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Growing tropical forage legumes in full sun and silvopastoral systems

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ABSTRACT. Growth was evaluated three tropical forage legumes in two cropping systems: silvopastoral system (SSP) and full sun. A completely randomized design was adopted in factorial three legumes (estilosanthes cv. Campo Grande (*Stylozanthes macrocephala* x *Stylozanthes capitata*), tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth) and macrotiloma (*Macrotyloma axillare cv. Java*)) x two farming systems, with 4 repetitions. A eucalyptus SSP already deployed, with spatial arrangement of 12 x 2 m between trees was used. Legumes were planted in January 2014 a uniform cut being made in May 2014. The court assessment was carried out 125 days after the uniformity cut. There was difference for mass production of dry legumes (PMMSL) between cultivation systems, evidencing increased productivity in the farming full sun. The macrotiloma showed higher PMSL (5.29 kg DM ha^{-1} cut^{-1}), while the kudzu obtained the lowest yield (3.42 kg DM ha^{-1} cut^{-1}) in the sun growing full. The cultivation of legumes in SSP increased the levels of mineral matter, crude protein and neutral detergent fiber. The shade provided by the SSP caused a reduction in the mass of dry matter production, but also altered the chemical composition of the studied legumes.

Keywords: Fabaceae, shading, forage production, chemical composition.

Cultivo de leguminosas forrageiras tropicais em sistema silvipastoril e a pleno sol

RESUMO. Avaliou-se o crescimento de três leguminosas forrageiras tropicais em dois sistemas de cultivo: sistema silvipastoril (SSP) e pleno sol. Foi adotado um delineamento inteiramente casualizado, em arranjo fatorial com três leguminosas (estilosanthes cv. Campo Grande (*Stylosanthes macrocephala* x *Stylozanthes capitata*), kudzu tropical (*Pueraria Phaseoloides*) e macrotiloma *Macrotyloma axillare*)) x dois sistemas de cultivo, com quatro repetições. Foi utilizado um SSP de eucalipto já implantado, com arranjo espacial de 12 x 2 m entre árvores. As leguminosas foram plantadas em janeiro de 2014, sendo feito um corte de uniformização em maio de 2014. O corte de avaliação foi realizado 125 dias após o corte de uniformização. Observou-se diferença para produção de massa de matéria seca de leguminosa (PMMSL) entre os sistemas de cultivo, sendo evidenciada maior produtividade no cultivo a pleno sol. O macrotiloma apresentou maior PMSL (5,29 kg de MS ha^{-1} corte^{-1}), enquanto o kudzu obteve a menor produtividade (3,42 kg MS ha^{-1} corte^{-1}) no cultivo a sol pleno. O cultivo de leguminosas no SSP incrementou os teores de matéria mineral, proteína bruta e fibra em detergente neutro. O sombreamento proporcionado pelo SSP acarretou redução na produção de massa de matéria seca, como também, alterou a composição bromatológica das leguminosas estudadas.

Palavras-chave: Fabaceae, sombreamento, produção de forragem, composição bromatológica.

Introduction

Pastures are the main food for livestock in Brazil, with satisfactory constitution in nutrients, especially during rainy season, and lower cost when compared to other foods used for animal production. However, inefficient management of pastures over the years, influenced primarily by extractive practices in monoculture grasses, has caused reduced production and excessive increase of degraded pastures in the country (Dias-Filho, 2011).

The adoption of systems that couple greater efficiency in the exploration of animals and areas with reduced environmental impact has become vital to consolidate Brazil's outstanding position face agribusiness worldwide. In this context, forest-livestock integration, just as the case of the silvopastoral system (SPS), is an interesting alternative that associates the concepts of production and sustainability to cattle farming activity. SPS can be understood as an integrated exploration of the tree x pasture x animal combination, aiming at obtaining products in the same area and simultaneously (Andrade et al., 2004; Bernardino & Garcia, 2009; Castro et al., 2009).

