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SILVOPASTORAL SYSTEM COMPARED TO OTHER CONVENTIONAL PRODUCTION SYSTEMS IN THE MARANHÃO STATE CERRADO

Edvan Costa da Silva[1*], Léo Vieira Leonel[2], Fabrício de Oliveira Reis[2], Paulo Henrique Aragão Catunda[2], Luciana Sabini da Silva[1], Wagner Menechini[1]

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ABSTRACT - Silvipastoral systems are identified as options for land use due to the high potential they offer to increase the level of income from agronomic, social, economic, and ecological aspects. Given the above, this study aimed to evaluate the environmental benefits of implementing a silvopastoral system in Cerrado Maranhense, in comparison to other conventional production systems. The same was done in 2013 from February to May on a private property located in São Francisco do Brejão (MA) during the rainy season. The experiment evaluated three types of system: a) silvopastoral, composed of leucaena, grasses, and beef cattle, b) rotational system, and c) extensive system. A randomized block design in a 3x3 factorial scheme with three replications was used. Three pasture management systems (silvopastoral system, rotational system with native regeneration and extensive system) and three evaluation times (08:00 h, 12:00 h, and 16:00 h) were evaluated. After sample collection, dry biomass was determined. In the evaluation of ecophysiological parameters, the photochemical efficiency and estimate of the relative chlorophyll content in brachiaria plants of the three systems were determined. The photochemical efficiency was determined in the grasses of each system, being randomly evaluated three leaves per plant. The silvopastoral system was the one that showed the greatest increase in dry biomass of forage and the best results for the photochemical parameters, standing out as the best system for livestock.
Keywords: *Urochloa decumbens* Stapf., *Leucaena leucocephala* (Lam.) de Wit., plant ecophysiology, production systems.

SISTEMA SILVIPASTORIL EM COMPARAÇÃO A OUTROS SISTEMAS CONVENCIONAIS DE PRODUÇÃO NO CERRADO MARANHENSE

RESUMO - Os Sistemas Silvipastoris são apontados como opções de uso das terras pelo alto potencial que oferecem para aumentar o nível de rendimento dos aspectos agronômicos, sociais, econômicos e ecológicos. Diante do exposto, objetivou-se com o presente trabalho avaliar os benefícios ambientais da implantação de um sistema silvipastoril no Cerrado Maranhense, em comparação a outros sistemas convencionais de produção. O mesmo foi realizado em 2013 no período de fevereiro-maio em uma propriedade particular, localizada na cidade de São Francisco do Brejão (MA), durante a estação chuvosa. O experimento avaliou três tipos de sistema: a) silvipastoril, composto por leucaena, gramíneas e gado de corte, b) sistema rotacionado e c) sistema tradicional de superpastejo. O delineamento experimental utilizado foi blocos casualizados, em esquema fatorial 3 x 3 [3 sistemas de manejo de pastagem (sistema silvipastoril, sistema rotacionado com regeneração nativa e sistema extensivo) x 3 horários de avaliação (08:00 h, 12:00 h e 16:00 h)], contendo 9 repetições por tratamento e 3 repetições por parcela. Após a coleta das amostras, determinou-se a biomassa seca. Na avaliação dos parâmetros ecofisiológicos, foram determinadas a eficiência fotoquímica e estimativa do teor de relativo de clorofila em plantas de braquiária dos três sistemas. A eficiência fotoquímica foi determinada nas gramíneas de cada sistema, sendo avaliadas aleatoriamente três folhas por planta. O sistema silvipastoril foi aquele que apresentou maior incremento para biomassa seca de forragem e melhores resultados para os parâmetros fotoquímicos, destacando-se como o melhor sistema para a criação de animais.
Palavras-chave: *Urochloa decumbens* Stapf., *Leucaena leucocephala* (Lam.) de Wit., ecofisiologia vegetal, sistemas de produção.

INTRODUCTION

The agricultural sector has stood out in the Brazilian economy in recent decades, due to its significant increase in productivity and its growing importance for maintaining the balance of the country's trade balance. With the modernization of agriculture and the increase in the intensive use of machinery and inputs, the levels of land and labor productivity increased, also contributing to the growth of the industry associated with the sector (GASQUES et al., 2010).

The Brazilian agricultural sector has evolved over the past decades. IBGE data (2017) show that this sector occupies an area of approximately 350 million hectares, of which approximately 172 million hectares are used for pasture, with an estimated 50% of these areas being in some state of degradation.

