Scientific Paper

Defoliation of *Digitaria eriantha* Steudel: forage production, structure and radiation and water use efficiency

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Abstract

In order to evaluate the effect of defoliations on forage production, structure and efficiency of radiation and water utilization of *Digitaria eriantha* Steudel spp. *eriantha* cv. Irene, a trial was conducted at the National University of San Luis, Villa Mercedes campus, –San Luis, Argentina–. Three defoliation treatments were evaluated: cycle end (CCC), in mean leaf lifespan (CMLL) and at fixed time every 30 days (CFT). There were significant differences in forage production, total mass and number of cuts ($p < 0,05$) for CMLL, CCC and CFT (1 100 g DM/m^2; 912,693 g DM/m^2; and 4, 1 and 6 cuts, respectively). The high frequencies altered the vertical structure, by decreasing stem production; and the horizontal structure, by increasing the tiller density, with lower total biomass production. CFT improved L/S (CFT: 45,45 *vs.* CMLL: 16,13) and increased tiller density (CFT: 3 773 *vs.* CMLL: 2 264 tillers/m^2). CMLL did not show alterations on the horizontal structure, but the interception (CMLL: 0,85 *vs.* CCC: 0,97) and radiation capture were weakened with regards to CCC; nevertheless, it generated high leaf production which allowed to maximize the efficiency of water and radiation use (1,38 g DM/m^2.mm and 1,30 g DM/MJ, respectively). Defoliation management influences the crop structure and has incidence on the forage offer. Managing forages under morphogenetic concepts induces a balanced utilization of production and quality, and improves the efficiency of the use of environmental resources.

Keywords: biomass, morphogenesis, mowing

Introduction

Natural pastures have constituted the main source of forage resources for the central semiarid region of Argentina. Since the 1960's, the introduction and utilization of megathermal perennial species allowed to increase the forage and animal husbandry production of the region (Frasinelli and Veneciano, 2014). In addition, such species combined with natural pastures result in a nutritional alternative in agreement with the requirements of the rearing systems of the semiarid environment of the San Luis province (Privitello, 2004).

Digitaria eriantha Steudel spp. eriantha (digit grass) is a perennial grass species of summer cycle, native from eastern and southern Africa, widely disseminated in the country (Avila *et al*., 2014). The San Luis province is located in the temperate semiarid region, where this species is adapted to extreme cold weather during the winter rest; but during the early spring regrowths, late frost can interrupt its first growth (Frigerio *et al*., 2016). Different levels are reported in the annual production of aerial biomass for digit grass, which oscillate between 1 200 and 12 500 kg DM/ha, from south of San Luis to Villa Mercedes (center of the province), and according to input technologies (fertilization and irrigation) and defoliation management (Privitello *et al*., 2009; Frasinelli, 2014; Frasinelli *et al*., 2014; Celdrán *et al*., 2015).

Dry matter production is linked to the capacity of capturing radiation and, thus, to the leaf area index (LAI). When the plant grows it increases its LAI and, thus, the light interception capacity until reaching the elongation status or flowering onset, in digit grass type forage species (Ugarte, 2014).

To emit management guidelines that favor the compensation between forage availability and quality it is convenient to know the morphogenetic and structural performance of the species. Morphogenesis comprises the transformations that determine the formation, expansion and death of the plant organs in space and time. In forage species it is described by three variables: leaf emergence, leaf elongation rate (LER) and mean leaf lifespan (MLL). The morphogenetic variables define the structural changes that occur during tiller development: leaf size, tiller density and number of leaves per tiller (Lemaire and Agnusdei, 2000).

Mean leaf lifespan (MLL) is the interval between a leaf emergence and the beginning of its senescence, and it is an indicator of the moment in which the plant starts to accumulate dead material (Lemaire and Agnusdei, 2000). In morphogenetic studies conducted in the region, digit grass showed MLL values between 444 and 690 ºC day^{-1}, with five green leaves per tiller in seasonal regrowths of spring and summer, respectively, in a growth cycle (Privitello *et al*., 2012). For another cycle, Rossi *et al*. (2015a) determined a MLL of 613 ºC day^{-1} (56 days), with four live leaves per tiller.