The implementation of SPSs has been rising in the country in recent decades; however, said system has been massively adopted exclusively with the cultivation of grasses in their understory. Nevertheless, the adoption of tropical forage legumes in the understory of silvopastoral systems has been little studied (Barcellos et al., 2008).

Forage legumes are a promising alternative to increment farming production for having good vegetal cover, contributing to incorporate atmospheric nitrogen into the soil and being an important nutritional source to animals, with high protein and mineral levels, besides satisfactory dietary fiber digestibility compared to tropical grasses (Barcellos et al., 2008; Carvalho & Pires, 2008). These characteristics encourage the utilization of tropical forage legumes in SPSs, especially when the exploration's objective involves matters related to recovery of degraded areas and greater animal production.

Moreover, for presenting C3-type photosynthetic metabolism, tropical forage legumes have lower light saturation point than tropical grasses (C4), which can be an advantage for the cultivation of these forages under shading conditions, as it is the case of SPSs. Some studies have evidenced changes in forage mass yield and in the bromatological composition of tropical forage legumes when cultivated under natural and artificial shading conditions. Species of tropical legumes that showed potential to be cultivated in SPSs include: *Arachis pintoi*, *Calopogonium mucunoides*, *Stylosanthes spp., Pueraria phaseoloides* and *Macrotyloma axillare* (Andrade et al., 2004; Carvalho & Pires, 2008; Almeida et al., 2015).

The present study aimed to assess the cultivation of three tropical forage legumes – *Stylosanthes* cv. Campo Grande *(Stylosanthes macrocephala* x *Stylozanthes capitata*), *Pueraria Phaseoloides* e *Macrotyloma axillare* – in two cropping systems: silvopastoral and full sun.

Material and methods

The experiment was conducted at the Experimental Farm of the Federal University of Vales do Jequitinhonha and Mucuri [Universidade Federal dos Vales do Jequitinhoha e Mucuri] (UFVJM), located in Curvelo, Minas Gerais, Brazil. The region's climate is characterized as tropical savanna, with annual average temperature of 22ºC, annual average rainfall of 1,300 mm and well defined seasons – rainy summers and dry winters.

The conduction of this study adopted a completely randomized design (CRD) with the following factorial arrangement: 3 tropical forage legumes (stylosanthes campo grande (80% *Stylosanthes capitata* + 20% *Stylosanthes macrocephala*), tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth) and macrotiloma (*Macrotyloma axillare* cv. Java)) x 2 cropping systems (silvopastoral and full sun), with 4 repetitions.

The silvopastoral system (SPS) was implanted before this study was conducted (2011); eucalyptus stands (*Eucaliptus urograndis* I144) were set eastbound, with 12 meters between rows and 2 meters between trees (12 x 2 m). The total experimental area used in the present study was 4 ha, with 2 ha being reserved to SPS and 2 ha reserved to the implantation of legumes for full sun cultivation.

Legumes were planted in the experimental area over the second half of January 2014, when the eucalyptus trees reached 6 m high on average. In the week preceding the planting of the legumes, the trees were pruned to the height of 2.5 m.

The soils of both cropping systems were prepared through the conventional method (plowing and harrowing) 30 days after planting. Soil analysis, carried out 120 days prior to planting, did not show need for soil acidity correction. The day before planting, the area was harrowed again and shallow planting grooves were made (2 to 4 cm deep), with 50 cm between lines. Legumes were manually planted in both areas (SPS and full sun), with seedbeds measuring 70 m^2 (10 x 7 m) for each legume. A total of 24 seedbeds were planted – 12 in the SPS understory and 12 in the full sun area. The planting of the seedbeds in the full sun area had the same orientation as that of seedbeds planted in the SPS understory (eastbound). Planting fertilization complied with soil analysis recommendations, using 10 kg of N, 60 kg of P_2O_5, 80 of k_2O and 8 kg of micronutrients per ha, in the forms of urea, single superphosphate, potassium chloride and FTE-BR12 mix, respectively. Sowing used 30 seeds per linear meter. Legume seeds were scarified by physical process (water sandpaper) to reduce their numbness effect. The seeds were not inoculated.

