SCAP
SOCIEDADE DE CIÊNCIAS AGRÁRIAS DE PORTUGAL

Ecophysiology of *Brachiaria decumbens* in grazing systems

Ecofisiolologia de *Brachiaria decumbens* em diferentes sistemas de manejo

Letícia Moura Ramos[1], Fabrício de Oliveira Reis[2]*, Paulo Henrique Aragão Catunda[3], Eduardo Henrique Santana Sousa[4] and Alena Torres Netto[5]

[1] State University of Maranhão, Doctoral student, Postgraduate Program in Agroecology, Paulo VI campus, 65055-970, São Luís, Maranhão, Brazil
[2] State University of Maranhão, Department of Chemistry and Biology, Postgraduate Program in Agroecology, Paulo VI campus, 65055-970, São Luís, Maranhão, Brazil
[3] State University of Maranhão, Department of Rural Economy, Paulo VI campus, 65055-970, São Luís, Maranhão, Brazil
[4] State University of Maranhão, Postgraduate Program in Agroecology, Paulo VI campus, 65055-970, São Luís, Maranhão, Brazil
[5] Estácio de Sá University, Department of Environmental Engineering, Luís Carlos de Almeida St., 113, Granja Cavaleiros, 27930-050, Macaé, Rio de Janeiro, Brazil
http://dx.doi.org/10.19084/RCA17242

Received/recebido: 2017.09.21
Received in revised form/recebido em versão revista: 2018.02.16
Accepted/aceite: 2018.03.27

ABSTRACT

Plant Ecophysiology was used as a tool to interpret the responses and adaptation of pastures to environmental conditions. The objective of this study was to evaluate ecophysiological parameters in *Brachiaria decumbens* grown in different grazing systems in the *Cerrado*'s biome in the south state of *Maranhão*, Brazil. The experiment was conducted in a completely randomized design with nine replications, using a 3×2×3 factorial arrangement consisted of three grazing management systems (silvopastoral, a rotation system with regeneration of native vegetation, and extensive) two seasons (dry and rainy), and three evaluation times along the day. The photochemical efficiency, performance index, and estimation of chlorophyll content were evaluated. According to the results, most of the parameters of the variables evaluated for *B. decumbens* presented stress conditions, thus compromising their photosynthetic apparatus. *B. decumbens* presented the best photochemical efficiency and estimated chlorophyll content throughout the day in the silvopastoral system, in both evaluated seasons, therefore, it is a promising species of grass for this system.

Keywords: *Brachiaria decumbens*, photochemical efficiency, estimation of chlorophyll content, silvopastoral system.

RESUMO

A Ecofisiologia Vegetal é uma ferramenta usada para ajudar na compreensão e interpretação das respostas e aclimatação das pastagens às variantes ambientais. Nesse contexto, o presente trabalho teve como objetivo avaliar variáveis ecofisiológicas em *Brachiaria decumbens*, cultivadas em diferentes sistemas de manejo de pastagem em área de Cerrado do sul do Estado do Maranhão, Brasil. No experimento foi utilizado esquema fatorial 3x2x3, sendo constituído no primeiro fator: três sistemas de manejo de pastagem (sistema silvipastoril, rotacionado com regeneração nativa e extensivo), segundo fator: duas épocas do ano (seca e chuvosa) e terceiro fator (três horários do dia), em esquema de delineamento inteiramente casualizado, com nove repetições. Foram avaliadas: variáveis de eficiência fotoquímica, índice de performance e estimativa do teor de clorofila. Como resultado no estudo, observou-se que, o sistema extensivo, apresentou a maior quantidade das variáveis em estresse, apresentando assim comprometimento do aparato fotossintético, já o sistema silvipastoril, apresentou as melhores relações de eficiência fotoquímica e estimativa do teor de clorofila durante o dia e nas duas épocas do ano. A *Brachiaria decumbens* no sistema silvipastoril se mostrou com melhor eficiência ecofisiológica em todas as variáveis em relação aos outros sistemas, apresentando potencialidade nesse tipo de pastagem.

Palavras-chave: *Brachiaria decumbens,* eficiência fotoquímica, estimativa do teor de clorofila, sistema silvipastoril.