The forage offer is modified when the pasture is subject to defoliation schemes for species with different leaf turnover rate. The lack of knowledge about the morphogenetic characteristics of pastures leads to utilizing similar defoliation strategies in species with different leaf growth and development. Experiences carried out in Villa Mercedes suggest different leaf turnover rates among the most widespread megathermal forage plants of the region, for which the defoliation frequencies must be higher for *Eragrostis curvula* (Schrader) Ness, intermediate for *Digitaria eriantha* spp. eriantha Steudel and lower for *Panicum coloratum* L. (Privitello *et al*., 2012). Studies conducted in *Chloris gayana* Kunth show that, for the studied zone, this pasture could withstand defoliations with brief resting periods given its fast rate of leaf emergence and short longevity (MLL) (Guerra *et al*., 2017), besides its high leaf elongation rate (Falco *et al*., 2017); while others such as *Tetrachne dregei* Nees and *Panicum coloratum* L. have a long mean leaf lifespan, for which they are apt for defoliations with longer resting periods (Lucero *et al*., 2015). In digit grass, when studying the effects of defoliation during one cycle, it was determined that cuts in MLL allow higher radiation capture and LAI compared with higher frequencies (Rossi *et al.,* 2015b).

The objective of the work was to evaluate the effect of defoliations on forage production, structure and utilization efficiency of radiation and water in *D. eriantha* Steudel spp. eriantha cv. Irene.

Materials and Methods

Characterization of the study area. The work was conducted at the School of Engineering and Agricultural Sciences of the National University of San Luis, campus located in the Villa Mercedes locality (latitude: -33º 38′ 30″ S, longitude: -65º 26′48 ″ W) within the San Luis province in the Argentinean Republic.

Edaphoclimatic conditions. The soil on which this experimental essay was conducted belongs to the Villa Mercedes series, which is described with a typically little developed profile A-AC-C, of thick limey texture, susceptible to wind erosion, with low organic matter contents (around 1,5 %). These soils are classified as entic Haplustolls, according to the Soil taxonomy denomination (Peña Zubiate *et al*., 2000).

Part of the San Luis province is within the central temperate semiarid region of the Argentinean Republic, where the historical rainfall records (1903-1999) for Villa Mercedes (San Luis) show an average regime of 594 mm per year; but just like in the rest of the region, increases have been determined by displacements of the isolines. Veneciano and Federigi (2008) established the mean monthly rainfall and temperatures of the period 2000-2008 for Villa Mercedes and, when comparing them with the values of the historical average (1903-1999), they observed increases in the hydric levels. During the growth period of the species (September to April), the rainfall reported by these authors were 538 and 659 mm, respectively.

When these records were compared with the rainfall occurred for the growth season of the pasture (September, 2015-April, 2016), it is observed that they reached higher values than the above-mentioned ones. All the treatments accumulated a total of 837,2 mm of water between regrowth and late March (figure 1), which means 27 and 56 % more with regards to both comparison periods (2000/2008 and 1903/1999, respectively). During the growth cycle of digit grass, a spring appeared with lower temperatures than the averages and more rainfall; while in the summer, the temperatures were higher and the rainfall slightly higher than the historical average of the region.

Treatments and experimental design. Three treatments were used with different cutting frequencies, according to different growth statuses: final production, CCC (only one cut at the end of the cycle or «complete cycle cut»); cut in mean leaf lifespan, CMLL (starting senescence); and cut at fixed time, CFT, in leafy status (every 30 days from initial regrowth). A complete randomized block design was applied with three repetitions, on a *D. eriantha* spp. eriantha cv. Irene pasture with more than five years of establishment and on 4-m^2 experimental units.