Planting was followed by cultural treatments such as: ant control, manual control of weeds, and top-dressing fertilization (30 kg of P_2O_5 and 50 kg of K_2O split in two applications) in experimental seedbeds. Three weeks after the implantation of the legumes in the two cropping systems, the seedbeds that showed some sort of flaw were replanted.

The legumes were subjected to a uniformity cut performed on May 15, 2014, in both cropping systems (SPS and full sun). The cut was made manually with the aid of cutting tools (cutlass and machete) at a height of 5 cm from the soil. Subsequently, the cleaning of the seedbeds and top-dressing fertilization were performed. All this was followed by an aspersion mobile irrigation system to water the whole experimental area (SPS and full sun), whenever rain scarcity reached an interval longer than 14 days.

On September 20, 2014, when forages had been growing for 125 days, a cut was made to assess the forage mass yield, leaf/stem ratio and bromatological composition of the studied legumes in the two cropping systems. Forage mass yield was determined by the square method (1 m^2), with 5 samples being randomly extracted from each of the experimental seedbeds. The cut was made according to the same procedures adopted for the uniformity cut. The samples were individually weighed, with the extraction of two subsamples: one weighing 500 g to determine the leaf/stem ratio, and another weighing 300 g to determine partial dry matter (55ºC for 72 hours).

For the quantification of leaf/stem ratio, leaf and stem fractions were manually separated and, after identification and weighing, the samples had their partial dry matter content determined (55ºC for 72 hours). After the drying time, the samples were weighed so as to obtain their partial dry matter content

The dry samples were processed in a Wiley mill with a 1mm sieve. The milled material was identified, stored in lidded plastic containers and sent to UFVJM's Animal Nutrition Laboratory for bromatological composition assessment. For bromatological composition determination, the following contents were determined: dry matter (DM), crude protein (CP) and mineral matter (MM) (Association of Official Analytical Chemists [AOAC], 2006); and neutral detergent fiber (NDF), according to Van Soest, Robertson, and Lewis (1991). Legume dry matter mass yield (LDMMY), expressed as kg of DM ha^{-1} cut^{-1}, was determined after total dry matter correction, considering air-dry matter (ADM) and oven-dry matter (ODM).

Obtained results were then subjected to analysis of variance, using the PROC GLM procedure through the SAS software (Statistical Analyses System [SAS], 2008), version 9.1, adopting the critical level of 5% probability.

Results and discussion

For the legume dry matter mass yield (LDMMY) variable, the interaction effect observed was ($p < 0.05$) legume species (stylosanthes, tropical kudzu and macrotyloma) x cropping system (silvopastoral and full sun). Full sun legume cultivation resulted in greater LDMMY compared to the silvopastoral system (SPS). LDMMY results obtained in the present study are displayed in Table 1.

Table 1. Dry matter mass yield (kg ha^{-1} cut^{-1} of DM) of three tropical forage legumes (Stylosanthes Campo Grande, tropical kudzu and macrotyloma) cultivated in two cropping systems: silvopastoral (SPS) and full sun systems.

Legume	Cropping systems			
	Silvopastoral system	Full sun	Means	CV (%)
Macrotyloma	843Ab	5,285Aa	3,064	85.23
Tropical kudzu	1,388Ab	3,419Ba	2,404	55.76
Stylosanthes	1,036Ab	4,365Aa	2,701	76.42
Means	1,089	4356		
CV (%)	25.38	21.42		

Means followed by different letters, uppercase in the column and lowercase in the line, differ from each other by Tukey test at a 5% probability. CV = coefficient of variation.

Results pointed differences in dry matter yield between the two treatments, evidencing mean values of 4,356 and 1,089 kg of DM ha^{-1} cut^{-1} for full sun and SPS cultivations, respectively. In this case, it can be stated that the micro-environment created in the assessed SPS understory severely limited the development of studied forages, since productive performance in full sun cultivation was approximately 4 times higher.

