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Productive and nutritional characteristics of Piatã-grass in integrated systems

Características produtivas e nutricionais do capim-Piatã em sistemas integrado

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SUMMARY

This study aimed to evaluate the pasture productive and nutritional characteristics of *Brachiaria brizantha* cv. BRS Piatã in integrated systems with different densities of trees. Considering as plot the systems: integrated crop-livestock-forest with rows of trees (eucalyptus) spaced at 14 m and 357 trees ha^{-1} (ICLF-14m), ICLF with rows of trees spaced at 22 m and 227 trees ha^{-1} (ICLF-22m) and the integrated crop-livestock (ICL) with five remaining native trees ha^{-1}; period of the year as subplots, and sampling points as sub-subplots (A, B C, D, and E) arranged perpendicular to trees alleys. It was evaluated the production of forage and leaf blade dry mass, leaf:stem ratio, soil coverage, radiation photosynthetically active interception, canopy height, crude protein (CP), neutral detergent fiber (NDF), *in vitro* digestibility of organic matter (IVDOM) of the leaf blade, and stem associated with the leaf sheath. There was a significant difference (P<0.05) for all variables due to the month within the integrated systems. Mainly in January and March, showing the forage and leaf blade dry mass reduction due to a higher trees density. System with higher trees density showed the lowest soil coverage and canopy height sampling points A and E in ICLF-22m showed lower forage and leaf blade dry mass production and soil coverage. The system with higher trees density showed lower value of NDF of the leaf blade, and higher CP contents. The IVDOM of the leaf blade was higher in ICLF systems. For the evaluated parameters the best results were for the ICLF-22m.

Key words: agroforestry, *Brachiaria brizantha*, crude protein, shading, tropical pasture

RESUMO

Objetivou-se com este estudo avaliar as características produtivas e nutricionais da pastagem de *Brachiaria brizantha* cv. BRS Piatã em sistemas integrados com diferentes densidades de árvores. Considerando como trama os sistemas: planta integrada-pecuária com fileiras de árvores (eucalipto) espaçadas a 14 m e 357 árvores ha-1 (ICLF-14m), ICLF com fileiras de árvores espaçadas a 22 m e 227 árvores ha^{-1} (ICLF-22m) e o cultivo-pecuária integrado (ICL) com cinco árvores nativas restantes ha^{-1}; período do ano como subparcelas e pontos de amostragem como sub-sub-parcelas (A, B C, D e E) dispostas perpendicularmente às vielas das árvores. Foi avaliada a produção de massa seca de lâmina e folha, relação folha: caule, cobertura do solo, intercepção fotossintética de radiação, altura do dossel,

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proteína bruta (PB), fibra de detergente neutro (FDN), digestibilidade *in vitro* de matéria orgânica (DIVMO) da lâmina da folha e haste associado com a bainha da folha. Houve uma diferença significativa (P <0,05) para todas as variáveis devido ao mês dentro dos sistemas integrados. Principalmente em janeiro e março, mostrando a redução da massa seca da forragem e das folhas devido a uma maior densidade de árvores. O sistema com maior densidade de árvores mostrou a menor cobertura de solo e a altura do dossel. Os pontos de amostragem A e E em ICLF-22m apresentaram menor produção de massa seca e lâmina foliar e cobertura do solo. O sistema com maior densidade de árvores apresentou menor valor de FDN da lâmina da folha e maior índice de PB. A DIVMO da lâmina da folha foi maior nos sistemas ICLF. Dos parâmetros avaliados os melhores resultados foram para o sistema ICLF-22m.

Palavras-chave: agroflorestal, *Brachiaria brizantha*, proteína bruta, sombreamento, pastagem tropical

INTRODUCTION

The integrated crop-livestock-forest system, known as agroforestry system, is a planned agroforestry practice, aiming to take advantage of each interactions, and have benefits without damage to both parties (PACIULLO et al., 2011).

