



# Dry matter production and chemical composition of tropical forage legumes under different shading levels

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**ABSTRACT.** This study aimed to evaluate the shading influence on production and qualitative traits of four tropical forage legumes (calopo, puero, archer and perennial soybean). Legumes were cultivated under levels of artificial shading (0; 30; 50 and 70%) from January 2006 to June 2007. Dry matter production (DM), crude protein (CP), neutral detergent fiber (NDF), cellulose (CEL), hemicellulose (HEM) and lignin contents were evaluated. In the summer, increases in legumes DM yield were observed when grown under increasing shading levels. Calopo, puero, and archer production showed quadratic effect. Regression analysis derivation for dry matter yield showed levels of maximum values at 35.0; 33.78 and 45.45% in the summer and 34.94; 34.83 and 33.29% in the fall. Significant effect of species for CP, NDF, CEL, HEM and L/S (leaf/stem) ratio and shading level effect for NDF, CEL, HEM and L/S ratio were observed in the summer, however, no interaction was reported. In addition, significant effect of species for CP, NDF, CEL, HEM and L/S ratio was observed in the autumn. Only L/S ratio presented a negative response according to increasing shading levels. The shading promoted an increase in the fiber components and a decrease in the leaf/stem ratio, and the perennial soybean was the most tolerant to the increased shading.

**Keywords:** Agroforestry; archer; calopo; perennial soybean; puero.

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## Introduction

The utilization of legumes as forage in livestock farming represents an alternative that combines animal production performance with sustainability. Carvalho and Pires (2008) reported legumes relevance for reducing costs in dairy and beef cattle productions due to biological nitrogen fixation along with nutritional quality improvement of animal diet. In addition, plants of this family have provided nitrogen for grasses in an intercropping through direct transfer, exudation of the root cells and tissue decomposition (Paynel, Lesuffleur, Bigot, Diquélou, & Cliquet, 2008).

Agroforestry systems allow optimizing the production per unit area, always following the precepts of conservation of natural resources, through the aspects of dynamism and interaction between the components of the system (Pereira et al., 2015). Among many legumes used in the cattle industry, the intercropping with tropical grasses in silvopastoral systems (SPS) constituting the understory must be highlighted. However, one of the major obstacles to the adoption of such systems is related to the low forage productivity when subjected to shading conditions, thus, these plants must be tolerant to shading, as well as, adapted to the environment (Castro et al., 2008).

The shade of the trees is an important factor in silvopastoral systems, since they intercept 25 to 88% of the radiation, reducing the productive yield of the herbaceous stratum by up to 40% in relation to the pastures without trees (Devkota, Kemp, Hodgson, Valentine, & Jaya, 2009). In addition, low persistence of legumes has been reported as limiting factors to pasture implementation with grasses and legumes intercropping (Morais et al., 2017).

Most studies evaluating shading effects were performed with grasses, and failures by legumes consortium were pointed out as well (Bernardino & Garcia, 2009). Therefore, in order for the intercropping

between grasses and legumes in silvopastoral systems to work, it is necessary to introduce species that are tolerant to shading, seeking greater productivity of the herbaceous component for the persistence of the pasture (Gobbi, Garcia, Ventrella, Garcez Neto, & Rocha, 2011). Likewise, plants grown in shaded environments modify their nutritional and productive characteristics, and this means that plants growing in shady environments, such as in sub-forests of silvopastoral systems, present variations in the quality of the forage produced compared to plants that develop in full sun (Gobbi, García, Garcez Neto, Pereira, & Rocha, 2010).

The aim of this study was to evaluate the response of four tropical forage legumes (*Calopogonium mucunoides*, *Pueraria phaseoloides*, *Macrotyloma axillare*, *Neonotonia wightii*) to different levels of shading (0; 30; 50; 70%) in relation to dry matter (DM) production and chemical composition during fall and summer.

## Material and methods

### Study Site

The study was carried out at the Forage and Pastures Sector of the Animal Nutrition and Pasture Department of the Institute of Animal Science at Universidade Federal Rural do Rio de Janeiro, Seropédica, State of Rio de Janeiro, Brazil (22°46'27"S and 43°41'11"W, 33m above sea level) from January 2006 to June 2007.