The lowest LDMMY obtained in the SPS associates with the higher light incidence on that treatment compared to the full sun system. In this case, the adopted spatial arrangement of trees (12 x 2 m) proved determinant to reduce luminosity on the herbaceous community of the assessed silvopastoral system, which caused an intense level of shading that limited forage growth under that condition. Reduction in forage production caused by moderate to intense levels is reported in the literature for grasses (for instance, *Brachiaria spp*. and *Panicum spp*. genuses) and tropical legumes (*Arachis*, *Pueraria* and *Stylozanthes*) (Paciullo et al., 2007; Sousa et al., 2007; Soares et al., 2009; Gobbi et al., 2009).

In addition to the amount of light hitting the SPS understory being reduced, the quality of luminosity that reaches the pasture of these systems suffers changes. In this way, it is believed that the canopies of the SPS trees work as filters that, consequently, change the wavelength of the light that reaches the understory of theses systems in relation to the light that hits the arboreal community. Thus, important wavelengths for forage development can be absorbed in high concentrations by treetops, which change the quality of the light hitting the SPS pasture, thus resulting in the effective reduction in forage yield (Rodrigues et al., 2014). It is worth reporting that this effect is greater as the spatial arrangement of trees becomes denser. For this reason, in order to promote adequate forage yield in the SPSs understory, using less dense spatial arrangements of trees is recommended, as they mean lower level of shading on the herbaceous community of these systems.

To a lesser extent, there is also the possibility of legumes having suffered with the allelopathic effect coming from the arborous community (eucalyptus). The literature reports that several species of eucalyptus synthetize allelopathic substances capable of influencing negatively the growth of vegetables cultivated in the understory of agroforestry systems (Goetze & Thomé, 2004). However, Andrade, Valentim, Carneiro, and Vaz (2004) showed that pasture growth in SPSs is limited directly by reduced luminosity (shade) and indirectly by greater nitrogen utilization under these cropping conditions. The authors reported that the allelopathic effect of the eucalyptus had little influence on the development of the pasture cultivated in the SPSs understory. Although allelopathic effects have not been assessed in this study, the hypothesis described by Andrade et al. (2004) is taken into account as well, attributing limited forage yield to more intense shading.

As for the yield of legumes cultivated under full sun conditions, during dry season, macrotyloma and tropical kudzu showed the highest (5,290 kg DM ha^{-1} cut^{-1}) and the lowest (3,420 kg DM ha^{-1} cut^{-1}) LDMMY values, respectively. Stylosanthes obtained an intermediate value (4,370 kg DM ha^{-1} cut^{-1}) but its mean did not differ from the values presented by macrotyloma and tropical kudzu. Deminicis et al. (2009) reported yields of 4,500, 3,500 and 3,800 kg DM ha^{-1} cut^{-1} for macrotyloma, tropical kudzu and stylosanthes species, respectively, values similar to those found in the present study.

It is worth highlighting that full sun legume yield was very satisfactory. It is important to stress that a mobile irrigation system was used in a uniform manner during 2 consecutive days whenever rain scarcity reached 12 days. In this way, it is reported that the values obtained in the present study for legume production are a bit higher than those reported in the literature for dry period with no irrigation.

The higher LDMMY value found in macrotyloma, under full sun cultivation, evidenced the good yield that this legume presents during the season unfavorable to forage development (dry season). When considering that throughout the farming year four cuts can be obtained (90 days of growth on average), macrotyloma might reach an average value of 21.1 ton of DR ha^{-1} $year^{-1}$, similar to the annual yield of some tropical grasses. Even under unfavorable climate conditions (for instance, reduced rainfall, temperature and solar radiation), macrotyloma showed potential to be introduced in livestock farming systems to compose the ecosystem of pastures. Specific anatomical-physiological mechanisms are likely to be involved to promote better utilization of water by this vegetable. It is believed that both radicular system development and mechanisms that control the vegetable's water loss to the environment can be involved to increment the macrotyloma's forage yield face other species.