INTRODUCTION

The meat and milk production indexes are very low in Brazil. Several factors contribute to this situation, including low natural soil fertility, pasture degradation, and reduced availability of nutrients, such as phosphorus; as well as the water deficit due to the poor rainfall distribution throughout the year (Fagundes *et al*., 2005).

Animal production systems in Brazil must become more productive and sustainable. The challenges of the globalized market, requires investments in new technologies and environmentally viable production processes. The use of silvopastoral systems is a promising alternative to reduce problems from deforestation and ecosystem degradation (Martuscello *et al.,* 2009).

The inappropriate use of pastures has led to extensive degraded areas. Moreover, the increasing demand of society for environmentally sustainable production models has forced producers and the scientific community to look for new alternatives. Crop-livestock-forestry systems are viable alternatives for the improvement and sustainability of the agricultural sector due to its effects on ecological and social processes (Carvalho *et al*., 1995).

Although, in system, arboreal and herbaceous species can compete for environmental resources such as water, light and nutrients. Thus, information on plant ecophysiology is important for agriculture and livestock in order to understand the development and adaptation responses of the plants in different environments. In addition, it is necessary to develop management practices adapted to the productive capacity of forage plants in a given environment (Dias Filho, 2006).

Studies evaluating ecophysiological variables in silvopastoral systems are scarce. The objective of this study was to evaluate ecophysiological variables in *Brachiaria decumbens* grown in different grazing management systems in the *Cerrado* biome in the south state of Maranhão, Brazil.

MATERIAL AND METHODS

The study was carried out from April to October 2013 in the municipality of São Francisco do Brejão, Maranhão, Brazil (5º7'24"S; 47º25'6''W).

The experiment was conducted in a completely randomized design with nine replications, using a 3×2×3 factorial arrangement consisted of three grazing management systems, two seasons (dry and rainy), and three evaluation times of the day (08:00 a.m., 12:00 p.m., and 04:00 p.m.). The three grazing management systems (treatments) consisted of a silvopastoral system (SS), a rotation with regeneration of native vegetation (RS), and an extensive system (ES).

The treatment SS had *Brachiaria decumbens*, *Samanea saman*, and *Leucaena leucocephala*. This treatment had padlocks, and the system was rotated every three months. *Leucaena leucocephala* was used as temporary feed for the cattle, and no supplementation was used during the dry season for the animals.

In the treatment RS, the *Brachiaria decumbens* was rotated every five months with native species of the Cerrado biome—*Cecropia concolor*, *Clitoria fairchildiana*, *Dimorphandra mollis*, *Ormosia sp*, *Samanea saman*, *Senna reticulata*, *Solanum paniculatum*, *Tabebuia Serratifolia*, *Vernonia polyanthus*, and *Bauhinia* sp.

The treatment ES consisted of conventional grazing management, with permanent pasture of *B. decumbens*, and cattle raised extensively. The soil was prepared with harrowing.

The climate of the experimental area is Aw', tropical hot and humid, according to the Koeppen (1948) classification, with two well defined seasons—rainy and dry (LABGEO/LABMET, 2002). Climatological data of São Francisco do Brejão was collected by a mini-weather station (WatchDog 2,900ET; Spectrum Technologies Inc., Illinois, USA) during the experiment period. The results showed monthly averages of the evaluated period: rainy season, temperature from 17.6ºC to 33.8ºC; relative humidity of 83.1%, and precipitation of 93.1 mm; and dry season, temperature from 16.6ºC to 37.2°C, relative humidity of 65.9%, and precipitation of 2.7 mm.

Samples of *B. decumbens* plants of each evaluated system were collected to analyze their photochemical efficiency; three leaves per plant were collected and evaluated at three times along the day. The analyses of fluorescence emission (initial photochemical efficiency (F_0), maximum quantum efficiency of photosystem II (PSII) (F_v/F_m), and performance index (PI)) were carried out using the non-modulated Fluorometer Pocket-PEA (Hansatech Instruments Ltd, King's Lynn, Norfolk, UK). Clips provide by the manufacturer were used to adapt the leaf tissue to the dark for thirty minutes for the reaction centers to reach the opened condition (oxidized Qa). Then, fluorescence was induced using a single strong one-second light pulse (3,500 μmol m^{-2} s^{-1}), applied with three light emitting diodes (650 nm).