Experimental procedure

A cleaning cut was performed at the end of winter (August, 2015), before applying the treatments. The growth cycle of the crop started

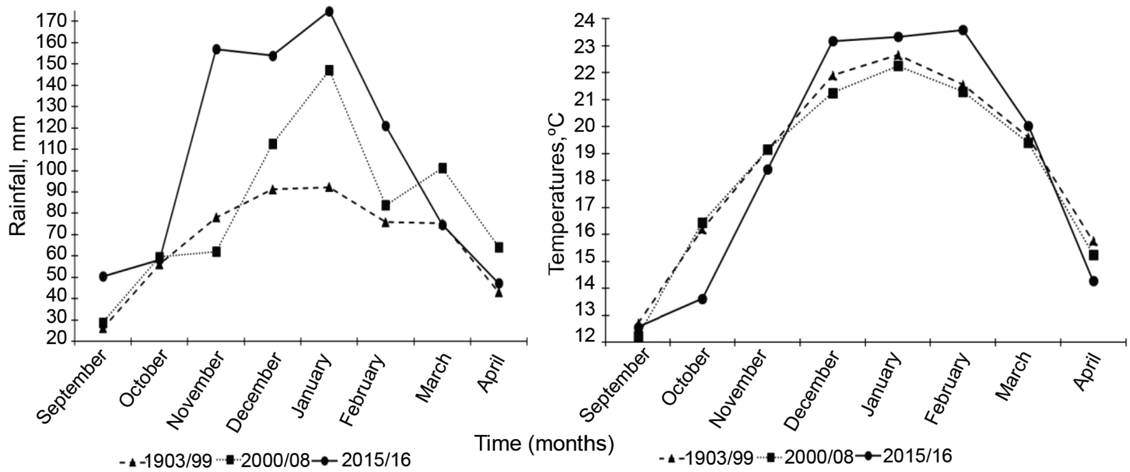


Figure 1. Mean monthly temperatures and rainfall for different periods, and for the ones occurred during the essay (2015-2016).

[1] Data supplied by the Department of Climate Studies of the National University of San Luis.

[2] Veneciano and Federigi (2008).

with the spring regrowth (September 17, 2015). This moment coincided with the first days with mean daily temperature higher than the basis growth temperature –7 ºC– (Rossi *et al.*, 2018) and subsequent to the occurrence of the last frost. To determine the occurrence of MLL five tillers were identified per plot and, once per week, they were observed to detect the beginning of senescence of the first leaf.

Measured variables: accumulation of total aerial biomass (ATAB) and accumulation of biomass for each cut for the treatments CFT and CMLL, accumulation of leaf biomass (ALB), accumulation of stem biomass (ABs), leaf:stem ratio (L/S), tiller density at the end of the cycle, interception of radiation (IR), intercepted photosynthetically active radiation (IPAR), leaf area index (LAI), water utilization efficiency (WUE) and radiation utilization efficiency (UEPARi).

In order to determine the aerial biomass cuts were performed in the plot, utilizing a 1 m x 0,50 m (0,5 m^2) frame. After its collection, the material was taken to stove in paper bag at 60 ºC until reaching constant weight (48 to 72 h). The fractions leaf and stem were separated to determine the leaf:stem ration (L/S). At the end of the cycle the tiller density in a ring of 10 cm diameter was defined and it was expressed in number of tillers per square meter. To calculate the ATAB of the entire cycle in the treatments with defoliation (CFT and CMLL), the addition of the product in each cut was made. The same procedure was followed to determine ALB and ABs.

The interception of radiation (IR) and leaf area index (LAI) were measured with a ceptometer (Accupar AR LP-80). The incidental photosynthetically active radiation (PAR) was calculated correcting the incidental radiation (obtained at the meteorological station of the FICA-UNSL) by the factor 0,48. The intercepted PAR per each treatment during the cycle (total PARi) was calculated from the interception value (IR) and of the incidental PAR (Collino *et al.*, 2007). The maximum IR and LAI values were also determined for each treatment, during the entire cycle.

The resource utilization efficiency (UEPARi and WUE) was calculated as the quotient between total produced dry matter (summation of cuts) and the corresponding environmental variable (PARi and total received water).

Statistical analysis. Excel was used to elaborate the graphs, and the Infostat software (Balzarini *et al.*, 2016) version 2016 was utilized for the statistical analyses of the data. Likewise, variance analysis (ANOVA) and LSD Fisher test were made to identify the differences of means among treatments. Through the simple regression analysis the variables IR and LAI were related. The following were taken as statistical criteria to choose the model: significance values of the coefficients and the model ($p < 0,05$), determination coefficient (R^2), mean squared prediction error (MSPE), and Akaike information criteria (AIC) and Bayesian information criteria (BIC). The normal distribution of the residues (Shapiro-Wilks test) and variance homogeneity (Levene's test) was verified (Balzarini *et al*., 2016).