The soil of the experimental area presented the following characteristics at a 0.20 cm layer: 2.2 cmol dm<sup>-3</sup> of Ca<sup>+2</sup>; 1.5 cmol dm<sup>-3</sup> of Mg<sup>+</sup>; 7mg L<sup>-1</sup> of P; 154 mg L<sup>-1</sup> of K; 0.93% of C<sub>org</sub>; 85% V at 6.3 pH. The region climate is AW, according to the Köppen and Geiger (1928) classification.

Figure 1 illustrates maximum and minimum temperatures (°C) and rainfall (mm) data over the experimental period.

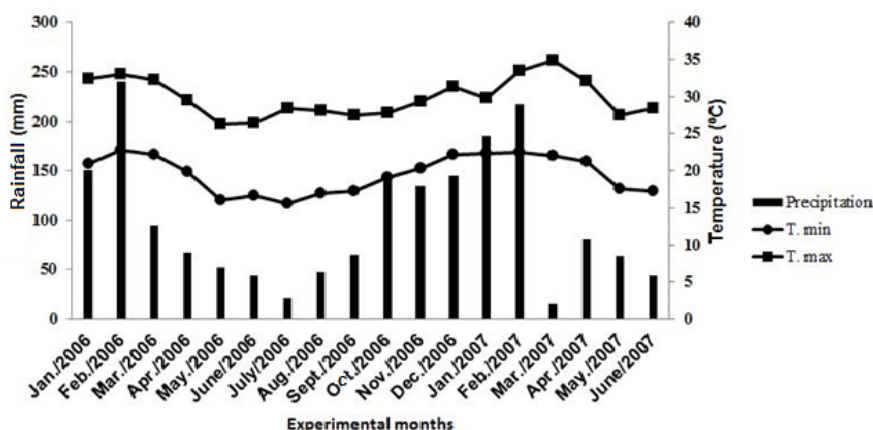
### Plant Material and Experimental Design

This was a 4×4 factorial completely randomized block design with four replicates. Four legumes: *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Macrotyloma axillare* and *Neonotonia wightii* under four levels (0, 30, 50, 70%) of artificial shading by polypropylene mesh were evaluated. In the fall, calopo was not assessed, justifying the absence of DM data, due to its annual growth behavior.

Fertilization with 40 Kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> and 50 Kg ha<sup>-1</sup> K<sub>2</sub>O was performed before the legumes seeding in 6m<sup>2</sup> plots. In March and May 2007, the legumes were mowed at 5cm from the soil from a 0.5x0.5m area placed at the center of the experimental plot for the evaluations.

### Traits measured

Whole plant, leaf and stem, were evaluated to determine DM production and leaf/stem ratio (L/S) and analyzed for crude protein (CP) (AOAC, 2005). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LIG) were analyzed according to Van Soest, Robertson, and Lewis (1991). Hemicellulose (HEM) was estimated from the difference between NDF and ADF, as well as, cellulose (CEL) from NDF less LIG.



**Figure 1.** Rainfall (mm), monthly maximum and minimum temperatures (°C) during the experimental period (January 2006-June 2007) in Seropédica, State of Rio de Janeiro, Brazil (Instituto Nacional de Meteorologia [INMET], 2007).

### Statistical analysis

Qualitative data of legume species were tested by ANOVA (F test,  $\alpha = 0.05$ ). The means were compared using the Student-Newman-Keuls test (SNK) at 5% of probability. Due to the quantitative character of the trait shading, significant contrasts were adjusted by regression analysis using the t-test at 5% of probability. The results were interpreted by SAEG software (Universidade Federal de Viçosa [UFV], 2001) according to the analysis of variance.

### Results and discussion

An interaction effect between species and shading level ( $p < 0.05$ ) was found in the summer. Calopo, puero and archer presented quadratic behavior for dry matter production with increasing shading levels (Table 1).

Regression analysis derivation for dry matter yield showed maximum values at 34.94, 34.83 and 33.3% of shading for calopo, puero and perennial soybean, respectively. Those values were close to the ones studied. However, the best positive linear performance of all the shading levels was demonstrated by perennial soybean.