Plant vitality can be characterized by the photosynthetic index or performance index (PI). This variable was assessed by integrating three other independent variables: density of active reaction centers (RC) per unit of chlorophyll molecules in the antenna system of the PSII (RC/ABS); efficiency of the electron that reduced Quinone A (Qa) and entered into the electron transport chain (ET/TR-ET); and ratio between the reduction capacity of Qa by the absorbed photon and the energy dissipated as heat (F_v:F_0). The variable PI indicates the activity of photosystems I and II, and provides quantitative information about the current state of leaf photochemical activity, and stress conditions (Strasser *et al*., 2000).

Estimation of chlorophyll content was performed using the chlorophyllometer SPAD-502 (Minolta, 1989) on the same samples, simultaneously to the fluorescence emission analyses. Five point of each leaf were read, according to the method described by Swiader and Moore (2002).

The Assistat 7.6-beta software was used for the statistical analysis. The data were subjected to the Lilliefors normality test, then, the variables that presented normality (F_0, F_v/F_m and SPAD) were subjected to ANOVA and compared by the Tukey's test at 5% probability.

The performance index (PI) was subjected to the non-parametric analysis; Kruskal-Wallis and Man-Whitney tests at 5% probability were used to compare the means of the grazing management systems, and the means of the dry and rainy seasons, respectively.

RESULTS AND DISCUSSION

The photochemical efficiency data revealed lower initial fluorescence (F_0) for the *B. decumbens* in the silvopastoral system (SS) in the rainy season, at the three evaluation times, compared to the other two evaluated systems (Table 1). The plants of the SS treatment indicated stress only at the evaluation time of 12:00 p.m. F_0 values around 500 indicate healthy plants, and above 550 indicate plants under stress, according to Gonçalves *et al*. (2005a).

The F0 increased from 8.00 am to 12:00 pm and after decreased until 4:00 pm (Table 1). These data are similar to the results reported by Vieira *et al*. (2010), which found lower F0 values at 07:00 a.m., rising 8:00 am and keeping high until 4:00 am when it began to decline.

The *B. decumbens* in the SS treatment had higher maximum quantum efficiency of PSII (F_v/F_m) in the rainy season than in the other systems, with maximum of 0.82 at 08:00 a.m. (Table 2). The F_v/F_m, of all evaluated treatments, was below the optimal range for the photosynthetic process at 12:00 p.m.

Table 1 - Means of initial fluorescence (F_0) in leaves of *B. decumbens* grown in silvopastoral system (SS), rotation system with regeneration of native *cerrado* vegetation (RS) and extensive system (ES) evaluated at three times of the day (08:00 a.m., 12:00 p.m., and 04:00 p.m.) during the rainy and dry seasons

08:00 a.m.		F_0		
		12:00 p.m.	04:00 p.m.	
Rainy season	SS	474.99 dC	629.33 cA	508.70 cB
	RS	517.00 cB	632.66 cA	628.70 bA
	ES	530.33 cC	672.66 bA	602.03 bB
Dry season	SS	540.56 cC	657.23 bcA	625.16 bB
	RS	584.76 bC	675.766 bA	633.06 bB
	ES	652.80 aC	789.66 aA	730.73 aB
Average		550.07	676.13	621.40
CV(%)			2.60	

For each season, averages followed by the same lowercase letter in the column and uppercase in the row do not differ by Tukey test (5%).

