

Chemical composition of Tanganyika grass under tree shading levels in a silvopastoral system

Composição química do capim-tanganica submetido a níveis de sombreamento arbóreo em sistema silvipastoril

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ABSTRACT

This study aimed to evaluate the effect of different *Clitoria fairchildiana* tree shading levels on the Tanganyika grass (*Megathyrsus maximus* Jacq. cv. Tanganyika) chemical composition, in summer I (2011/2012), spring (2012) and summer II (2012/2013) seasons. For this purpose, an experiment was conducted in a completely randomized design with four treatments (shading levels) and five repetitions at Seropédica, state of Rio de Janeiro, Brazil. The following variables were evaluated: dry matter (DM), crude protein (CP), neutral detergent (NDF) and acid detergent (ADF) fiber, neutral (NDIP) and acid (ADIP) detergent insoluble protein, lignin (LIG) and mineral matter (MM) contents. Data were analyzed by PROC MIXED SAS[®], with repeated measures in time, and treatment means compared by Tukey's test ($P<0.05$) or by PROC REG ($P<0.05$ for regression analysis). There was a significant interaction between season and shading level for DM, CP, NDF, ADF, NDIP, ADIP and MM contents ($P<0.05$). Lignin content was only influenced by shading level ($P<0.05$). The DM, NDF, ADF and lignin contents were reduced by shading increase while CP, NIDP and MM contents were increased. Higher ADIP contents were found only in the spring. The increase in *Clitoria fairchildiana* tree shading improves the chemical composition of Tanganyika grass forage during summer season.

Keywords: crude protein, insoluble protein, *Megathyrsus maximus*, neutral detergent fiber, shadow.

RESUMO

O objetivo deste trabalho foi avaliar o efeito de diferentes níveis de sombreamento arbóreo da espécie *Clitoria fairchildiana* sobre a composição bromatológica do capim-tanganica (*Megatyrus maximus* Jacq. cv. Tanganica), nas estações do verão I (2011/2012), primavera (2012) e verão II (2012/2013). Para tanto, foi instalado um experimento sob delineamento inteiramente casualizado, com quatro tratamentos (níveis de sombreamento) e cinco repetições em Seropédica, Rio de Janeiro, Brasil. Foram avaliados os teores de: matéria seca (MS), proteína bruta (PB), fibra em detergente neutro (FDN) e em detergente ácido (FDA), proteína insolúvel em detergente neutro (PIDN) e em detergente ácido (PIDA), lignina (LIG) e matéria mineral (MM). Os dados foram analisados pelo PROC MIXED do SAS[®], com medidas repetidas no tempo, e as médias dos tratamentos comparadas pelo teste de Tukey ($P < 0,05$); ou pelo PROC REG do SAS[®] para as análises de regressão ($P < 0,05$). Houve efeito de interação entre nível de sombreamento e estação do ano para teores de MS, PB, FDN, FDA, PIDN, PIDA e MM. Os teores de lignina foram influenciados apenas pelo nível de sombreamento. Os teores de MS, FDN, FDA e lignina foram reduzidos, enquanto aqueles de PB, PIDN e MM aumentaram linearmente em função dos níveis de sombreamento. Maiores teores de PIDA foram verificados somente na primavera. O aumento do sombreamento arbóreo de *Clitoria fairchildiana* melhora a composição bromatológica da forragem do capim-tanganica, durante o verão.

Palavras-chave: fibra insolúvel em detergente neutro, *Megatyrus maximus*, proteína bruta, proteína insolúvel, sombra.

INTRODUCTION

Brazil has a cattle herd estimated at 172.2 million of animals, besides 149,670,217 hectares of grasslands (ABIEC, 2020). Thereby, there is a pressure for a more sustainable livestock and a consequent demand for integrated production, like silvopastoral systems (LIMA et al., 2013). The success of these systems also depends on the choice of forage species, which should present resistance and adaptation to tree shading, besides high forage quality and productivity (LIMA et al., 2020).

In silvopastoral systems, light radiation is lower under the treetops, which influences the morphogenetic traits of productivity and the nutritional value of forage (LIMA et al., 2018). Thus, tolerance to shading will depend on the

morphophysiological adaptation of the plant to the reduced levels of light radiation (PACIULLO et al., 2017a).

