms ha^{-1} and the lowest in the systems with 131 and 160 palms ha^{-1}. In the dry season, the highest appearance rate of basal tillers was observed in the monocrop and in the system with 131 palms ha^{-1}. The mortality rate was higher during the rainy season ($p < 0.001$) and, among the systems, was highest in the monocrop and the 160 palms ha^{-1}.

Additionally, there was interaction ($p < 0.001$) between systems and seasons for the stability index. Analyzing the systems within each season, it can be seen that the highest values were observed in the rainy season, attributed to the monocrop and the system with 80 palms ha^{-1}. It was observed that during the dry season, the stability index of the palm systems were equal to each other, and the monocrop had higher values.

Table 2. Dynamics of Marandu grass tillers in silvopastoral systems with different densities of babassu palm trees, grazed by cattle under continuous stocking.

Season	Systems (palms ha^{-1}) 0	80	131	160	Mean	S.E.M	p-value Season x System
	Tiller population density (tillers m$^{-2(-1)}$)						
Rainy	522.66	728.00	729.60	625.76	651.1 a		
Dry	341.33	468.00	445.33	384.00	409.67 b	29.97	0.884
Mean	432.00 B	598.00 A	587.47 AB	504.88 AB			
	Tiller appearance rate (tillers 100 tillers^{-1} day^{-1})						
Rainy	1.76 Ba	1.88 Aa	1.07 Ca	1.02 Ca	1.43		
Dry	0.73 Ab	0.49 Bb	0.71 Ab	0.48 Bb	0.605	0.057	<0.001
Mean	1.25	1.19	0.89	0.75			
	Tiller mortality rate (tillers 100 tillers^{-1} day^{-1})						
Rainy	0.43	0.64	0.81	0.53	0.605 b		
Dry	0.95	1.12	1.21	0.96	1.063 a	0.312	0.292
Mean	0.69 C	0.88 B	1.01 A	0.75 C			
	Tiller survival rate (tillers 100 tillers^{-1} day^{-1})						
Rainy	3.13	2.88	2.76	3.03	2.95 a		
Dry	2.63	2.44	2.35	2.60	2.51 b	0.308	0.419
Mean	2.88 A	2.66 B	2.56 C	2.82 A			
	Tillering stability index						
Rainy	1.049 Aa	1.047 Aa	1.038 Ca	1.042 Ba	1.044		
Dry	1.033 Ab	1.029 Bb	1.031 Bb	1.031 Bb	1.031	0.0008	<0.001
Mean	1.041	1.038	1.034	1.035			

Means followed by different letters, uppercase in the rows and lowercase in the columns, are significantly different according to Tukey's test at 5% probability.

The seasonal effects on the basal tillering rate of each generation can be seen in Figure 1. The monthly variation patterns of the basal tillering rate were similar for all systems. The first generation corresponded to the number of tillers existing on the day of the first marking, whose date of appearance could not be identified and, therefore, always had more numerous tillers. A gradual decrease in the appearance rate of tillers was observed from the first to the fifth generation. The monocrop consistently showed the highest basal tillering rate, followed by the system with 80 palms ha^{-1} up to the fourth generation. In the fifth generation, the differences between palm densities in pasture and the monocrop were minimal.