Results and Discussion

Accumulation of aerial stem, leaf and total biomass

The CCC treatment showed the highest stem accumulation (ABs); while for CMLL the value of this variable was moderate and lower in CFT ($p < 0,05$). Higher values of leaf accumulation (ALB) were obtained with cuts at the beginning of senescence (MLL), with significant differences ($p < 0,05$), which generated higher total aerial biomass (table 1).

Higher defoliation frequencies altered the vertical structure of the pasture, by decreasing stem production; but they guaranteed higher leaf production (97,6 %). Experiences in the same region indicate that digit grass subject to several defoliation frequencies (28, 35, 42 days and end of cycle), when fertilizing it with diammonium phosphate (Veneciano *et al*., 2005) and without fertilization (Veneciano *et al*., 2006), also showed decrease in the accumulation of total biomass when the cutting frequency increased, and, at the same time, the proportion of generated leaves was favored.

When performing only one cut at the end of the cycle, ATAB was moderate with regards to the treatments subject to defoliations with different frequencies. However, Veneciano *et al*. (2006) mention that the highest production was obtained with one cut at the end of each cycle. In the cycle of study, the lower ATAB of CCC coincided with a lower relative generation of flower culms (12 % in CCC *vs*. 60 % of stems in cited studies), as likely effect of the edaphic nitrogen leaching coincident with high rainfall regime. Nevertheless, the highest rainfall level occurred during the study did not damage the leaf yield.

Higher DM productions were reached in Villa Mercedes (SL) by Privitello *et al*. (2009), who studied the productive potential of the species and found maximum productions of 722 g DM/m^2 for digit grass under irrigation and fertilization (300 kg N/ha), only for the summer period (late December-January).

Similarly, different studies concluded that the forage yield is reduced when increasing the defoliation frequency, for perennial pastures in general (Hakl *et al*., 2017) as well as for digit grass in particular (Gargano and Adúriz, 2005).

Aerial biomass offer per cut and its distribution

Taking into consideration that the treatment CCC received only one cut and, also, that it was not performed when the conditions favored the pasture growth, only the results for the treatments in which the defoliation frequencies were applied within the pasture growth period (CFT and CMLL) were analyzed.

The treatments had a variable number of cuts during the cycle according to the above-mentioned frequencies, which defined a certain production and distribution of the forage offer, and also showed a different number of leaves per tiller. Morphogenetic studies in *D. eriantha* spp. eriantha cv. Irene show that, in the same region, it can reach between four and five live leaves per tiller before starting senescence of the first leaf (Rossi *et al*., 2015a). In cuts at fixed time (CFT), six defoliations were made every 31,8 ± 1,47 days, with an average of 3,10 ± 0,42 leaves/tiller at the moment of cutting, lower leaf value than the one the species can reach

Table 1. Accumulation of aerial stem, leaf and total biomass (ATAB) in *D. eriantha* spp. eriantha cv. Irene, under different management strategies.

Treatment	Number of cuts	Accumulation of aerial biomass, g DM/m^2					
		ABs		ALB		ATAB	
		Mean	SE ±	Mean	SE ±	Mean	SE ±
CMLL	4	81,5^b	0,621	1 018,9^a	41,821	1 100,4^a	42,253
CCC	1	110,7^a	10,609	801,0^b	14,106	911,7^b	24,456
CFT	6	17,0^c	0,491	675,8^c	0,542	692,7^c	0,067

Different letters in the same column differ significantly ($p < 0,05$).
ABs: accumulation of aerial stem biomass, ALB: accumulation of biomass in leaves, ATAB accumulation of total biomass, CCC: defoliation at the end of the cycle, CMLL: defoliation in mean leaf lifespan, CFT: defoliation at fixed time every 30 days.

before beginning senescence. On the other hand, in CMLL four cuts were made every 55,25 ± 6,95 days, with 4,92 ± 0,50 leaves/tiller, a number of leaves that is more appropriate for a management of defoliation with morphogenetic foundations.