The search of *Megatyrus maximus* Jacq. for silvopastoral systems has been increased, because this species shows a large genetic variability that allows selection of shading tolerant genotypes (VICTOR et al., 2015; PACIULLO et al., 2017). The Tanganyika cultivar, whose origin center is Occidental Africa, has a short size (1.20 to 1.50 m), thin stem (1.0 to 1.5 cm-thickness) and narrower leaves than other genotypes from the species (ALCÂNTARA & BUFARAH, 1980). These morphological aspects suggest that this cultivar presents better nutritional value and higher shading tolerance than other

cultivars as Tanzania and Mombaça grasses (SILVA et al., 2018). Shading exerts a positive effect on the nutritional value of harvested forage. Lower photosynthetic efficiency by plants and lower evapotranspiration of plant-soil system occur (TAIZ et al., 2017). Therefore, there is a lower growth and the plant tissues present more cell content, besides thin and less lignified cell walls (SANTOS et al., 2019). Paciullo et al (2017a) evaluated the nutritional value of Tanzania grass (*Megatyrus maximus* cv. Tanzania) forage and observed an increase of 54 g kg⁻¹ in the CP content as function of shading increase from zero to 58%. Moreover, Wong et al. (1985) classified the Tanganyica grass (*Megatyrus maximus* Jacq. cv. Tanganyica) as shading tolerant due to its productivity and morphological composition (PEREIRA et al., 2015). Based on this context, this study aimed to evaluate the effect of *Clitoria*

fairchildiana shading level on the chemical composition of Tanganyica grass, during the summer I (2010/2011), spring (2011) and summer II (2011/2012) seasons.

MATERIAL AND METHODS

The experiment was carried out at the Experimental Field of Animal Nutrition, Grasslands Department, Animal Science Institute from Federal Rural University of Rio de Janeiro (DNAP/IZ – UFRRJ), municipality of Seropédica– RJ, 22°45' S, 43°41' W, at 33 meters altitude. The climate of the region is Aw (KÖPPEN, 1828), with dry season lasting from April to September, and rainy season lasting from October to March. Climate data during the experimental period (Figure 1) were obtained from INMET (2013).

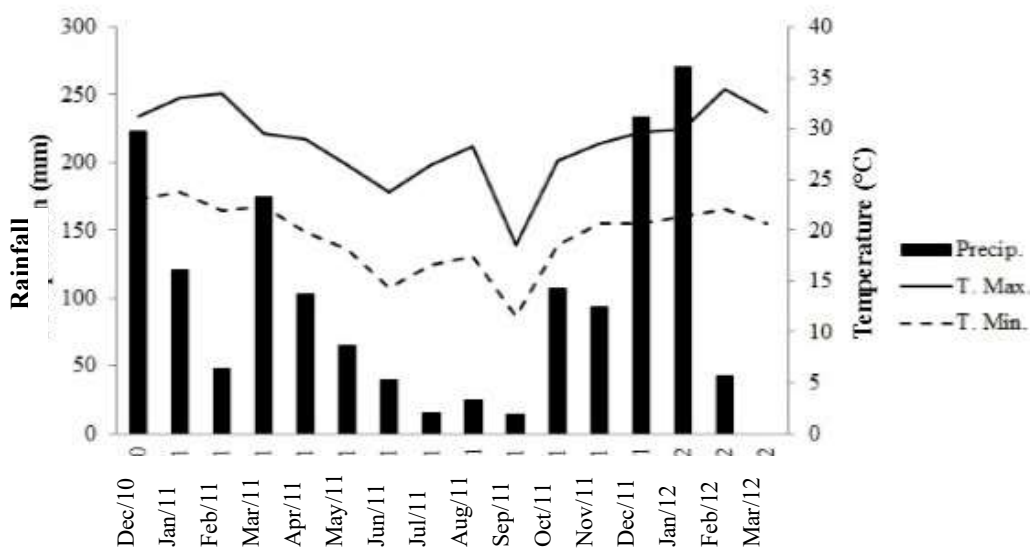


Figure 1. Maximum (T. Max.) and minimum (T. Min.) temperature, besides the average monthly rainfall (Rainfall) recorded during the experimental period. Source: Seropédica-Agricultural Ecology-A60 Station, Seropédica- RJ.