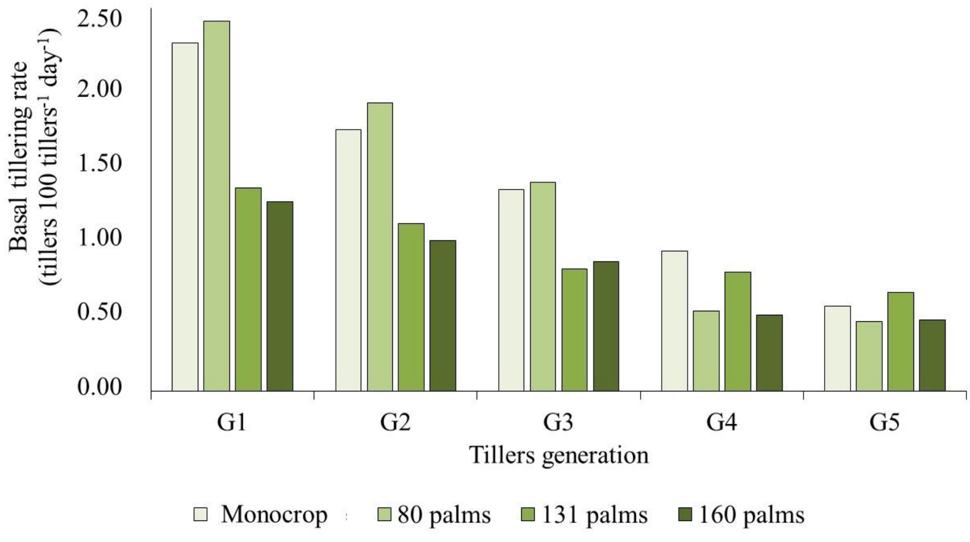

Figure 1. Basal tillering rate in the monocrop of Marandu grass and in silvopastoral systems with different densities of babassu palm trees, grazed by cattle under continuous stocking.

The basal tiller mortality rate of the systems within each generation showed a gradual increase in basal tiller mortality rate for all systems until the last generation of tillers evaluated (Figure 2). In the monocrop, the basal tiller mortality increased from 18 to 377%, from the first to the fifth generation of tillers, respectively. In the system with 80 palms ha^{-1}, the increase was from 8.33 to 126%, from the first to the fifth generation of tillers. For the pastures with 131 palms ha^{-1}, tiller mortality increased from 41.66 to 167%, from the first to the fifth generation. Finally, in the system with 160 palms ha^{-1}, tiller mortality increased from 21 to 212% from the first to the fifth generation.

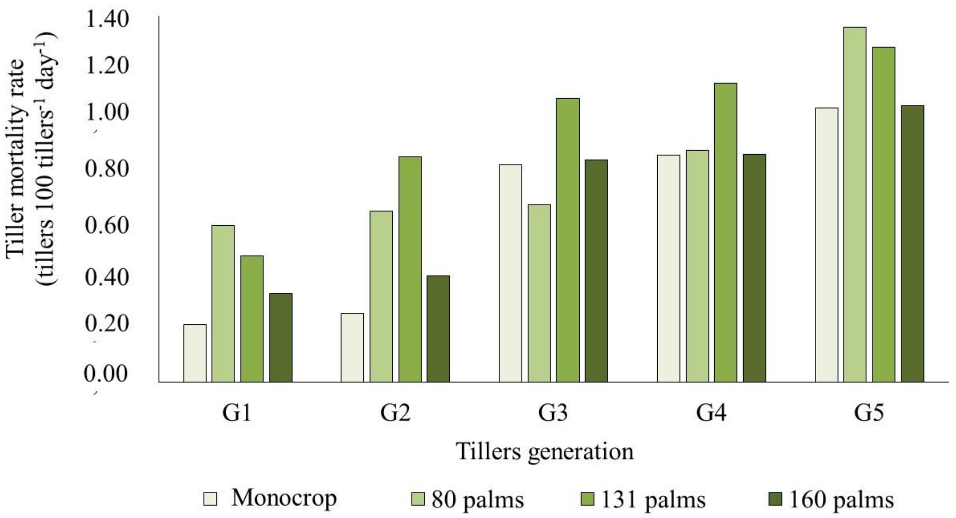

Figure 2. Basal tiller mortality rate in the monocrop of Marandu grass and in silvopastoral systems with different densities of babassu palm trees, grazed by cattle under continuous stocking.

In the comparison of the systems within each generation, it was observed that in the first generation of tillers, the system with 80 palms ha^{-1} presented the highest basal tiller mortality rate. In G2, the highest rates occurred for the systems with 80 and 131 palms ha^{-1}, while the lowest rates were observed in the monocrop and in the system with 160 palms ha^{-1}. In G3, the highest basal tiller mortality rate occurred in the system with 131 palms ha^{-1}, while for the other systems, the values were less than that but similar to each other, and this response was repeated in G4. In G5, systems with 80 and 131 palms ha^{-1} presented the highest basal tiller mortality rates. The response between the monocrop and the system with 160 palms ha^{-1} was similar.

The basal tiller survival rate was influenced by the generation of tillers (Figure 3). The basal tiller survival rate was always higher in G1 and lower in G5. Analyzing each system within each generation, the monocrop ranged from 1.19 - 25%; the silvopastoral systems with 80, 131, and 160 palms ha^{-1} ranged from 3.03 to 25.25%, 12.29 to 25.88%, and 1.85 to 22.29% from the first to the last generation, respectively.