However, regarding the other species, an interaction effect between the species and the shading levels for DM was observed ( $p < 0.05$ ). Increases in DM for the three legumes (63.0% puero, 22.9% archer and 29.6% perennial soybean) were found at the 50% level of shading, in which the perennial soybean presented lower production than puero and archer (Table 1). Regression analysis derivation indicated the highest DM for puero, archer and perennial soybean at 35.0; 33.78 and 45.45% shading level, respectively.

The increase in DM observed in this study might be attributed to light shortening on legumes due to shading levels. According to Carvalho and Pires (2008), legumes present lower light saturation in comparison to grasses, differing on shading tolerance. Because of  $C_3$  photosynthetic mechanism, legumes are physiologically adapted to less light when compared to tropical grasses ( $C_4$ ). Also, legumes have an advantage due to the less aggressiveness of grasses when under shading effect (Bernardino & Garcia, 2009).

Difference in incident radiation requirement in each plant was suggested by the different DM yields. The highest DM yield of perennial soybean at 70% shading indicates this legume as the most efficient one for capturing light in relation to the other ones, as well as, agreeing with Tardieu (2013) data, which showed that the limitation of photosynthetically active radiation acts in different ways in each genotype.

Legume shading tolerance and production ability are relevant factors for silvopastoral systems (SPS) promoting benefits, such as increase in organic matter in the soil (Andrade, Valentim, Carneiro, & Vaz, 2004), as well as, food resource for grazing animals. Legumes employed in intercropping systems should present tolerance and productivity under reduced light conditions when managed together with tropical grasses (Aroeira et al., 2005).

Evaluating the chemical composition and L/F ratio in the summer, it was observed an effect for species as well as for shading level; however, no interaction was detected (Tables 1 and 2).

**Table 1.** Dry matter yield (DM) and chemical composition of tropical legumes subjected to different shading levels (0; 30; 50 and 70%) in the summer.

Sp.	Shading				Regression	R <sup>2</sup>
	0%	30%	50%	70%		
Dry matter yield (t/ha/harvest)						
Calopo	1.9±0.30 b	3.1±0.72b	2.5±0.17c	2.0±0.20b	$\hat{Y} = 1.93 + 0.058x - 8.3 \cdot 10^{-4}x^2$	0.92
Puero	3.0±0.18 a	4.2±0.57a	5.1±0.16a	2.6±0.15b	$\hat{Y} = 2.90 + 0.108x - 1.55 \cdot 10^{-3}x^2$	0.80
Archer	3.0±0.54 a	3.7±0.30ab	3.9±0.59b	2.6±0.51b	$\hat{Y} = 2.95 + 0.059x - 8.86 \cdot 10^{-4}x^2$	0.88
P. Soybean	2.2±0.38 b	3.1±0.19b	3.7±0.93b	4.2±0.34a	$\hat{Y} = 2.20 + 0.029x$	0.99
Chemical Composition (%)						
NDF	47.03	49.75	51.76	53.62	$\hat{Y} = 46.99 + 0.094x$	0.99
CEL	23.52	24.98	26.06	27.83	$\hat{Y} = 23.34 + 0.06x$	0.98
HEM	13.77	15.12	15.72	16.34	$\hat{Y} = 13.77 + 0.049x - 2.0 \cdot 10^{-4}x^2$	0.99
L/S R	1.95	1.64	1.49	1.33	$\hat{Y} = 1.93 - 0.009x$	0.99

Means followed by the different letters in the same column are different by SNK test ( $p > 0.05$ ).

**Table 2.** Crude protein (CP), neutral detergent fiber (NDF), cellulose (CEL), hemicellulose (HEM), lignin (LIG) and leaf/stem ratio (L/S R) of tropical legumes subjected to different shading levels in the summer.

Sp	CP (%)	NDF (%)	CEL (%)	HEM (%)	LIG (%)	L/S R
Calopo	15.7±1.72ab	48.4±2.33a	24.1±1.40a	15.2±1.61	8.1±0.93	1.74±0.31a
Puero	17.5±2.60a	53.1±1.54d	27.2±1.38c	15.3±1.27	8.7±1.50	1.53±0.26b
Archer	14.4±2.17b	50.7±2.27c	25.7±2.12b	15.4±1.06	8.5±1.53	1.44±0.17b
P. Soybean	16.8±1.21a	50.0±2.16b	25.4±2.02b	15.1±1.21	8.7±1.08	1.70±0.39a

Means followed by the different letters in the same column are different by SNK test ( $p > 0.05$ ).