Herbaceous forage growth on shaded environments, present variations influencing productivity dynamics and numerous forage characteristics (GARCIA et al., 2010), provided by changes in quantity and quality of light available in the understory (SOARES et al., 2009), thus influencing the nutritional value and productivity dynamics.

Depending on the forage species and shading level, there is usually a positive influence on the nutritive value of grasses such as higher crude protein levels, cell wall content reduction, and digestibility increase (PACIULLO et al., 2007). However, there is a trend to produce less forage, mainly due to the lower light radiation in the understory (ALMEIDA et al., 2012).

The forage growth in the integrated system depends on its shading tolerance and shade percentage imposed to the understory. Shading caused by tree species may impair or favor forage growth, depending on the degree of shading and the amount of solar radiation that is intercepted by the tree canopy, as it restricts the interception potential of the forage that responds for this situation with adaptation and acclimatization phenotypical (OLIVEIRA et al., 2014; PACIULLO et al., 2011; GOBBI et al., 2009). In this context, it is worth highlighting the *Brachiaria brizantha* (Syn. *Urochloa brizantha*) cv. BRS Piatã by presenting adaptation to shading, high foliar growth rate, good nutritional value (VALLE et al., 2007), an average productivity of 11.5t ha^{-1} of dry matter in conventional grazing system (DIM et al., 2015).

In this regard, this study aimed to evaluate the productive and nutritional characteristics of Piatã-grass in agroforestry system.

MATERIAL AND METHODS

The experiment was performed at Campo Grande – MS, Brazil (Latitude 20º 27' South; Longitude 54º 37' West; Altitude of 530 m). The experimental area consists of red Latosol (SANTOS et al., 2006), characterized by clayey, acid pH, low base saturation, high aluminum concentration, and low phosphorus content.

The climate, according to Köeppen (1948) classification, belongs to the transition range between Cfa and Aw tropical rain; and the average annual rainfall is 1,560 mm. During the experiment, climate data were collected at

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the weather station of Embrapa Beef Cattle, located at 3 km of the experimental area, from September 2014, corresponding to the end of dry season, to February 2015, corresponding to the beginning of the wet season (Table 1).
This study evaluated the pasture of April 2014, with *Brachiaria brizantha* cv. BRS Piatã [Syn. *Urochloa brizantha*], in integrated systems established in 2008/2009, which is the agroforestry system (ICLF) with hybrid eucalyptus seedlings "urograndis" (*Eucalyptus urophylla* x *Eucalyptus grandis*, clone H 13) in two arrangements of trees: one in simple lines, spaced 14 m between the lines, 2 m between plants, and density of 357 trees ha^{-1} (ICLF-14m); another with eucalyptus seedlings in simple lines, spaced 22 m between the lines, 2 m between plants, and density of 227 trees ha^{-1} (ICLF-22m), and agropastoral system (ICL, control) with five remaining native trees ha^{-1}. Each system consists of four paddocks of 1.5 ha^{-1} area, in a total of 12 experimental paddocks.

Table 1. Mean values of maximum temperature (Tmax), minimum temperature (Tmin), relative humidity (RH), and rainfall from 2014 to 2015

Month	Tmax (ºC)	Tmin (ºC)	RHmin (%)	Precipitation (mm)	Global radiation (µmol m^{-2} s^{-1})
September	32.3	20.3	22	66.0	163.5
November	30.8	19.9	32	217.8	163.7
January	32.2	21.2	44	263.6	187.8
March	31.1	21.1	49	164.4	181.8