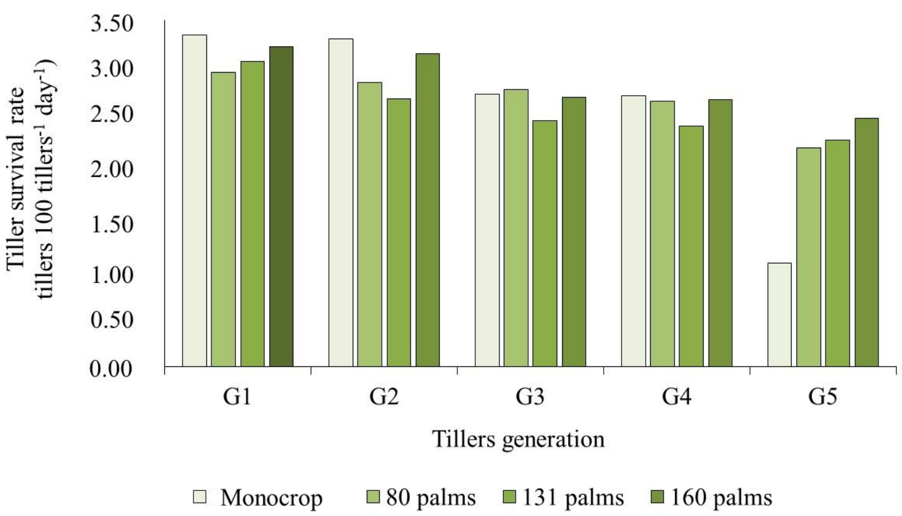

Figure 3. Basal tiller survival rate in the monocrop of Marandu grass and in silvopastoral systems with different densities of babassu palm trees, grazed by cattle under continuous stocking.

In G1, the monocrop presented a higher basal tiller survival rate but was similar to the systems with 131 and 160 palms ha^{-1}. The system with 80 palms ha^{-1} presented the lowest basal tiller survival rate. In G2, the tiller survival of the monocrop was equal to that of the silvopastoral system with 160 palms ha^{-1}. The 80 and 131 palms ha^{-1} systems had the lowest tiller survival in G2. In G3, only the system with 131 palms ha^{-1} was significantly different from the other systems, having the lowest basal tiller survival rate, which was repeated in G4. In G5, the monocrop and the system with 160 palms ha^{-1} presented the highest basal tiller survival rates.

The values of the angular coefficients for the basal tillering rate of each system across the generations are listed in Table 3, where it can be observed that the system with 80 palms ha^{-1} presented the highest angular coefficient for basal tillering rate.

Table 3. Angular coefficients of the basal tillering rate over time, for different generations, in silvopastoral systems with different densities of babassu palm trees and in the monocrop of Marandu grass grazed by cattle under continuous stocking.

Parameters	Systems (palms ha^{-1})				CV (%)
	0	80	131	160	
	Angular coefficients of basal tillering rate				
$\hat{a}_0$	2.50 b	2.91 a	1.34 c	1.22 c	6.99
$\hat{a}$	-0.39 b	-0.53 a	-0.14 c	-0.14 c	11.00

Means followed by different letters are significantly different according to Tukey's test at 5% probability. $\hat{a}_0$= linear coefficient; $\hat{a}$= angular coefficient.

The values of the angular coefficients for basal tiller mortality rate of each system across generations are presented in Table 4, where it can be observed that the system with 131 palms ha^{-1} presented the highest linear coefficient for the basal tiller mortality rate, while the monocrop system had the highest angular coefficient for the basal tiller mortality rate.

Table 4. Angular coefficients of the basal tiller mortality rate over time, for different generations, in silvopastoral systems with different densities of babassu palm trees and in monocrop of Marandu grass grazed by cattle under continuous stocking.

Parameters	Systems (palms ha^{-1})				CV (%)
	0	80	131	160	
	Angular coefficients of basal tiller mortality rate				
$\hat{a}_0$	-0.08 c	0.36 a	0.39 a	0.24 b	29.82
$\hat{a}$	0.23 a	0.16 b	0.19 ab	0.20 ab	20.30

Means followed by different letters are significantly different according to Tukey's test at 5% probability. $\hat{a}_0$ = linear coefficient; $\hat{a}$ = angular coefficient.