Puero and perennial soybean presented the highest CP contents in comparison to archer ( $p < 0.05$ ). However, calopo presented intermediate results not differing from the other legumes ( $p > 0.05$ ). Puero presented the highest NDF content; followed by calopo, perennial soybean and archer. Calopo presented the lowest CEL content followed by perennial soybean and archer not differing between both and the highest CEL content was verified in puero. HEM and LIG did not differ between legumes ( $p > 0.05$ ). Regarding the leaf/stem ratio ( $p < 0.05$ ), calopo and perennial soybean presented the highest values when compared to archer and puero.

Tropical legumes chemical analysis and L/S R in the autumn are presented on Table 3. Puero CP content was the lowest one ( $p < 0.05$ ) when compared to the other species, which did not differ from each other ( $p > 0.05$ ). Regarding to NDF, CEL and HEM, all of the species differed from each other ( $p < 0.05$ ), in addition perennial soybean presented the lowest content, puero the highest one and archer the intermediate one. No difference among the species was observed in the variable LIG ( $p > 0.05$ ). L/S R differed among the species ( $p < 0.05$ ); in addition perennial soybean presented the highest ratio, followed by puero presenting the intermediate one and archer the lowest one.

Pádua, Almeida, Silva, Rocha, and Nepomuceno (2006) reported 15.42; 15.5 and 16.46% of CP and 50.42; 62.47 and 60.29% of NDF for archer, puero and perennial soybean, respectively, when evaluating free and tutored cropping systems. 52% NDF for perennial soybean were reported by Ladeira et al. (2002). The differences might be associated to environmental conditions, soil, management and plant age. With the lowest NDF and the highest DM contents, the food digestibility was positively influenced. CEL (27 and 20%) and LIG (12%) for perennial soybean and calopo reported by Ladeira et al. (2002) confirmed the results obtained in the present study.

Crude protein (CP) and lignin (LIG) contents were not affected by shading in the summer. In the regression analysis, NDF and CEL presented a positive linear performance. On the other hand, HEM presented a quadratic effect, furthermore, regression analysis showed higher HEM content at the highest shading level. The L/S ratio showed negative linear performance as the shading level increased in the summer (Table 4).

The variable LIG was not influenced by shading differently from L/S ratio and chemical composition which were influenced by species and by shading ( $p < 0.05$ ) in the fall. However, no interaction between these two factors was found ( $p > 0.05$ ) (Table 4). CP, CEL and HEM presented a quadratic effect, in addition NDF presented positive linear effect and L/S ratio presented negative effect for shading levels. CP maximum content was obtained at 36.87% shading level. CEL maximum content was obtained at 77.5%, whereas HEM maximum content was observed in full shading.

Calopo presented the lowest NDF and CEL contents, as well as, the highest L/S ratio in the rainy season. LIG content did not differ between the species, perennial soybean and archer presented intermediate NDF and CEL contents and puero the highest values. No difference was detected ( $p > 0.05$ ) in HEM and LIG contents, so different NDF contents between species might be attributed to different CEL contents.

Plant species survival ability in the under forest increase with some morphophysiological traits modification under low radiation, such as: net photosynthetic rate increase,  $\alpha/\beta$  chlorophyll ratio decrease, specific leaf area mass and area ratio increase, improving plant growth and use of available radiation (Franco & Dillenburg, 2007).

Eriksen and Whitney (1982) assessing butterfly pea, leucaena, siratro and stylo subjected to different shading levels (0; 30; 55; and 73%) observed no reduction in protein content, but a decrease in nitrogen by biological fixation. Moreover, evaluating legumes and grasses under shading conditions, Lin, McGraw, George, and Garrett (2001) reported that the shading has little effect on the crude protein content of legumes. Legume fiber fraction increase observed in regard to shading levels is related to the adaptive response of plants to growth. According to Paciullo et al. (2011), plants subjected to shading conditions, tend to accelerate physiological maturity, resulting in increased fiber content in forage.