The experimental design for plant component was performed in split-split-plot randomized blocks design with four replications. Plots treatments consisted of integrated systems ICLF-14m, ICLF-22m, and ICL. Subplots treatments correspond to the time of the year (spring and summer), and the split-plots treatments corresponded to the sampling places: A, B, C, D and E
Forage evaluations were performed in two perpendicular transects to trees rows per plot. In each transect, five equidistant points were delimited (A, B, C, D and E), where A and E were located at 2 m from trees trunks, and C correspond to the intermediate position, totalizing ten samples per plot.
At each point of 1.0 x 1.0 m, the canopy height measure was performed from the distances average of the plant base to the leaves curvature, measured with rulers graduated in centimeters in each point, within each plot; the soil coverage was visually evaluated and determined in percentage, then the forage was cut at surface level with a brush cutters. Two transects randomly arranged in the pasture were considered for system with native remaining trees. Cut material in 49-day intervals was taken to the laboratory, and weighed and divided into sub-samples.
Photosynthetically active radiation (PAR) readings were performed in each sampling point, by a ceptometer model PAR-80, Decagon Devices. A reading in both canopy top and ground level was performed at each point. Samples were separated in leaves (only foliar blade), stems (leaf sheath and stem) and aged material (leaves or stems with more than 50% of the dry area), then taken to drying in forced air chamber at

55ºC, until reaching constant mass in 72 hours. After pre-drying, subsamples were ground separately in "Thomas Wiley" mill grinder, model 4, using 1 mm mesh sieve, identified and packaged in glass pot for chemical-bromatological analysis.

Forage productivity and different components as leaf and stem of living material were estimated based on dry matter. By dry matter data of leaf:stem fraction, it was calculated the leaf:stem ratio (L/S ratio), according to the methodology described by Mannetje (1978).

Bromatological composition, crude protein (CP), neutral detergent fiber (NDF), and *in vitro* organic matter digestibility (IVDOM), was evaluated from a representative sample, by means of near infrared reflectance spectroscopy (NIRS), according to Marten et al. (1985).

Statistical analyzes were submitted to variance analysis, and the averages were submitted to Scott-Knott test with 5% probability, by using the SAS – Statistical Analysis System, version 8.0 (2002).

RESULTS AND DISCUSSION

There was a significant difference between the periods of the year and the integrated systems for all variables (Table 2).

March presented higher production of TFDM and LDM (kg ha^{-1}) in all studied systems; however, ICL showed the highest total forage production of 2,867 kg ha^{-1} and leaf blade of 1,091 kg ha^{-1}. However, November presented lower forage production of 839 kg ha^{-1} for THDM variable of ICLF-22m. September and November presented lower production of LDM in ICLF-22 and 14m, assuming an average production around 216 and 99 kg ha^{-1}, respectively.

The increment in the total forage dry matter and in the leaf blade can be associated with less trees competition for light, nutrients, and water, according to Martuscello et al. (2009), environments with shading level increased linearly reduces the dry matter production of *Brachiaria decumbens* and *B. brizantha.*

The leaf:stem ratio (L/S ratio) for ICL was higher in November and January with average of 2.45. ICLF-14m showed a higher leaf:stem ratio in November, January and March. ICLF-22m showed the highest ratio in November with 2.50. It is probably the highest leaf:stem ratio presented in the months aforementioned, because of the rainy season, and favorable environmental resources for plant development.

Green leaves show high crude protein content, as well as digestibility and consumption, which is an advantage for grazing since the leaves have better nutritional value. According to Araújo et al. (2013) the leaf:stem ratio is a variable influenced by the incident radiation level, and may result in stem etiolation reducing the leaf:stem ratio, or in a contrary way, may result in leaf size increase, increasing the leaf:stem ratio.

According to Gobbi et al. (2009), shaded grasses provide structural, adaptive, and competitive changes in the leaves to capture more light and invest in higher assimilate proportion. These authors also report that the increase of shoot: root ratio, elongation of stems and leaf blade, reduction of branching and tillering, the increase of specific leaf area and changes in leaf: stem ratio are morphological alterations of grasses under shading conditions.