Tanganyika grass was planted in 20 plots (experimental units) with 8.0 m² each, on March 2010. Maintenance fertilizations were done with 200 kg ha⁻¹ year⁻¹ N and K₂O using urea and potassium chloride as sources. Fertilizers were equally divided in five applications: three in spring and summer; the remaining two in fall and winter. Phosphate fertilizer was also applied on 11/23/2010, with 80 kg ha⁻¹ P₂O₅ using simple superphosphate. The experiment was conducted in the seasons of summer I (12/27/2010 to 03/20/2011), the spring (09/02/2011 to 12/20/2011) and the summer II (12/21/2011 to 03/01/2020). Historically, these seasons have important climatic differences as to the average rainfall and temperature (ALCÂNTARA & SCHUELER, 2015). Treatments consisted of the average shading levels evaluated under treetops of *Clitoria fairchildiana*, commonly known as “sombbrero” or “cow’s shadow”. The trees already existed in the 0.5 hectares of pasture over than 15 years, with 20 trees randomly dispersed, a fact that allowed stratified shading intensities in the experimental area. Below the trees, areas that presented homogeneous shading levels were selected, sites in which the experimental units (plots) were allocated. Shading levels were weekly evaluated under the trees at 9:00 a.m., 12:00 p.m. and 3:00 p.m., using the canopy analyzer AccuPAR Linear PAR/LAI *ceptometer*, Model PAR – 80 in 12 points below the trees and above the forage canopy of each plot, and described as averages of the three evaluated seasons (Table 1). These shading levels were classified as slight (SS), mild (MS) and heavy (HS). Moreover, Tanganyika grass was also

evaluated under full sun (FS) condition as the control treatment. The experiment was conducted in a completely randomized design with five repetitions. Photosynthetic active radiations (PAR) above the treetops in the summer I, spring and summer II were 1,564, 1,307 and 1,776 μmol m⁻² s⁻¹, respectively.

Forage samples were harvested in the plots, inside a frame of 0.25 m² (0.5 × 0.5 m) that was positioned at the center of each plot and 15 cm above the ground, when the average light interception (LI) of the forage canopy reached 95%. For this purpose, 12 measures of LI per plot were taken simultaneously below (at the ground level) and above the forage canopy, on a weekly frequency and, thereafter, at 2-day frequency when the average LI was 90% or more.

The chemical composition of Tanganyika grass was evaluated through the dry matter (DM), neutral (NDF) and acid (ADF) detergent-insoluble fiber, crude protein (CP), mineral matter (MM) and lignin (LIG) contents, according to Silva & Queiroz (2012) and Detmann et al. (2012). Neutral (NDIP) and acid (ADIP) detergent-insoluble protein contents were determined according to Licitra et al. (1996).

Data were analyzed by PROC MIXED from SAS[®] version 9.3 (SAS, 2008), with repeated measures in time. The shading level, season of year and their interactions were considered fixed effects. The variance and covariance matrices were selected by the Akaike’s information criterion (AKAIKE, 1974). Means were compared by Tukey’s test, and the PROC REG from SAS[®] analyzed the quantitative data by simple linear regression, under probability error of 5%.

Table 1. Average levels of *Clitoria fairchildiana* shading on Tanganyika grass canopy in the seasons of summer I (201/2011), spring (2011) and summer II (2011/2012).

Season	Shading level			
	FS (%)	SS (%)	MS (%)	HS (%)
Summer I	0	26	46	54
Spring	0	27	54	59
Summer II	0	31	47	56

FS: full sun; SS: slight shading; MS: mild shading; HS: heavy shading.