[1]State University of Western Paraná (Unioeste), *Campus* Marechal Cândido Rondon, Marechal Cândido Rondon, Paraná, Brazil. E-mail: edvan_costa@outlook.com;. *Corresponding author.
[2]State University of Maranhão (UEMA), *Campus* of São Luís, São Luís, Maranhão, Brazil.

Agriculture goes through a continuous modernization process, through the incorporation of new technologies, generating economic growth on the one hand and potential risks to the environment on the other. These risks are mainly caused by inadequate soil and crop management practices, deforestation, loss of biodiversity, salinity, desertification, soil erosion, and contamination of natural resources (BARBOZA et al., 2012).

The conventional farming system is considered highly dependent on external inputs, such as chemical fertilizers and pesticide (ADL et al., 2011), which can when used improperly, cause contamination of soil, water, and air, besides to causing resistance to pests and increased greenhouse gas emissions (TSCHARNTKE et al., 2012). Agriculture is responsible for 30 to 35% of GHG (greenhouse gas) emissions.

The silvopastoral system (SPS) is a modality of the agroforestry system that consists of the integration between trees, pastures, and animals in the same area and at the same time, to promote the sustainable use of the soil (BOSI et al., 2014). This type of system covers social and environmental aspects, bringing the benefit of a more uniform distribution of income, greater diversification of products and food, generation of jobs, and multiple land use (CAETANO and CAETANO JÚNIOR, 2015). This system model can also be an option to aid in the recovery and formation of pastures in the process of degradation (DIAS FILHO, 2011).

About tree species, leucaena (*Leucaena leococephala*), a leguminous tree plant, has the main role of fixing nitrogen and has high acceptability for animals (COSTA et al., 2011), in addition to excellent regrowth and multiple uses, mainly in protein banks, and stands out positively for rural producers. Forage leguminous species fixing atmospheric nitrogen in consortium with grasses can be an alternative to contribute to the system (MACEDO et al., 2018), for establishing symbiosis with nitrogen-fixing bacteria.

The use of forage legumes provides advantages, such as: reducing the use of nitrogen in the system, improving the quality of the grazing animals' diet, better ground cover, and reduced feed cost (BALBINO et al., 2011). The intercropping between grasses with legumes provides greater weight gain to the animals, makes the environment more pleasant, as it reduces the incidence of solar radiation, protects the soil from weathering, thus maintaining soil moisture, a fact that mitigates the dehydration of the pasture (LEONEL et al., 2015).

Despite the importance and benefits, the Silvopastoral System is still poorly studied. Given the above, this study aimed to evaluate the environmental benefits of implementing a silvopastoral system in the Cerrado Maranhense, in comparison to other conventional production systems.

MATERIAL AND METHODS

The experiment consisted of three treatments: the silvopastoral system, which is based on the intercropping between grasses and leucaena (*Leucaena leucocephala*), sown in the study area a year ago (T1), a rotational system with native regeneration, called dirty pasture, where the native vegetation is interspersed with grasses (T2) and extensive system, in which cattle are raised in large areas (T3).

In each system, a survey of the main plant species was carried out. In the silvopastoral system, brachiaria (*Urochloa decumbens*), white lead tree (*Leucaena leucocephala*), and rain tree [*Samanea saman* (Jacq.) Merr]. Among the species in the rotational system, brachiaria (*Urochloa decumbens*), embaúba (*Cecropia concolor* Willd), fairchild pigeonwings (*Clitoria fairchildiana* Howard), fava d'anta (*Dimorphandra mollis* Benth), olho-de-cabra (*Ormosia* sp.), rain tree [*Samanea saman* (Jacq.) Merr], mangerioba grande [*Senna reticulata* (Willd.) H.S.Irwin & Barneby], jurubeba (*Solanum paniculatum* L.), yellow ipe [*Tabebuia Serratifolia* (Vahl.) Nich], assa peixe (*Vernonia polyanthes*), and pata-de-vaca (*Bauhinia* sp.). In the extensive system, only the brachiaria was observed.

A randomized block design in a 3x3 factorial scheme with three replications was used. Three pasture management systems (silvopastoral system, rotational system with native regeneration and extensive system) and three evaluation times (08:00 h, 12:00 h and 16:00 h) were evaluated. The data were submitted to the normality test (Kolmogorov-Smirnov, Lilliefors, Cramér-von Mises, and Watson test) and analysis of variance. The means were compared by the Tukey test at 5% probability, using the Sisvar software (FERREIRA, 2011).