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Table 2. Total forage dry matter (TFDM), leaf blade dry matter (LDM), leaf:stem ratio (L/S ratio), soil coverage (SC), photosynthetically active radiation (PAR), and pasture height according to the period of the year, in three integrated systems

System	Period of the year				
	September (2014)	November (2014)	January (2015)	March (2015)	SEM[1]
			TFDM (kg ha^{-1})		
ICL	2.234^{aB}	1.726^{aC}	2.007^{aB}	2.867^{aA}	67.76
$ILCF_{14m}$	498^{cB}	464^{bB}	637^{cB}	1.024^{cA}	52.01
$ICLF_{22m}$	1.156^{bB}	839^{bC}	1.230^{bB}	2.172^{bA}	78.11
			LDM (kg ha^{-1})		
ICL	451^{aC}	520^{aC}	960^{aB}	1.091^{aA}	36.64
$ILCF_{14m}$	64^{bC}	135^{bC}	237^{cB}	511^{cA}	27.22
$ICLF_{22m}$	167^{bC}	266^{bC}	678^{bB}	834^{bA}	38.46
			L/S ratio		
ICL	1,95^{aB}	2,60^{aA}	2,30^{aA}	1,10^{aC}	0.093
$ILCF_{14m}$	0,35^{cB}	1,45^{bA}	1,20^{bA}	1,55^{aA}	0.071
$ICLF_{22m}$	1,25^{bC}	2,50^{aA}	1,60^{bB}	1,00^{aC}	0.119
			CS (%)		
ICL	77^{aB}	73^{aB}	83^{aA}	73^{aB}	0.79
$ILCF_{14m}$	37^{bB}	27^{cC}	41^{bB}	46^{bA}	1.77
$ICLF_{22m}$	50^{bB}	50^{bB}	75^{aA}	51^{bB}	1.63
			PAR (µmol m^{-2} s^{-1})		
ICL	858^{aB}	1.691^{aA}	553^{aC}	1.527^{aA}	66.02
$ILCF_{14m}$	875^{aA}	657^{bB}	158^{bC}	970^{bA}	69.22
$ICLF_{22m}$	913^{aB}	741^{bB}	105^{bC}	1.247^{abA}	76.62
			Pasture height (cm)		
ICL	32^{aB}	30^{abB}	42^{bA}	43^{aA}	0.86
$ILCF_{14m}$	26^{aB}	24^{bB}	25^{cB}	49^{aA}	1.56
$ICLF_{22m}$	31^{aC}	34^{aC}	56^{aA}	47^{aB}	1.41

Averages followed by the same letters, uppercase letters in the lines, and lowercase letters in the columns, belong to the same grouping by Scott-Knott test at 5% probability.
ICL = integrated crop-livestock; ICLF22m = integrated crop-livestock-forest, spaced 22 m between lines; ICLF 14m = integrated crop-livestock-forest spaced 14 m between lines.
SEM[1] = Standard error of the mean.

Therefore, in this study, we observed that the denser arrangement of trees reduced the leaf: stem ratio especially in September, November and January.

The highest soil coverage percentage (SC) was observed in January for ICL and ICLF-22m, 83% and 75%, respectively. However, ICLF-14m presented the highest soil coverage percentage in March, even though, was lower than the other systems, 46%. The soil coverage variable response in this study is an indication that the wider spacing of eucalyptus favored for higher soil coverage, since areas with higher trees density present less incident radiation intercepted by the canopy.

The soil coverage, provided by Piatã-grass is associated with the pasture productive capacity, which present less space of uncovered areas. On the other hand, the soil coverage is an important opportunity to prevent the soil surface from water runoff, and hence erosion

(GALHARTE & CRESTANA, 2010). Thus, the weed reduction is guaranteed, improving soil quality, and increasing the forage species productivity.

The highest incidence of photosynthetically active radiation (PAR) occurred in ICL, in November and March, with an average of 1,609 μmol m^{-2} s^{-1}. ICLF-22m showed the highest value in March, 1,247 μmol m^{-2} s^{-1}. However, this has not differ statistically from values presented by ICLF-14m, for all analyzed months. It was expected that ICLF-14m presented lower solar radiation on canopy in September and November, due to their lower leaf:stem ratio in the same period, where PAR intercepted and absorbed by the leaves, by means of chloroplast pigments would be different between systems.