RESULTS AND DISCUSSION

There was an interaction effect between shading level and season of year for DM and MM contents of Tanganyika grass forage (Table 2). The DM contents were higher during the summer II at full sun (FS), during the spring in the slight shading (SS), similar between the seasons for the mild shading (MS) and higher during the summer I for the heavy shading (HS). During the summer I, the DM contents were similar between the shading levels (average of 226.0 g kg⁻¹), and were linearly reduced (P<0.05) during the spring and summer II. This was possibly because of the highest mean values of shadings verified in SS, MS and HS for the spring and summer II, in comparison to those shadings of summer I (Table 2).

Sousa et al. (2010) also observed a decreasing DM content in marandu grass (*Urochloa brizantha* Syn. cv. Marandu) according to tree shading, from 294 to 258 g kg⁻¹. The authors justified these results due to the highest proportion of leaves in forage harvested from the

shaded pastures, because high shade levels promote lower water losses by leaf tissues, which increases the moisture content and consequently reduces the dry matter content (SANTOS et al., 2019).

The MM content were higher in the summer I for all shading treatments, and for spring and summer II the observed values were similar (Table 2). There were linear increases in MM content as a function of shading levels, in all seasons (P<0.05), which is beneficial to animal nutrition due to the higher concentration of essential minerals in the available forage for the animals, such as Ca, P, K and Mg (BROUDER et al., 2020). Although the light does not act directly on the uptake of minerals by plants, it affects some biological processes such as respiration, transpiration and photosynthesis, which can indirectly reduce the MM content in shaded forage plants (REIS et al, 2013).

Table 2. Dry matter (DM) and mineral matter (MM) of *M. maximus* cv. Tanganyika under the evaluated tree shading levels and seasons of the year.

Season	Shading level ¹ (%)				SEM	Regression equation	R ²
	FS	SS	MS	HS			
DM (g kg ⁻¹)							
Summer I	258.0b	214.0ab	207.0a	226.0a	17.3	$\hat{Y}=226.0^{ns}$	-
Spring	249.0b	247.0a	194.0a	181.0b	3.3	$\hat{Y} = 259.6-1.195X^{**}$	0.80
Summer II	313.0a	210.0b	188.0a	172.0b	12.9	$\hat{Y} = 298.8-2.433X^{**}$	0.86
MM (g kg ⁻¹)							
Summer I	91.0a	106.0a	123.0a	122.0a	2.6	$\hat{Y} = 90.69+0.449X^*$	0.84
Spring	78.0b	72.0b	100.0b	103.0b	2.5	$\hat{Y} = 71.57+0.477X^*$	0.62
Summer II	68.0c	70.0b	95.0b	103.0b	2.4	$\hat{Y} = 64.51+0.679X^*$	0.78

¹Values respectively described in Table 1 for each season of year. FS: full sun; SS: slight shading; MS: mild shading; HS: heavy shading. The seasons of year occurred between the following dates: summer I from 12/27/2010 to 03/20/2011; spring occurred from 09/02/2011 to 12/20/2011 and summer II from 12/21/2011 to 03/01/2012. X: percentage of shade. Means followed by different letters in the same column are significantly different by Tukey's test (p<0.05). SEM: standard error of the mean. *(p<0.05), **(p<0.01) and ns: non-significant.

The increase in MM content found in the present experiment indicates the Tanganyika grass as a potential forage resource that should be more studied for animal nutrition, especially when grown under shading.

Lower NDF and ADF contents were found in summer I compared to spring and summer II (P<0.05) at FS (Table 3). For the SS, NDF contents were lower in the summer II compared to the other seasons, and there was similarity between these seasons for the ADF content. For MS, lower values of NDF and ADF were observed in the spring, while in the most shaded treatment (HS), the lowest NDF value was found in the spring. The increment in shading levels promoted a similar effect for NDF and ADF, with linear

reduction (P<0.01) for both variables only in the spring, besides non-significant difference between the summers II and I.

Santiago-Hernández et al. (2016) also observed a decrease in ADF content (from 312 to 310 g kg⁻¹), to compare the Tanzania and Mombaça grasses under full sun with those grown under tree shading.

Both reducing of NDF and ADF contents, especially that related to spring season (Table 3), can be explained by the probably lower growth rate of plants under shading, due to the light restriction (PACIULLO et al., 2017b). With lower growth under these conditions, the plant tissues present more cell content, besides less thick and lignified cell walls (SANTOS et al., 2019).