**Table 3.** Dry matter yield (DM) and chemical composition of tropical legumes subjected to (0; 30; 50 and 70%) shading levels in the fall.

Species	Shading				Regression	R <sup>2</sup>
	0%	30%	50%	70%		
Dry matter yield (ton ha <sup>-1</sup> cut <sup>-1</sup> )						
Puero	2.7±0.23b	3.5±0.13b	4.4±0.32a	2.7±0.45b	$\hat{Y} = 2.5 + 0.07X - 1.0 \cdot 10^{-3}X^2$	71.19
Archer	3.5±0.39a	4.3±0.26a	4.5±0.55a	3.7±0.21a	$\hat{Y} = 3.4 + 0.05X - 7.4 \cdot 10^{-4}X^2$	95.03
P. Soybean	2.7±0.48b	3.2±0.24b	3.5±0.42b	3.2±0.23ab	$\hat{Y} = 2.6 + 0.03X - 3.3 \cdot 10^{-4}X^2$	93.79
Chemical Composition (%)						
CP	15.06	17.57	18.37	15.29	$\hat{Y} = 14.944 + 0.177X - 2.4 \cdot 10^{-3}X^2$	0.91
NDF	48.35	50.95	52.77	54.34	$\hat{Y} = 48.372 + 0.086x$	0.99
CEL	23.77	25.02	25.69	26.98	$\hat{Y} = 23.797 + 0.031X + 2.0 \cdot 10^{-4}X^2$	0.99
HEM	15.01	16.27	17.12	17.55	$\hat{Y} = 14.994 + 0.051X + 2.0 \cdot 10^{-4}X^2$	0.99
L/S R	1.95	1.71	1.44	1.34	$\hat{Y} = 1.952 - 0.009x$	0.98

Means followed by the different letters in the same column are different by SNK test ( $p > 0.05$ ).

**Table 4.** Crude protein (CP), neutral detergent fiber (NDF), cellulose (CEL), hemicellulose (HEM) and lignin (LIG) of tropical legumes subjected to shading levels in the fall

Sp	CP	NDF	CEL	HEM	LIG	L/S
Puero	15.2±2.03b	53.9±1.90c	26.0±1.32c	17.2±1.26c	8.9±1.14	1.67±0.37b
Archer	17.0±1.91a	51.2±2.12b	25.4±1.77b	16.7±1.41b	8.3±1.09	1.39±0.20c
Perennial Soybean	17.6±1.85a	49.9±2.04a	24.8±1.82a	15.5±1.32a	8.2±1.58	1.76±0.25a

Means followed by the different letters in the same column are different by SNK test ( $p > 0.05$ ).

This behavior has demonstrated relevant strategy of legumes for mitigating shading effects, making themselves productive when subjected to those conditions. Based on the results obtained in this study, the fiber fraction increase might decrease nutritional value because it is directly related to intake control and digestibility (Daniel et al., 2013). It can be concluded that the plant digestibility was not affected since it was not observed effect of shading levels on LIG content.

L/S ratio values in this study were consistent to those reported in literature. Teixeira et al. (2010) reported 0.8 and 0.9 L/S ratio values for calopo and puero, respectively, close to those demonstrated in the present study. Almeida et al. (2015) reported a negative linear effect for that ratio in calopo, archer, puero and perennial soybean in the summer, under the same shading levels. L/S ratio presented a 0.2% reduction for each increase in shading level in the summer and in the fall.

Results difference reported in the present study might be attributed to each trial condition performed. Legume L/S ratio has influence on animal intake since animals prefer better nutritional value leaves except in conditions of forage shortage. Plants use the strategy of reducing energy consumption in order to maximize structures' function to survive under stressful conditions. L/S ratio decrease observed in this study might be due to a plant strategy to prioritize supporting tissue for capturing light, because there are morphological changes in shaded forage plants that allow the plant to tolerate different levels of shade (Gobbi et al., 2009). Although not quantified, legumes leaf/stem area increase was observed, being shading level increase responsible for the increase in leaf size.

## Conclusion

Legumes present production potential for cultivation under shading conditions. Among the legumes studied, perennial soybean is the most tolerant to increased shading. The increase in shading promotes an increase in neutral detergent fiber, cellulose, hemicellulose, as well as a decrease in the leaf/stem ratio.

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