Biomass productivity of a culture is related, among other factors, to the radiation photosynthetically active fraction absorbed by canopy. According to Martins et al. (2010), chloroplastid pigments contents, chlorophyll, and carotenoids are related to the photosynthetic efficiency of plants, therefore, the radiation quantity ratio incident on the cultivation environment provides an adjustment in the plants photosynthetic system, which is essential for the absorption efficiency and energy transfer for photosynthetic processes.

The radiation quantity reduction incident on canopy of cultivated forage in understory can interfere with the shoot development and root growth, decreasing them. The absorbed PAR represent the efficiency in which the plant absorbs the incident photosynthetically active radiation (PAR_i) in the canopy, which is variable over the cycle, and in the growth and development conditions of plants (FONTANA et al., 2012).

In the case of pasture height variable, the highest values were observed in ICLF-22m and ICLF-14m, in March, as well as the highest average height observed for ICL was 42.5 cm in January and March. Piatã-grass growth was favored by wet conditions provided by treetop, by the highest PAR values recorded in March, and the weather condition presented by the month (Table 1).

Plant growth depends on the availability of favorable environmental factors, and assimilates partitioning between shoot and root. In case of cultivated pastures when shaded, it present strategies in response to less light, in order to reach a higher extract and go out of the shadow, starting the stem elongation process (SILVA et al., 2009), and reducing the tillers population density (SBRISSIA & SILVA, 2008).

The higher stems length and petioles can represent a plant effort to increase its access to the light available to the canopy (PERI et al., 2007). However, pastures under shading show lower forage dry matter, compensating it showing higher crude protein content and *in vitro* digestibility of organic matter (ALMEIDA et al., 2012).

There was a significant difference between the periods of the year and integrated systems on the parameters related to forage quality shown in Table 3.

The higher crude protein content of the leaf blade was observed in March, 16.65% in ICLF-14m. However, the same system had the lowest percentage in January, 11.5% for the same variable. Probably, the best response can be related to the favorable microclimate that trees provided in the understory, promoting moisture retention and nutrient recycling; however, the particularity presented in January, can be explained by the influence of the higher radiation photosynthetically active interception in the canopy (Table 2).

Table 3. Crude protein (CP), neutral detergent fiber (NDF), and in vitro digestibility of organic matter (IVDOM) of leafe blade and stem+sheat, according to the period of year, in three integrated systems

System	Period of the year				
	September	November	January	March	SEM[1]
			Leaf Blade		
			CP (%)		
ICL	$8{,}55^{cB}$	$10{,}10^{cA}$	$7{,}90^{bB}$	$10{,}30^{cA}$	0.16
$ICLF_{22m}$	$11{,}45^{bA}$	$12{,}40^{bA}$	$9{,}80^{bB}$	$13{,}25^{bA}$	0.32
$ICLF_{14m}$	$13{,}30^{aC}$	$14{,}45^{aB}$	$11{,}50^{aD}$	$16{,}65^{aA}$	0.27
			NDF (%)		
ICL	$70{,}95^{aB}$	$70{,}15^{aB}$	$76{,}75^{aA}$	$71{,}20^{aB}$	0.37
$ICLF_{22m}$	$69{,}95^{aB}$	$68{,}65^{abB}$	$75{,}50^{aA}$	$69{,}10^{abB}$	0.45
$ICLF_{14m}$	$65{,}25^{bC}$	$67{,}40^{bB}$	$72{,}25^{bA}$	$67{,}95^{bB}$	0.47
			IVDOM (%)		
ICL	$58{,}45^{bB}$	$62{,}70^{bA}$	$52{,}30^{bC}$	$58{,}85^{cB}$	0.53
$ICLF_{22m}$	$66{,}40^{aA}$	$67{,}20^{abA}$	$55{,}20^{bB}$	$64{,}70^{bA}$	0.83
$ICLF_{14m}$	$68{,}30^{aB}$	$69{,}95^{aB}$	$60{,}15^{aC}$	$72{,}30^{aA}$	0.86
			Stem + sheath		
			CP (%)		
ICL	$5{,}90^{aA}$	$6{,}65^{cA}$	$5{,}40^{bA}$	$5{,}90^{bA}$	0.10
$ICLF_{22m}$	$6{,}05^{aB}$	$8{,}60^{bA}$	$5{,}80^{bB}$	$6{,}60^{bB}$	0.27
$ICLF_{14m}$	$6{,}25^{aC}$	$10{,}35^{aA}$	$7{,}75^{aB}$	$9{,}75^{aA}$	0.25
			NDF (%)		
ICL	$75{,}50^{aB}$	$75{,}00^{aB}$	$79{,}70^{aA}$	$78{,}60^{aA}$	0.35
$ICLF_{22m}$	$77{,}50^{aA}$	$73{,}45^{abB}$	$78{,}90^{aA}$	$78{,}90^{aA}$	0.40
$ICLF_{14m}$	$76{,}35^{aA}$	$71{,}40^{bB}$	$76{,}15^{bA}$	$74{,}55^{bA}$	0.39
			IVDOM (%)		
ICL	$51{,}65^{aA}$	$54{,}65^{bA}$	$52{,}70^{aA}$	$51{,}40^{bA}$	0.44
$ICLF_{22m}$	$51{,}60^{aB}$	$58{,}80^{aA}$	$53{,}00^{aB}$	$50{,}80^{bB}$	0.85
$ICLF_{14m}$	$48{,}05^{aC}$	$61{,}30^{aA}$	$55{,}60^{aB}$	$59{,}40^{aA}$	0.69