Forage biomass assessment

Three grazing systems formed by brachiaria (silvopastoral system, rotational system with native regeneration, and extensive system) were evaluated in the rainy season. Each system constituted a treatment, with fifteen repetitions per treatment.

In the silvopastoral system (T1) and the rotational system with native regeneration (T2), the forage biomass was estimated by cutting samples of 1.0 m^2, close to the ground, allocated at random, by the direct method (FLORES et al., 2008). In the extensive system (T3), the forage biomass was estimated using three cages in the exclusion area (1 m^2) per picket and by the direct method. The dry biomass, inside and outside the cage (using the direct method), was obtained by cutting the plant close to the soil.

Forage accumulation (kg ha^{-1} of dry biomass) was obtained by the difference between the forage masses observed inside and outside the cage (FLORES et al., 2008). After collection, the samples were bagged and placed in an air-forced circulation oven, at 70ºC, for 72-96 h, and the dry biomass was determined.

Evaluation of ecophysiological parameters

In the assessment of ecophysiological parameters, photochemical efficiency, and chlorophyll content estimation in brachiaria plants (grass) present in the three systems were determined. The photochemical efficiency was determined in the grasses of each system, being randomly evaluated three leaves per plant. Measurements were made at three times of the day (8:00 h, 12:00 h and 16:00 h). The evaluations were performed using a non-modulated fluorometer (Pocket-PEA model, Hansatech Instruments Ltda, King's Lynn, Norfolk, UK). Measurements were made on fully expanded sheets and exposed to the sun. Before the measurements, the leaf area to be measured remained in the dark for 30 min. The photochemical efficiency was induced using a red-light pulse (650 nm), for 2 s, with an intensity of 2,500 µmol m^2 s^{-1}, obtained using LEDs (Light Emitting Diodes), located on the device's probe.

Simultaneously to the photochemical efficiency analyzes, the relative chlorophyll content was determined; this in a non-destructive way, using a portable SPAD chlorophyll meter, model 502DL (MINOLTA, JAPAN).

RESULTS AND DISCUSSION

The data in Table 1 show that higher values of dry pasture biomass were observed in the silvopastoral system (1.00 kg ha^{-1}), presenting itself as the best treatment, statistically different when compared to the other systems (rotational and extensive systems). The extensive system proved to be an inferior treatment (0.53 kg ha^{-1}), compared to silvopastoral and rotational systems.

TABLE 1 - Dry biomass (kg ha^{-1}) of brachiaria leaves (*Urochloa decumbens*) in the silvopastoral system (T1), rotational system with native regeneration (T2), and extensive system (T3), evaluated from February to May 2013.

Production system	From February to May
Silvopastoral system	1.00 a*
Rotational system	0.83 b
Extensive system	0.53 c
Mean	0.79
CV (%)	25.00

*Means followed by the same lowercase letter in the column do not differ, by Tukey's test, at 5% probability of error.

According to Sousa et al. (2007), the higher the values of precipitation and relative humidity, the greater the dry matter production of a production system; the performance of grasses is related to the precipitation and relative humidity of the place where it is grown. In silvopastoral systems as a production system that contains trees, the values of forage dry matter production, depend less on the conditions of precipitation and relative humidity (LEONEL et al., 2015). In this way, the tree component contributed to the modification of the environment with the reduction of solar radiation on the herbaceous component, wind speed, and in the maintenance of soil moisture, given the lower rates of evapotranspiration (GARCEZ NETO et al., 2010). On the other hand, Oliveira et al. (2014) reinforce decision making when choosing grass as an herbaceous component in integrated systems.

Figure 1 shows the chlorophyll content in the leaves in the different production systems, where the silvopastoral system (T1) differed statistically (39.58) from the other systems. The extensive system was the one with the lowest result. This superiority of T1 may be related to the presence of leucaena, considered a nitrogen-fixing plant in the soil, and capable of mobilizing nutrients from the deepest layers to the soil surface (DRUMOND and RIBASKI, 2010). The inexpressive result of T3 is possibly due to the system being made up only of brachiaria and not having adequate pasture management or practices.