The period comprised by each treatment between the beginning of growth and the last cut was different in CFT (191 days) and in MLL (221 days). When considering the distribution of aerial biomass offer, the treatment MLL stood out for its total yield (table 2). With frequent defoliations or at the beginning of senescence, productive differences were verified among cuts for the same treatment. The highest production in both cases was reached in the cuts during the summer (CFT: 4th cut at the end of January; CMLL: 2nd and 3rd cut at the end of December and January, respectively); while the last defoliations were lower ($p < 0,05$) (table 2). Veneciano *et al.* (2006) found similar results for this species in Villa Mercedes (SL), where the cuts in mid cycle (full summer) offered higher DM production, and the last ones lower production, for pre-fixed defoliation frequencies every 28, 35 and 42 days.

In CMLL the mean production of the cuts was higher than CFT, and produced higher aerial biomass ($p < 0,05$): 275,1 ± 36,521 *vs.* 115,5 ± 8,094 g DM/m^2. Higher defoliation frequencies generated a higher quantity of regrowths, but the differences in mean production indicate that they were not able to equate the production in CMLL. On the other hand, Rossi *et al.* (2015b) found that a high cutting frequency prevents maximizing the accumulation of aerial biomass.

When analyzing the moments in which the defoliations were performed, it was detected that the last cut in CFT occurred one month earlier than in CMLL (late March *vs.* late April). This was due to the fact that there was a disturbance because of the applied treatment (more frequent defoliation) on the leaf expansion of regrowth after the sixth cut, which prevented to reach an accumulation of sufficient biomass to be harvested (height lower than 10 cm).

When considering the cutting moments and production per cut, it is deduced that there was an important accumulation of biomass in the second cut in CMLL which generated higher production in lower time (374 g DM/m^2 in 45 days). Such production was equaled in the third cut, but the accumulation time was higher (59 days), which indicates an acceleration in the biomass accumulation between late spring and early summer (2nd cut: November and 3rd cut: December). According to Frigerio *et al.* (2016), perennial megathermal grasses are adapted to conditions of marked summer seasonal (rainfall, high intensity of solar radiation and thermal regime), for which digit grass starts stages of intense biomass accumulation during flowering (mid to late December). For such reason, the increases in biomass accumulation in this study can be associated to a higher environmental offer of light, temperature and rainfall, which favor the stage of maximum growth expression (elongation-flowering; December, January). On the other hand, in CFT higher delay was observed in leaf growth, because production reached its peak in full summer (fourth cut: 01/21/16).

Leaf:stem ratio and tiller density per plant

Treatment CCC showed lower leaf: stem (L/S) ratio; while the highest defoliation frequency (CFT) prevented the pasture from generating an important quantity of flower culms ($p < 0,05$). The increases in defoliation frequency improved the plant structure, by having higher L/S ratio (table 3).

The results of leaf biomass production (table 1) and of the L/S ratio (table 3) show that the CFT treatment showed better vertical structure and higher leaf production, most wanted fraction by

Table 2. Accumulation of aerial biomass per cut (g DM/m^2) of *D. eriantha* spp. eriantha. cv Irene, under diferent management strategies.

Cut	Cut number[1]											
	1		2		3		4		5		6	
	Mean	SE ±	Mean	SE ±	Mean	SE ±	Mean	SE ±	Mean	SE ±	Mean	SE ±
CFT	101,4^{bc}	8,784	110,7^{b}	7,333	119,3^{b}	8,667	176,0^{a}	13,013	112,0^{b}	9,018	73,3^{c}	6,360
CMLL	204,7^{b}	16,826	374,0^{a}	9,866	402,0^{a}	37,470	119,7^{c}	8,110	-		-	

[1]Different letters in the same column significantly differ ($p < 0,05$).
CFT: defoliation at fixed time every 30 days, CMLL: defoliation in mean leaf lifespan.

Table 3. Comparison L/S and tiller density among treatments.

Treatment	Leaf:stem ratio		Tiller density, tillers/m²	
	Mean	SE±	Mean	SE±
CCC	7,4[c]	0,617	2489,9[b]	130,685
CMLL	16,4[b]	0,657	2263,5[b]	261,371
CFT	44,7[a]	0,708	3772,6[a]	494,767

Different letters in the same column significantly differ (p < 0,05).
CCC: defoliation at the end of the cycle, CMLL: defoliation in mean leaf lifespan, CFT: defoliation at fixed time every 30 days.

cattle and with higher protein content. In the region, increases have been detected in the quality of digit grass when increasing the defoliation frequency (Veneciano *et al*., 2005; Veneciano *et al*., 2006).