Averages followed by the same letters, uppercase letters in the lines, and lowercase letters in the columns, belong to the same grouping by Scott-Knott test at 5% probability.

ICL = integrated crop-livestock; ICLF-22m = integrated crop-livestock-forest, spaced 22 m between lines; ICLF-14m = integrated crop-livestock-forest spaced 14 m between lines.

SEM[1] = Standard error of the mean.

According to some authors (GOBBI et al., 2010; SOUSA et al., 2010; PACIULLO et al., 2011) in areas under trees influence, grasses have higher crude protein content than in full sun, being attributed to the higher nitrogen (N) recycling and soil moisture.

Fiber content in neutral detergent fiber (NDF) of leaf blade of Piatã-grass showed no significant difference throughout the year in ICL, except for the highest value obtained in January, 76.75%. This value is consistent with the results shown by ICLF-22m, in the same observation period. The lower NDF content was observed in ICLF-14m, in September. Dim et al. (2015) working with Piatã-grass, observed that the higher the pasture height, the higher the NDF content, corroborating with the results analyzed in ICLF-22m.

For *in vitro* digestibility of organic matter of leaf blade, the lowest percentages were observed in January, in ICL and ICLF-22m, which have not differed from each other, and ICLF-14m

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with 52.30, 55.20, and 60.15%, respectively. Reputedly, the most satisfactory values found for ICLF-14 in March, and for ICLF-22m in September and November are associated to crude protein content higher than the minimum required, i.e., 7% for ruminants (NRC, 1996), can reflect in a good steers performance in grazing (MERTENS, 1994).

Quintino et al. (2013), evaluating Piatã-grass production and nutritional value in different cutting ages in integrated systems, observed that the *in vitro* digestibility of organic matter was lower in rainy season (January), when the weather conditions favored pasture growth. The authors argue that this behavior may be related to competition between plants in the system, leading to increased leaf senescence and stalk length, contributing to the reduction of forage digestibility, just as occurred in this experiment.

Euclides et al. (2009) evaluating the nutritive value of *Brachiaria brizantha,* Marandu, Piatã, and Xaraés cultivars, in full sun, found average values of CP, IVDOM, and NDF in leaf blade and stem for Piatã-grass: 8.2%; 50.1%, and 73.0%, respectively. Different from the agroforestry systems evaluated in this study, it was observed that, due to the arboreal component, the grass composing the understory has a higher nutritional quality.

Evaluating ICL system, it was observed the average content of 5.96% of crude protein in stem and sheath, and only ICLF-14m stood out in November and March, with the highest average of the systems, approximately 10.1%.