Table 3. Insoluble neutral (NDF) and acid detergent fiber (ADF) contents of *M. maximus* cv. Tanganyika under the evaluated tree shading levels and seasons of the year.

Season	Shading level ¹ (%)				SEM	Regression equation	R ²
	FS	SS	MS	SS			
NDF (g kg ⁻¹)							
Summer I	649.0b	665.0a	645.0a	650.0a	8.4	$\hat{Y} = 653.0^{ns}$	-
Spring	668.0a	666.0a	588.0b	618.0b	4.0	$\hat{Y} = 675,74-1.238X^{**}$	0,80
Summer II	669.0a	636.0b	639.0a	662.0a	4.8	$Y = 651.0^{ns}$	-
ADF (g kg ⁻¹)							
Summer I	350.0b	346.0a	334.0a	340.0ab	5.4	$\hat{Y} = 342.0^{ns}$	-
Spring	378.0a	346.0a	327.0b	348.0a	3.9	$\hat{Y} = 377,78-01.132X^{**}$	0,86
Summer II	367.0a	344.0a	353.0a	348.0a	4.3	$Y = 353.0^{ns}$	-

¹Values described in Table 1 for each season of the year. FS: full sun; SS: soft shading; MS: moderate shading; SS: strong shading. The seasons of year occurred between the following dates: summer I from 12/27/2010 to 03/20/2011; spring occurred from 09/02/2011 to 12/20/2011 and summer II from 12/21/2011 to 03/01/2012. X: percentage of shade. Means followed by equal letters in the same column do not differ each other by the Tukey test (p<0.05). SEM: standard error of mean. *(p<0.05), **(p<0.01) and ns: not significant.

There was an interaction effect between shading level and season for CP, NDIP and ADIP contents of Tanganyika grass forage (Table 4). The CP contents did not differ between seasons for FS, and did not present a defined pattern of behavior. The increasing levels of shading promoted a linear response of CP content (P<0.01) for all seasons, fact that corroborates Gobbi et al. (2010) and Sousa et al. (2010) that also found increasing of N content in the plant tissues due to the light restriction.

Under shade, the plant presents lower growth rate, as previously mentioned, and this contributes to the increasing cell content compared to the plant cell wall (SANTOS et al., 2019). However, it is important to consider that shading reduces the evapotranspiration of plant-soil system and the N volatilization from soil

(LEMAIRE et al., 2011; MARSCHNER, 2012). These factors may have increased the CP content; because of the increasing of shading levels (Table 4) and considering that 200 kg ha⁻¹ year⁻¹ N were applied as urea source.

Nevertheless, not all protein contained in the plant tissue can be used as nutrient for ruminants. Part of crude protein can be linked to fiber fractions of the forage (LICITRA et al., 1996). This explains why there was a linear increase (P<0.01) in NDIP contents as a function of shading levels, in all seasons of the year. On the other hand, the NDIP contents of Tanganyika grass forage were similar between seasons in the FS and lower for the SS in the spring, compared to both summer seasons. For MS and HS, the lowest values were verified in the summer II.

Table 4. Crude protein (CP), neutral (NDIP) and acid (ADIP) detergent insoluble protein contents of *M. maximus* cv. Tanganyika under the evaluated tree shading levels and seasons of the year.

Season	Shading level ¹ (%)				SEM	Regression equation	R ²
	FS	SS	MS	HS			
CP (g kg ⁻¹)							
Summer I	60.0a	83.0b	108.0a	123.0a	3.7	$\hat{Y} = 56.92+0.822X^{**}$	0.83
Spring	69.0a	72.0c	94.0b	104.0b	3.7	$\hat{Y} = 64.65+0.583X^{**}$	0.67
Summer II	70.0a	99.0a	98.0ab	110.0b	3.7	$\hat{Y} = 77.84+0.573X^{**}$	0.57
NDIP (g kg ⁻¹)							
Summer I	34.0a	48.0a	64.0b	85.0a	2.1	$\hat{Y} = 30.67+0.607X^{**}$	0.80
Spring	31.0a	32.0b	62.0a	65.0b	3.9	$\hat{Y} = 50.13+0.634X^{**}$	0.65
Summer II	28.0a	51.0a	53.0b	56.0c	2.8	$\hat{Y} = 34.56+0.423X^{**}$	0.54
ADIP (g kg ⁻¹)							
Summer I	21.0a	22.0a	24.0a	24.0a	1.2	$\hat{Y} = 23,0^{ns}$	-
Spring	12.0b	13.0b	21.0a	22.0a	1.2	$\hat{Y} = 11,22+0,156X^*$	0.76
Summer II	13.0b	18.0ab	15.0b	20.0b	1.3	$Y = 17,0^{ns}$	-