The horizontal structure of the crop at the end of the cycle was altered in CFT, which showed higher tiller density (p < 0,05). However, CMLL as well as CCC showed a similar performance (p > 0,05) (table 3). High grazing frequencies increased tiller density; while a defoliation established according to the MLL did not alter the horizontal structure of the pasture during the evaluation cycle. The phenotypic compensation mechanisms of the species were not sufficient when the defoliation frequency was high (30 days), for which the tiller density increased; but the total biomass production was lower. Other studies show changes in the horizontal structure due to the grazing frequency (Da Silva *et al*., 2015).

Interception of radiation (IR), accumulation of intercepted photosynthetically active radiation (IPARi) and leaf area index (LAI)

There were significant differences for the maximum values of IR and LAI of all the cuts and for the total IPARi (table 4). Treatment CCC was significantly higher in the three variables (p < 0,05).

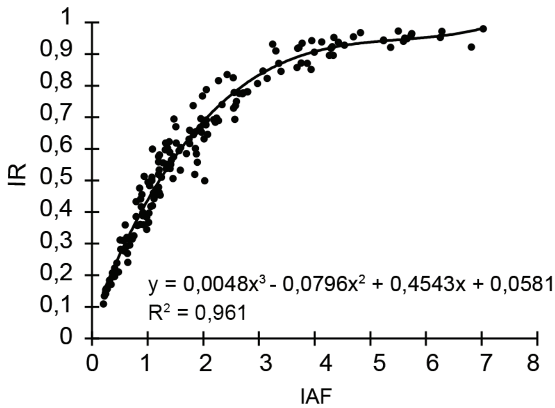
With defoliations at the beginning of senescence (MLL), the interception (IR) and capture of radiation (IPARi) were affected with regards to CCC, but both treatments were higher than CFT. Equally, the lower interception did not have repercussion on the leaf production of CMLL. Rossi *et al*. (2015b) found similar maximum interceptions (80 %) for plants subject to cuts every MLL (average cuts 65 days) and lower ones (65 %) with cuts every 30 days. Just like in the study cycle, the highest number of cuts for high defoliation frequencies could not compensate the radiation capture (841; 1 072 and 1 648 MJ/m² for CFT, CMLL and CCC, respectively), which affected leaf biomass production.

From the series of data obtained and without discriminating treatments, a third-degree regression model was obtained between IR and LAI ($R^2 = 0,96$; p < 0,001 for the model as well as for the coefficients, and lower values of MSPE, AIC and BIC). Figure 2 shows the progressive increase of the interception as the pasture aerial biomass was developed, with subsequent LAI increases. The maximum interception

Table 4. Maximum interception of radiation, maximum leaf area index and accumulation of intercepted photosynthetically active radiation of *D. eriantha* spp. eriantha cv. Irene.

Treatment	Maximum IR		Maximum LAI		Total IPARi (MJ/m²)	
	Mean	SE ±	Mean	SE ±	Mean	SE ±
CCC	0,97[a]	0,005	6,5[a]	0,396	1431,4[a]	19,067
CMLL	0,85[b]	0,011	2,4[b]	0,227	846,3[b]	28,794
CFT	0,73[c]	0,022	1,6[c]	0,097	642,3[c]	34,620

Different letters in the same column significantly differ (p < 0,05).
CCC: defoliation at the end of the cycle, CMLL: defoliation in mean leaf lifespan, CTF: defoliation at fixed time every 30 days, Max IR: maximum interception of radiation, LAI: maximum leaf area index, IPARi: accumulation of intercepted photosynthetically active radiation.



IR: interception, LAI: leaf area index.

Figure 2. Regression model for the relation between interception of radiation (IR) and LAI, without discriminating treatments.

of radiation (IR: 90-95 %) was attained, with LAI between 4 and 6; afterwards IR was stabilized and maximum LAI values were reached (7).