The lower NDF content of stem and sheath were observed in ICLF-22m and 14m, in November. However, it was observed that ICLF-22m have not presented significant difference when compared to ICL, in September and November.

ICL and ICLF-22m showed the lowest average content of 51.1%, of IVDOM, of stem and sheath in March; ICLF-14m showed an average of approximately 60.4% in November and March.

In general, the crude protein content and *in vitro* digestibility of organic matter found in foliar blades were higher than those found in stem and sheath, except in neutral detergent fiber. Probably due to the higher lignified tissues rate of such fraction.

Santos et al. (2012) and Simoni et al. (2014) consider that the nutritive value of tropical grasses reduces insofar as occur the increase of senescent material quantity present in the pasture when the plant get closer to flowering stage, with higher involvement of stems in relation to leaves on biomass total composition, resulting in the decrease of crude protein content and digestibility, and increase of neutral and acid detergent fiber content.

Analyzing the delimited points in transects (A, B, C, D, and E), Table 4, it was observed that the lowest dry matter value of total forage in ICL was found in C, and there was no significant difference among other sampling points. Within ICLF-14m, C showed the highest dry matter production of the total forage, 730 kg ha^{-1}, whereas sampling points near the trees, represented by A and E, showed the lower biomass production, an average of 510 kg ha^{-1}. Although ICLF-22m showed similar behavior, it presented higher values for C point (1,640 kg ha^{-1}), and lower values for points A and E (average 1,141 kg ha^{-1}). The PAR probably influenced to obtain the lowest values in these sampling points.

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Table 4. Total forage dry matter (TFDM), leaf blade dry matter (LDM), soil coverage (SC), photosynthetically active radiation (PAR), according to sampling location in three integrated systems

System	Sampling location					
	A	B	C	D	E	SEM[1]
			THDM (kg ha^{-1})			
ILC	2.293^{aA}	2.221^{aA}	2.004^{aB}	2.199^{aA}	2.324^{aA}	67.76
ICLF $_{14m}$	471^{cB}	794^{cA}	730^{Ab}	734^{cA}	550^{cB}	52.01
ICLF $_{22m}$	1.189^{bC}	1.433^{bB}	1.642^{aA}	1.390^{bB}	1.093^{bC}	78.11
			LDM (kg ha^{-1})			
ILC	836^{aA}	763^{aA}	673^{aB}	770^{aB}	740^{aB}	36.64
I ICLF $_{14m}$	192^{cA}	269^{cA}	260^{bA}	274^{cA}	190^{cA}	27.22
ICLF $_{22m}$	416^{bB}	534^{bA}	569^{aA}	524^{bA}	388^{bB}	38.45
			SC (%)			
ILC	79^{aA}	76^{aA}	74^{aA}	75^{aA}	79^{aA}	0.79
ICLF $_{14m}$	35^{bB}	39^{bA}	42^{bA}	41^{cA}	33^{Bc}	1.77
ICLF $_{22m}$	48^{bC}	60^{cB}	64^{aA}	60^{bB}	49^{bC}	1.62
			PAR (µmol m^{-2} s^{-1})			
ILC	1.181^{aA}	1.226^{aA}	1.119^{aA}	1.081^{aA}	1.178^{aA}	66.02
ICLF $_{14m}$	729^{bA}	828^{bA}	751^{bA}	693^{bA}	325^{bB}	69.22
ICLF $_{22m}$	563^{bB}	991^{abA}	1.094^{abA}	985^{abA}	126^{bC}	76.61

Averages followed by the same letters, uppercase letters in the lines, and lowercase letters in the columns, belong to the same grouping by Scott-Knott test at 5% probability.
ICL = integrated crop-livestock; ICLF-22m = integrated crop-livestock-forest, spaced 22 m between lines; ICLF-14m = integrated crop-livestock-forest spaced 14 m between lines.
SEM[1] = Standard error of the mean.