Discussion

The rainy season presented on average 34% more tillers compared to the dry season. This difference can be considered large, since at least for the silvopastoral systems, it was expected that the number of tillers would be higher in the dry season because shading inhibits evapotranspiration, allowing the plants to maintain forage production for longer periods of water deficit due to the greater survival of tillers. Nevertheless, the advantage to the plant provided by shading is counterbalanced by a decrease in the root: shoot ratio that, in association with competition for water by palm roots, buffers the positive effects of evapotranspiration (Feldhake, 2009; Dias-Filho & Chagas Júnior, 2000). During the experimental period, a greater amount of senescent forage was found around the babassu plantations, indicating competition for nutrients and water. It should be noted that the rainy season lasted until June/July and the dry season from July to October, with precipitation decreasing sharply from rainy season to dry season, together with higher temperatures further supporting the hypothesis presented.

The systems with 131 and 160 palms ha^{-1} presented, together with the monocrop, the lowest tiller population density. In the monocrop, the tall height due to nitrogen fertilization and high animal load, especially in the rainy season, influenced the tiller population density. However, in the silvopastoral systems, taller height is due to competition for light (Lonsdale & Watkinson, 1982; Sackville-Hamilton, Matthew, & Lemaire, 1995), since light penetration at the base of the canopy is one of the main factors that interfere with tillering (Langer, 1958). It is noteworthy that such changes interfere with the sward structure and, consequently, with the grazing behavior of the animals. Araújo et al. (2017) reported that in systems with higher densities of babassu palms there was grass etiolation and the movement of the animals along the paddock varied according to sward height.

The values observed for tiller population density were lower than the values obtained by Sbrissia et al. (2010), who evaluated the Marandu grass at different grazing heights and obtained 665 tillers $m^{2(-1)}$ at a height of 40 cm. As in this study, the highest density of tillers was found in the rainy season. The tiller appearance rate was higher than that reported for tropical grasses for a Cameroon grass pasture with up to 6 ha^{-1} steers (Rezende et al., 2008) in the rainy season, with a mean of 47.9%. Meanwhile, Santos et al. (2011) obtained a mean tiller appearance rate of 34% for *Brachiaria decumbens* with sward height from 25 to 35 cm, under continuous grazing by cattle.

The lower tiller appearance rate observed with increasing densities of babassu palm trees in the systems is due to the greater shading at the base of the plants, which inhibited the tillering of Marandu grass in the systems with 131 and 160 palms ha^{-1} trees. According to Rodrigues et al. (2014), the shading promoted by the silvopastoral systems leads to a reduction in the incident radiation and the light spectrum ratio (red: extreme red) in *Urochloa decumbens* pastures. Feldhake (2001) observed that such differences in the ratio can make the temperature milder, increase the air humidity, reduce the evapotranspiration rate and increase the soil moisture. These microclimatic changes may cause significant changes in the morphophysiology of forage plants that interfere with the quantity and quality of the forage produced. In grass, changes in quantity occur mainly in the tillering stage.

Plants cultivated in silvopastoral environments with high densities are irradiated by light composed of wavelengths with a lower proportion of blue and a greater proportion of distant red, altering the structure of phytochrome and triggering several metabolic processes related to this type of environment (Ballaré, 1999). Among the characteristics affected by light quality, the decrease in tillering is of particular importance because it is this response is the most effective way of adapting to varying management and environmental conditions (Cândido et al., 2005).

The increase in tree density in silvopastoral systems and the decrease in tiller population density seen in this study agree with the reports described in the literature (Paciullo et al., 2007; Gobbi et al., 2009; Paciullo et al., 2016), since a higher density of trees generally results in greater stem elongation of grasses due to competition for light since the plants tend to elongate the stem to facilitate the capture of photosynthetically active radiation by the leaves. However, this factor may be of some benefit to plant quality because Araújo et al. (2016a), when evaluating the nutritional value of Marandu grass according to the shading provided by the babassu palm trees, observed positive changes in the nutritional value of the Marandu grass, mainly in the crude protein content, where in the silvopastoral systems, the crude protein content was higher in the leaves when compared to monocrop despite the fact that the shaded grass was younger.