Similar results were found in measurements carried out for another cycle, with equal defoliation treatments: a LAI of 5 with 95 % IR under lower hydric conditions than those of this cycle, but with higher radiation levels (Rossi *et al*., 2015b). When considering the LAI values recorded during the three treatments, the occurrence of critical LAI was shown in the inflection point of the curve, close to the maximum growth rate, with exiguous senescence which in this case coincided with the maximum LAI of MLL (2,4) and moderate IR (85 %). Over this point, treatment CCC (with decreasing growth rates) caused changes in the accumulated aerial biomass of the pasture, which showed maximum values of LAI (6,5-7,0) and IR (> 95 %), but with accumulation of senescent material. CFT showed its maximum LAI (1,6) and IR (0,7) below the inflection point, coinciding with the growth acceleration stage of the plant. This implies that management tending to maintain the pasture with high LAI values and maximum interceptions would allow higher biomass accumulation, but with significant senescence levels in the offered forage. Nevertheless, defoliations in MLL ensure a harmonization between the forage productive and nutritional yield; imposing frequent cuts on the pasture would imply restricting the DM offer, although the quality of the offered material is better than the other treatments (only live leaves).

Privitello *et al*. (2009) measured higher interceptions than 95 % with LAI values between 5,0 (98 %) and 6,6 (99 %) for digit grass, when increasing the offer of edaphic nitrogen (150 kg N/ha *vs*. 300 kg N/ha, respectively), using a drip irrigation system, and maintaining the soil at field capacity during growth in early summer (late December-January); while with neither irrigation nor fertilization, these growth indicators were depressed (75 % of interception of radiation with LAI 1,7).

Efficiency of the use of light and water resources

With defoliations at the beginning of senescence (CMLL), the use of solar radiation and rainfall water could be maximized ($p<0,05$). Higher cutting frequencies (CFT) generated a moderate UEPARi and lower WUE (table 5)

When analyzing comparatively the results, it is proven than in CCC the highest IPARi was recorded but no sufficient ATAB was achieved (CCC: 911,7 g DM/m^2 and CMLL: 1 100,4 g DM/m^2), which affected the UEPARi.

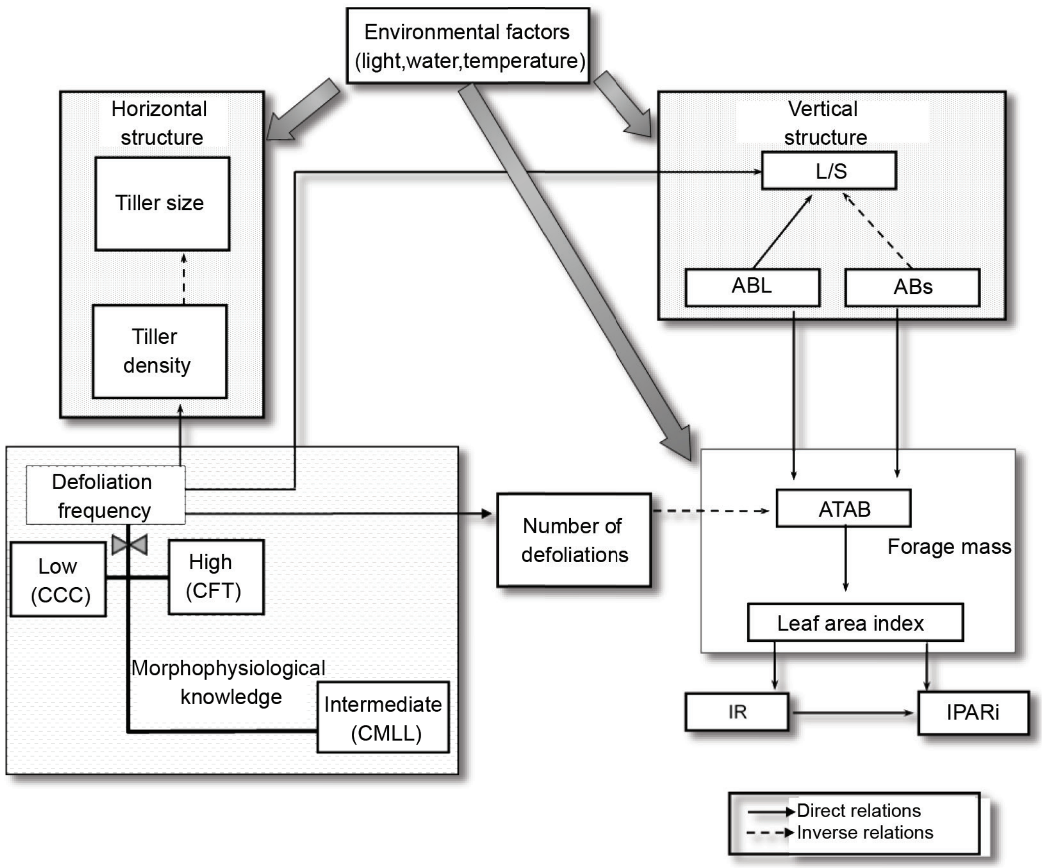
The maximum UEPARi and WUE shown with defoliations adjusted to the MLL (chronologically intermediate between CCC and CFT) indicate that the renovation of the aerial mass of forage due to the cut allowed a better utilization of environmental resources.