The ICLF-14m presented lower production of LDM at all analyzed point. ICLF-22m showed an average of 542 kg ha^{-1} in B, C and D points.
According to Leonel et al. (2009) the low incidence of light in canopy in C4 grasses, decrease the forage dry matter production, since it requires higher quantity of light energy for assimilates production in order to perform photosynthesis.
ICL showed not significant difference for soil coverage variable, and with regard to sampling points, it showed a higher percentage of soil covered, an average of 76.6%. Within ICLF-22m, C point showed the highest soil coverage. This is probably due to sampling point position be more central between trees rows, favoring the sunlight capture.
According to Gobbi et al. (2011) plants create acclimatization mechanisms in response to shading, trying to attenuate light allowing their survival.
PAR was influenced by sampling location in ICLF-22m, the highest PAR were observed in B, C and D points, showing an average of approximately 1,023 µmol m^{-2} s^{-1}. However, this system does not differ significantly from values presented in ICL and ICLF-14m, on B, C and D points. Possibly, the intermediate region between trees rows may have contributed to the results because of the higher solar incidence.
According to Oliveira et al. (2007b), solar radiation incidence depends on the distribution of trees, where higher light transmission levels is found in arrangements with higher spacing between lines and rows of the trees, which was observed in this study.

Table 5. Crude protein level (CP) of the foliar blade, stem and sheath of Piatã-grass, according to the sampling location, in three integrated systems

System	Sampling location					
	A	B	C	D	E	SEM[1]
Leaf Blade						
CP (%)						
ICL	9,13^{bA}	9,00^{cA}	9,25^{bA}	9,13^{cA}	9,56^{cA}	0.16
$ILCF_{14m}$	13,88^{aB}	14,38^{aA}	13,63^{aB}	13,00^{aB}	15,00^{aA}	0.32
$ILCF_{22m}$	12,75^{aA}	10,81^{bB}	10,38^{bB}	11,06^{bB}	12,38^{bA}	0.27
Stem + sheath						
CP (%)						
ICL	6,13^{bA}	5,94^{bA}	6,13^{bA}	5,69^{bA}	5,94^{bA}	0.10
$ILCF_{14m}$	8,50^{aA}	8,31^{aA}	8,44^{aA}	9,19^{aA}	8,19^{aA}	0.27
I $ILCF_{22m}$	8,13^{aA}	6,75^{bB}	6,06^{bB}	6,00^{bB}	6,88^{abA}	0.25

Averages followed by the same letters, uppercase letters in the lines, and lowercase letters in the columns, belong to the same grouping by Scott-Knott test at 5% probability, ICL = integrated crop-livestock; ICLF 22m = integrated crop-livestock-forest, spaced 22 m between lines; ICLF 14m = integrated crop-livestock-forest spaced 14 m between lines.
SEM[1] = Standard error of the mean.

Sampling location did not influence the crude protein content of leaf blades within ICL. They were higher in ICLF-14m, in E, with 15% of CP, and in ICLF-22m, in A and E with an average of 12.57%. ICLF-22m showed the lower crude protein contents in B, C and D, with 10.8% of CP. Possibly, the lowest CP contents are associated with the higher intensity of light on Piatã-grass, increasing the structural compound and increasing the cellular contents.

According to Soares et al. (2009) the photosynthetic radiation increment on forage is influenced by increasing the spacing between trees, which reduces the percentage of crude protein.

With regard to crude protein present in stem and sheath, the highest content was found in ICLF-22m, in A and E, 7.51%. In ICLF-14m, B and E points showed an average of 14.69% of CP.

Researcher as Paciullo et al. (2011, 2007) and Soares et al. (2009) reported that the highest contents of crude protein in pasture, in natural shading conditions, can be associated to trees presence favoring the increase of organic matter, and consequently, increasing the nitrogen cycling.

Integrated crop-livestock-forest system spaced 22 m, stands out with higher crude protein values and *in vitro* digestibility of organic matter.

The lower tree density provides marginal improvements in nutritional parameters of the Piatã grass in relation to the systems with greater density of trees, but it stands out in relation to the production of biomass.

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