¹Values respectively described in Table 1 for each season of year. FS: full sun; SS: soft shading; MS: moderate shading; SS: strong shading. The seasons of year occurred between the following dates: summer I from 12/27/2010 to 03/20/2011; spring occurred from 09/02/2011 to 12/20/2011 and summer II from 12/21/2011 to 03/01/2012. X: percentage of shade. Means followed by different letters in the same column are significantly different by Tukey's test (p<0.05). SEM: standard error of the mean. *(p<0.05), **(p<0.01) and ns: non-significant.

The ADIP contents were lower in the summer II for all treatments, and similar in the spring under FS. There was a linear increase (P<0.05) of 11.2 g kg⁻¹ ADIP for each shade percentage unity only in the spring, while this variable did not altered in both summer seasons in function of the highest shading levels (Table 4).

Therefore, under the shading effect, the Tanganyika grass presented a greater amount of protein linked to NDF (in all seasons) than adhered to ADF (only in spring), probably because the lignin contents (P<0.05) were linearly reduced with increasing shading levels, and the ADIP is quite linked to this indigestible fiber carbohydrate (SNIFFEN et al., 1992).

NDIP represents the protein fraction linked to the plant cell wall that is

moderately digestible and slowly degraded in rumen (Fraction B₃), while ADIP represents the protein fraction that is practically indigestible, also adhered to this cell wall (LICITRA et al., 1996). The fact that ADIP content increased only in spring season, while CP content increased in all ones, suggests that there was a moderate increment in protein digestibility of Tanganyika grass as function of increasing shading levels (HENRIQUES et al., 2007), at least in summers II and I.

Paciullo et al. (2017a) evaluated the ADIP contents of Massai grass under three shading levels (0; 37 and 58%) and observed an increase of 30 g kg⁻¹ in this protein fraction because of light restriction. The authors pointed that shading did not result in an effective improvement of the forage nutritional

value, because there was an accumulation of indigestible protein in the chemical composition. On the other hand, in the present study, as mentioned before, possibly there was a moderate increase in the nutritional value of Tanganyika grass.

There was only shading effect ($P < 0.01$) for the lignin content, with a linear decrease as a function of shading level. The average values observed for the shading levels were: 58.26, 54.14, 51.05 and 50.02 g kg⁻¹ for FS, SS, MS and HS, respectively. The regression equation was $[\hat{Y} \text{ (g kg}^{-1}\text{)} = 58.26 - 0.147\% \text{ shade}$ and the coefficient of determination (R^2) was 0.59.

Paciullo et al. (2007) found no differences between lignin content of *Urochloa decumbens* Stapf., when it was grown under the full sun compared to under reduced light. On the other hand, Baldassini et al. (2018) observed a little increase of 4% forage digestibility of Gatton Panic (*Megatyrus maximus* Jacq. cv. Gatton Panic) under tree shading in the Argentinian Chaco region, compared to the full sun. This evidences that there are differences in the nutritional value between forage species subjected to shading, and this can arouse the interest for Tanganyika grass exploitation in silvopastoral systems, due to positive effect of light restriction on lignin content.

CONCLUSIONS

Tree shading and the seasons of year together influence the chemical variables of Tanganyika grass forage.

The increase in shading level improves crude protein content and results in moderate digestible protein fractions of Tanganyika grass during the spring and

the summer seasons, at the same time that increases indigestible fractions in the spring.

The nutritional composition of Tanganyika grass shows improvement under intense shading in the summer season.

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