Stylosanthes showed good forage yield during the dry season too. The yield of this species over a year would be 18.5 tons of DM ha^{-1} $year^{-1}$ if four cuts throughout the year were considered. It is worth highlighting that this species is inserted in a genetic selection program of at least 30 years conducted by Embrapa aimed exclusively at cultivation under *cerrado* edaphoclimatic conditions, which prevailed in this experiment.

Tropical kudzu, among the assessed legumes, showed lower tolerance to the adverse climatic conditions of the dry season. Though presenting satisfactory forage dry mass yield, its productivity was statistically lower than the value presented by macrotyloma. When considering four cuts being obtained during the farming year, tropical kudzu would yield 13.6 tons of DM ha^{-1} $year^{-1}$. This response must relate to a difference between water demands of the studied vegetables. It is worth pointing out that massive use of tropical kudzu has occurred in Northern Brazil, where there is a high and well distributed volume of rain throughout the year, which greatly differentiates the climatic conditions under which the experiment was conducted.

Legume cultivation in SPS resulted in no difference between forage yield means. Forage yield under shading condition corresponded approximately to 16.0; 40.6 and 23.8% of the yield obtained in the full sun treatment for macrotyloma, tropical kudzu and stylosanthes, respectively. Results showed that legume cultivation under the shading conditions imposed in this study (intense) compromised effectively the production of these forages. However, before disregarding the cultivation of these legumes in agroforestry systems, new studies with less intense shading levels should be conducted.

As to leaf/stem ratio assessment, there was effect ($p < 0.05$) for species only, with no effect for cropping system being observed. Tropical kudzu showed higher value (0.90) between the studied legumes. Macrotyloma and stylosanthes did not differ from each other, with values reaching 0.66 and 0.62, respectively.

Results showed that tropical kudzu obtained a 40.6% increase in relation to the mean value of the leaf/stem ratio of macrotyloma and stylosanthes species (0.64). This response evidenced greater participation of leaves in the dry mass of the forage produced, which probably can have a direct influence on the bromatological composition of tropical kudzu compared to other species. It is worth highlighting that the leaf represents the vegetal component with the highest concentration of nutrients and, also, that this portion of the plant is the most selected one by animals, which reinforces the importance of incrementing the leaf/stem ratio obtained by tropical kudzu (Berchielli et al., 2011).

As for bromatological composition of the legumes in the different cropping systems studied, assessment was performed considering whole plant, leaf and stem. For mineral matter content assessment, no treatment effect was observed for the stem fraction (Table 2).

Table 2. Mineral matter content (g kg^{-1}) of whole plant and leaf fractions of three tropical forage legumes cultivated in two systems: full sun and silvopastoral (SPS).

Legume	Whole plant		Leaf	
	Full sun	SPS	Full sun	SPS
	Mineral matter content (g kg^{-1})			
Macrotyloma	49.6B	56.2B	43.9Bb	58.2Ca
Kudzu	85.2A	92.4A	82.9Aa	89.7Ba
Stylosanthes	75.4A	84.4A	88.8Ab	100.4Aa

Means followed by different letters, uppercase in the column and lowercase in the line, differ from each other by Tukey test at a 5% probability.

Regarding mineral matter (MM) contained in the whole plant, species and treatment effects were observed ($p < 0.05$) but interaction between treatments was not identified. Although it has not presented statistical effect, it was possible to observe an outward trend in MM content for forages cultivated in the SPS compared to the full sun system. Macrotyloma showed the lowest MM contents in both assessed cropping systems.

About the leaf fraction, there was species x cropping interaction for MM content ($p < 0.05$). This result reinforces the hypothesis that shading can influence the mineral composition of forages cultivated in agroforestry systems. It is speculated that increment in the MM content of legumes cultivated in the SPS occurred due to the likely increase in the leaf area (leaf size). Under moderate to intense shading conditions, the vegetal falls into a stress state, since reduced luminosity leads to decreased rate of photosynthesis, which directly compromises the plant's metabolism (Paciullo et al., 2007). Under said conditions, the vegetable uses some strategies to reduce stressful effects from the environment. When it comes to shading, there are morpho-physiological changes that allow for increased efficiency in light capture in places where luminosity is reduced (Belesky et al., 2006). The main changes in vegetables subjected to intense shading are: increase in leaf surface, leaf angle, reduction in the number of leaves (drains) and elongated stems (Andrade et al., 2004; Paciullo et al., 2008).