Figure 3 shows contrasting (CCC and CFT) and moderate defoliation frequencies (CMLL) with the evaluated response variables, when considering the horizontal structure (tiller density) and vertical structure of the pasture (L/S: quality indicators), production of aerial biomass (ATAB), growth and radiation capture (LAI), under the effect of environmental factors.

Table 5. Efficiency in the use of radiation and water, in *D. eriantha* spp. *eriantha* cv. Irene throughout the cycle.

Treatment	UEPARi g DM/MJ		WUE g DM/m²/mm	
	Mean	SE ±	Mean	SE ±
CCC	0,6[c]	0,025	1,2[b]	0,031
CMLL	1,3[a]	0,010	1,4[a]	0,050
CFT	1,1b	0,058	0,9[c]	0,0001

Different letters in the same column significantly differ ($p < 0,05$). UEPARi: efficiency in the use of radiation, WUE: water use efficiency, CCC: defoliation at the end of the cycle, CVMF: defoliation in mean leaf lifespan, CTF: defoliation at fixed time every 30 days.



CCC: defoliation at the end of cycle, CMLL: defoliation in mean leaf lifespan, CFT: defoliation at fixed time every 3 days, L/S: leaf:stem, ABs: accumulation of aerial biomass in stems, ALB: accumulation of biomass in leaves, ATAB: accumulation of total biomass, IR: interception, IPARi: accumulation of intercepted photosynthetically active radiation.

Figure 3. Relations between defoliation frequency and response variables.

The high defoliation frequencies increase the quantity of cuts that can be performed during the growth cycle, but decrease the foliage capacity to intercept radiation, produce biomass and utilize efficiently environmental resources such as water and radiation. At the same time they improve the vertical structure of plants and, consequently, the protein-richer fraction preferred by cattle increases. The phenotypical plasticity mechanisms modify the structure of pasture, by increasing tiller density, but are not able to compensate the biomass accumulation; for which there is productivity loss and an undesired effect is generated on the horizontal structure (increase of lower-size tiller density), according to the report by Da Silva *et al.* (2015). In addition, intensive utilization regimes can reduce the pasture persistence (Hakl *et al*., 2017).

Defoliation frequencies adjusted to MLL improve interception, increase radiation capture, increase efficiency of the use of environmental resources and allow higher LAI development, which cause higher production of aerial biomass.

Without defoliation, digit grass achieves the maximum interception of radiation (97 %) with high leaf area index (6,5), which shows its forage potential, supported by a corresponding plant architecture for light capture and high leaf growth.

Conclusions

Defoliation management influences the crop structure, by inducing the size-density compensation of tillers (horizontal structure), defining the morphological composition of the plant (vertical structure), and having incidence on the quantity and distribution of the forage offer.

According to the defoliation type used, the structure, produced biomass and generated LAI influence the utilization of environmental resources (light and water). Morphogenetic principles provide a reliable management alternative if the concomitance between forage production and quality is intended, as well as the improvement in the utilization efficiency of solar radiation and rainfall water.

It is necessary to continue studying the pasture response to different environmental and defoliation conditions, to propose technological tools that allow to generate a dynamic pasture management and better utilization of the available environmental resources.

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