Greater attention should be given from G3 onward, where the tiller appearance rate was lower than tiller mortality rate for the system with 131 palms ha^{-1} and the tiller appearance rate was equal to the tiller mortality rate for the environment with 160 palms ha^{-1} (Figure 1). From G4, with the exception of the monocrop, all silvopastoral systems presented higher tiller mortality rates than appearance rates, and in G5 all the pastoral environments had a higher mortality rate than appearance rate, which may be due to decreased rainfall. Greater tiller turnover is expected to compensate for the mortality, since the maintenance of the tiller population density is the result of the balance between these rates in a given environment and pasture management condition, which was not observed from G3. It would be interesting to see whether there would already be a decrease in the animal load from July/August, which should be gradual as the drought period advances, and whether there is a tendency for tillers to die off more than to appear. Araújo et al. (2016b) examined the stocking rate in different silvopastoral systems formed by babassu palm trees and observed that systems with 80 palms ha^{-1} maintained a more stable stocking rate over a six-month evaluation period, and it was even more stable than the monocrop of Marandu grass.

Knowledge about seasonal variations in tiller emergence and mortality patterns is important for understanding the mechanisms involved in the management and persistence of plants in pastoral environments. The monocrop pasture and the system with 80 palms ha^{-1} presented the highest stability index, which suggests that in other more shaded environments, the tiller population tends to decrease.

However, visual observations of the experimental units showed that the systems with 131 and 160 palms ha^{-1} were not very competitive since they were invaded by weeds. This indicates that although the response pattern was similar (Figure 1), the speed with which the changes occurred was different in each pasture environment, being faster and assuming higher values in the pasture with 80 palms ha^{-1}, followed by the monocrop system. The systems with 131 and 160 palms ha^{-1} did not show differences for the angular coefficient, which indicates that in these environments, there is only one response pattern but their tiller appearance rate is similar and much slower than the other systems, likely due to the lower incidence of light at the base of the plant clumps in these environments.

Although the tiller appearance rate of the systems with 80 palms ha^{-1} decreases at a faster rate than in the other pastoral environments, the opposite occurred with tiller mortality rate, that is, the tillers live longer in this type of environment and can be indicative of ecosystem stability. While in the monocrop regime, tiller mortality patterns were more intense, that is, they presented shorter longevity, followed by systems with 131 and 160 palms ha^{-1}, respectively. It is also worth mentioning the direct effect of shading on tillering mortality (Auda, Blaser, & Brown, 1966). Shading can trigger a more intense competition for nutrients, which stimulates tissue turnover (Moreira, Martuscello, & Fonseca, 2009), causing the mortality of older tillers and contributing to the appearance of new tillers through the remobilization of nutrients, such as carbon. One of the leading causes of tiller death in a high-density pasture is the lack of carbon supply generated by competition for light. According to Davies, Evans, and Exley (1983), in a community of shaded plants, a larger amount of photoassimilates are allocated to the growth of already existing tillers instead of to the formation of new tillers.

Despite the observed variations between the systems, the stability index was always higher than 1.0, indicating that the survival and the appearance of new tillers was sufficient to compensate for tiller mortality. These results indicate variations in the different environments evaluated that can and should be used in defining management strategies for each situation throughout the year in this region. Stability indices greater than 1.0 were also reported by Calvano et al. (2011) in a study of different grazing intensities on Marandu grass.

The highest angular coefficients presented by the monocrop and systems with 131 and 160 palms ha^{-1} indicate generations of shorter longevity, which reveal a younger profile of the tiller population under the conditions of these systems. This characteristic of the tiller population may influence grass forage production since younger tillers have higher growth rates than older tillers (Carvalho et al., 2001). Rodrigues et al. (2016) evaluated the forage production in silvopastoral systems with different densities of babassu palms and observed that in the rainy season, these systems with higher densities produced the same amount of forage as the monocrop system since the specific area of leaves subjected to shading increases.

Conclusion

Monocrop pastures and systems with 80 palms ha^{-1} have the highest rates of tissue turnover, tiller appearance and mortality. The system with 160 palms ha^{-1} presents the highest tiller survival rate. Palm densities between 131 and 160 trees ha^{-1} may impair canopy turnover due to low tiller appearance rate.

Our findings infer that there is an offset mechanism between the appearance and mortality rates of tillers in the systems studied, that is, the existing tillers remained alive longer, maintaining the stability of the tiller population and thus ensuring the persistence of the pasture.

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