Corroborating, Almeida et al. (2015), when working with rising shading levels on legumes (macrotyloma and tropical kudzu), reported increase in calcium, phosphorus and potassium values as shading level intensified. Despite the minerals added in the present study not being quantified specifically, exposed results corroborate with data reported by the abovementioned authors.

Koukoura et al. (2009) reported that increment in MM content associates with morpho-physiological changes in the vegetal caused by the shading effect. Thus, it is believed that increased leaf area is directly linked to increased MM in vegetables cultivated in shady places.

About crude protein (CP) content, only species effect was observed for whole plant and stem fractions ($p < 0.05$), which was not detected for the leaf fraction (Table 3).

Table 3. Crude protein content (g kg^{-1}) present in whole plant and stem fractions of three tropical forage legumes.

Legume	Whole plant	Stem
Macrotyloma	97.5B	52.0B
Kudzu	132.0A	89.0A
Stylosanthes	128.0A	83.0A

Means followed by the same letter in the same column do not differ from each other by Tukey test at a 5% probability.

The highest CP levels for whole plant and stem were found in tropical kudzu and stylosanthes species ($p < 0.05$), which differed from the CP level contained in macrotyloma. Deminicis et al. (2009) also reported lower CP content in macrotyloma (90 to 110 g kg^{-1}) compared to tropical kudzu (120 to 150 g kg^{-1}) and stylosanthes campo grande (120 to 160 g kg^{-1}).

Concerning CP level in the leaf, there was species x cropping system interaction, with macrotyloma and stylosanthes presenting increases in CP values ($p < 0.05$) when cultivated in the SPS understory (Table 4). The CP level contained in kudzu did not vary by cropping system. Gobbi et al. (2010) reported that shading effects on the bromatological composition of vegetables depend on both the forage species and the shading intensity to which the plant is subjected.

Table 4. Crude protein content (g kg^{-1}) in leaf fractions of three tropical forage legumes cultivated in two systems: full sun and silvopastoral.

Legume	Treatment	
	Full sun	Silvopastoral System
Macrotyloma	161.0Bb	181.0Aa
Kudzu	189.0Aa	194.0Aa
Stylosanthes	163.0Ba	182.0Aa

Means followed by different letters, uppercase in the column and lowercase in the line, differ from each other by Tukey test at a 5% probability.

Increment in CP values in vegetables cultivated under intense shading conditions has been reported in the literature (Andrade et al., 2004; Lacerda et al., 2009; Almeida et al., 2015). Castro et al. (2009) reported outward trend for N, P, K, Ca and Mg levels in tropical grasses cultivated under increasing shading conditions (0.30 and 60%). Carvalho et al. (1995) reinforced that forages cultivated under more intense shading conditions tend to show: bigger leaf size, lower dry matter percentage, and higher concentrations of nitrogen, phosphorus and potassium in leaves compared to vegetables cultivated under full sun conditions. Thus, since CP level is directly linked to the nitrogen contained in the vegetable, increased nitrogen values, caused by shading, has a direct impact on the increment of crude protein of the shaded vegetable.

Neutral detergent fiber (NDF) content for whole plant fractions showed species x cropping interaction effect ($p < 0.05$). Macrotyloma and tropical kudzu species showed increases in NDF values when cultivated in the SPS (Table 5).

Table 5. Neutral detergent fiber content (g kg^{-1}) in the whole plant fraction of three tropical forage legumes cultivated in two cropping systems: full sun and silvopastoral.

Legume	Treatment	
	Full sun	Silvopastoral system
Macrotyloma	623.0Ba	691.0Bb
Kudzu	531.0Aa	535.0Aa
Stylosanthes	545.0Aa	573.0Ab

Means followed by different letters, uppercase in the column and lowercase in the line, differ from each other by Tukey test at a 5% probability.