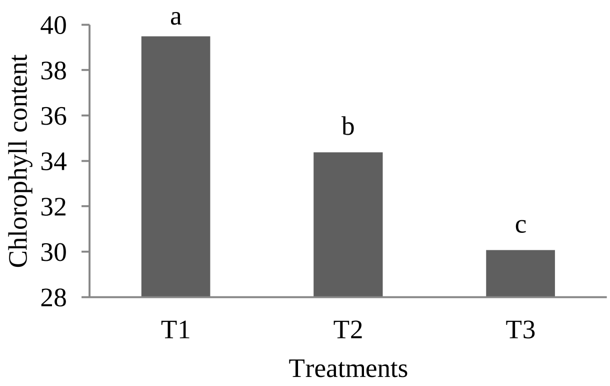

FIGURE 1 - Chlorophyll content in brachiaria leaves in the evaluated systems (T1 = silvopastoral system, T2 = rotational system with native regeneration and T3 = extensive system), from February to May 2013.

The mean values of photochemical efficiency (Fv/Fm) are shown in Figure 2. T1 again has higher values than the other treatments with Fv/Fm of 0.76; 0.75, and 0.73, at 8:00 h, 12:00 h and 16:00 h, respectively. T3 had the lowest Fv/Fm values, 0.55; 0.25, and 0.67, at 8:00 h, 12:00 h, and 16:00 h, respectively.

Values considered suitable for the Fv/Fm ratio may vary from author to author, as, for SILVA et al., (2014), values greater than 0.75 can indicate plants without stress symptoms. Gonçalves et al. (2010) report that values below 0.83 can characterize plants with symptoms of stress. For Martinazzo et al. (2013), the Fv/Fm ratio is not a reliable parameter for detecting stress in the plants.

The Fv/Fm ratio is related to the light energy absorbed by chlorophylls that are used in electron transport (MARENCO et al., 2014), and this relationship is an important tool in detecting changes in the photosynthetic capacity of plants due to the stress that occurred in the plant (SILVA et al., 2014).

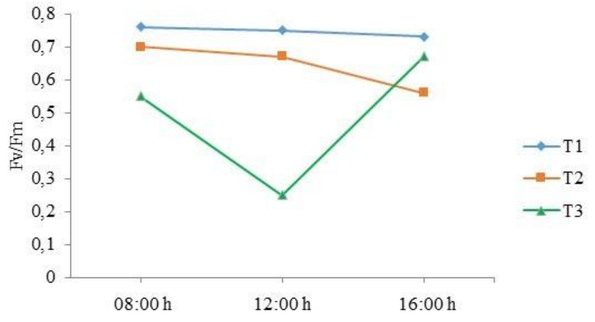

FIGURE 2 - Photochemical efficiency curves (Fv/Fm) in brachiaria leaves in the evaluated systems (T1 = silvopastoral system, T2 = rotational system with native regeneration, and T3 = extensive system), from February to May 2013, at the evaluation times (8:00 h, 12:00 h and 16:00 h).

Still, in Figure 2, it is observed that all treatments showed a reduction in the Fv/Fm ratio, at 12:00 h, with a recovery of photochemical efficiency at 16:00 h. The photosynthetic rate of plants can be influenced by some nutritional deficiency (PES and ARENHARDT, 2015), which can affect the plant physiologically, causing a deficiency in the functioning of the photosynthetic apparatus and low value of photochemical efficiency. According to Krause et al. (1995), the low values of the Fv/Fm ratio due to exposure to high radiation, as occurred in T3 (under the full sun), may be evidence of reversible dynamic photoinhibition, where there is a total recovery of the photochemical efficiency of the PSII at night.

According to Taiz et al. (2017), two types of photoinhibition are identified: dynamic and chronic. Under moderate excess light, dynamic photoinhibition is observed, where quantum efficiency decreases, but the maximum photosynthetic rate remains unchanged. Dynamic photoinhibition is caused by the deviation of light energy absorbed towards heat dissipation. Therefore, the decrease in quantum efficiency, which can be temporary and return to its initial or chronic value, which can damage the plant's photosynthetic system and decrease the quantum efficiency and the maximum photosynthetic rate. Chronic photoinhibition is associated with damage and replacement of protein D1 from the PSII reaction center. Unlike dynamic photoinhibition, these effects have a relatively long duration, persisting for weeks or months.

Through the factors evaluated in the research and the results obtained, the silvopastoral system emerges as an alternative for pasture management in the Cerrado Maranhense, due to having favored the integrity of the photosynthetic apparatus of forage plants cultivated in this management system and for providing higher values of dry biomass.

CONCLUSION

The silvopastoral system was the one that showed the greatest increase in dry forage biomass and the best results for the photochemical parameters, standing out as the best system for livestock.

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