Increment in NDF in shaded legumes highlighted a possible response from forages to reduced luminosity. Under said condition, morpho-physiological changes are promoted by the vegetable so as to ensure that the plant can survive and adapt to this stress factor. In this case, increment in NDF values may have been a result of elongated stems, which is the vegetable's strategy to try to increase light capture efficiency in shaded areas (Taiz & Zeiger, 2013).

In general, field observations pointed some morphological changes among vegetables cultivated in the SPS compared to the full sun treatment, which include elongated stems, increased leaf area and reduced number of leaves per plant for forages cultivated under the shade. Shading caused an effective increment in the height of plants grown under the shade, with increases of 10 to 30 cm in relation to the height obtained in the no-shade cropping. Such arguments justify the increment in NDF content of legumes cultivated under more intense shading conditions.

As for species effect in the whole plant, macrotyloma showed the highest NDF level (657.0 g kg^{-1} on average). These results combined with data referring to the CP (97.5 g kg^{-1}) and MM (49.6 g kg^{-1}) levels of this study showed a nutritional value inferior to that of macrotyloma compared to tropical kudzu and stylosanthes. The latter presented similar bromatological composition, with average CP and MM values reaching 132.0 and 88.8 and 128.0 and 79.9 g kg^{-1} for tropical kudzu and stylosanthes, respectively.

For NDF values in leaf and stem portions, only species effect was observed ($p < 0.05$). As for leaf fraction, macrotyloma showed the lowest NDF value (293.0 g kg^{-1}), followed by stylosanthes and kudzu tropical, which did not differ from each other (398.0 and 407.0 g kg $^{-1}$ of NDF, respectively). About stem fraction, difference was observed for the three studied forages, with kudzu obtaining the lowest NDF value (539.0 g kg $^{-1}$), followed by stylosanthes (640.0 g kg^{-1}) and, with the lowest value, macrotyloma species (750.0 g kg^{-1} of NDF).

The results of the present study showed that shading caused by SPS limited the yield of tropical forage legumes and promoted changes in their bromatological composition. In this case, it is speculated that the spatial arrangement of the arborous community (12 x 2 m) resulted in an intense shading level, which limited the development of the studied fabaceae. Gobbi et al. (2009) reported that shading resulting from the arborous community on the pasture of denser SPS systems can be pointed as the main limiting factor to the yield of agroforestry systems. According to Paciullo et al. (2011), the choice of the spacing between trees is a determining factor to the development and longevity of pastures cultivated in the understory of silvopastoral systems. In this case, even when working with legumes, which have lower light compensation point for photosynthesis compared to tropical forage grasses, the recommendation for spatial arrangements should be more than 12 meters between tree rows. Thus, for the cultivation of tropical forage legumes in SPS the adoption of less dense tree spatial arrangements are proposed so as to promote a level of shading on the pasture that does not limit forage growth in the understory of these systems.

Additionally, since assessment was performed in the middle of spring, that is, forage development happened more intensely during the winter, it is likely that the position of the sun during that period of the year has resulted in a different sun ray inclination. The result of that reflects directly on the lower amount of light that hits the understory of agroforestry systems during this period of the year. This variation of luminosity helps explain the different vegetable covers verified throughout growths before the uniformity cut (summer-fall) and growth until the assessment cut (winter-spring).

In this context, studies with less dense spacing, that is, lower shading level, should be conducted aimed at assessing the response of these tropical forage legumes in the SPSs. Moreover, other parameters such as biological nitrogen fixation, persistence of production and handling of the pasture in the silvopastoral system with legumes should be studied in order to elucidate the real potential of utilization of these forages in cattle farming-forest exploration.

Conclusion

Growing tropical forage legumes in the silvopastoral-system understory, with spatial arrangement (12 x 2 m), causes limited forage yield compared to full sun cultivation. Reduced dry mass yield and increment in values of mineral matter, crude protein and neutral detergent fiber are changes evidenced in tropical forage legumes grown under shading conditions.

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