Table 2 - Means of photochemical efficiency (F_v/F_m) in leaves of *B. decumbens* grown in silvopastoral system (SS), rotation system with regeneration of native *cerrado* vegetation (RS) and extensive system (ES) evaluated at three times of the day (08:00 a.m., 12:00 p.m., and 04:00 p.m.) during the rainy and dry seasons

		Fv/Fm		
		08:00 a.m.	12:00 p.m.	04:00 p.m.
Rainy season	SS	0.82 aA	0.64 aC	0.71 aB
	RS	0.73 bcA	0.63 aB	0.71 aA
	ES	0.71 bcA	0.67 aA	0.69 aA
Dry season	SS	0.78 abA	0.68 aA	0.66 aA
	RS	0.69 cA	0.63 aA	0.66 aA
	ES	0.69 cA	0.51 bB	0.55 bB
Average		0.73	0.63	0.67
CV(%)			4.81	

For each season, averages followed by the same lowercase letter in the column and uppercase in the row do not differ by Tukey test (5%).

According to Bolhar-Nordenkampf *et al*. (1989), when the plant has its photosynthetic apparatus intact, the F_v/F_m must be between 0.75 and 0.85; and a decrease in this variable may represent a photoinhibitory damage in the PSII reaction centers.

The F_v/F_m of the *B. decumbens* in the rotation system with regeneration of native cerrado vegetation (RS) and extensive system (ES) in the rainy season had similar results at 08:00 a.m. (0.73 and 0.71, respectively) (Table 2). These results indicate a possible starting of damage to the photosynthetic apparatus.

The results of this study confirm those found by Naumann *et al*. (2008), who reported a decreased F_v/F_m at 12:00 p.m., with a subsequent increase and stability of the photochemical efficiency from this time.

The F_v/F_m of the *B. decumbens* in the SS treatment had the best results at 08:00 a.m., both in the rainy (0.82) and dry (0.78) seasons, denoting a healthy photosynthetic apparatus. In the dry season, the F_v/F_m of the *B. decumbens* in the ES showed a greater decrease at 12:00 p.m. (0.51) and 04:00 p.m. (0.55).

Photosynthesis is affected by environmental conditions, such as temperature, humidity and wind speed. The soil water content is reduced and there are high temperatures in the dry season, which can be determining factors of stresses and, thus, decrease the quantum efficiency and reduce the crop productivity.

Ogaya (2011) performed an experiment simulating climate changes for two shrub species and reported that temperature and relative humidity are the most important factors affecting the F_v/F_m, more than the water availability. The author found the lowest F_v/F_m in the winter, due to the cold and low relative humidity; however, the F_v/F_m was 0.80 in ideal conditions of temperature and water availability.

In the rainy season, the *B. decumbens* in the SS presented the highest performance indexes (PI), followed by those of the RS and ES treatments (Table 3).

The best PI of the *B. decumbens* in the SS and RS may be explained by the trees presents in both systems that protected the grass from the high radiance conditions of the tropics; and the ES had only *B. decumbens*, making it more exposed to high temperature and light.

Gonçalves *et al*. (2005) stated that the reduction in the PI of plants subjected to high radiance indicates loss of efficiency by photoinhibition. PI is considered a more sensitive parameter for the detection and quantification of stress in plants than the response of the maximum efficiency of PSII (Christen *et al*., 2007; Oukarroum *et al*., 2007).

The estimations of chlorophyll content (SPAD) of the *B. decumbens* in the SS and RS were similar

Table 3 - Performance Index (PI) in leaves of *B. decumbens* grown in silvopastoral system (SS), rotation system with regeneration of native *cerrado* vegetation (RS) and extensive system (ES), during the rainy and dry seasons

	Rainy season	Dry season
SS	196 aA	196 aB
RS	131 bA	119 bB
ES	52 cA	62 bB
CV(%)		

Averages followed by the same lowercase letters in the columns and uppercase in the rows, which follow the rank sums, do not differ statistically from each other by the Kruskall-Wallis and Mann-Whitney tests, respectively, at the 5% probability level.

Table 4 - Means of estimation of chlorophyll content (SPAD) in leaves of *B. decumbens* grown in silvopastoral system (SS), rotation system with regeneration of native *cerrado* vegetation (RS) and extensive system (ES), during the rainy and dry seasons

	Rainy season	Dry season
SS	39.58 aA	27.66 aB
RS	33.89 aA	22.02 abB
ES	18.83 bA	12.98 bA
Average	30.76	20.89
CV(%)	17.01	

Averages followed by the same lowercase letter in the column and uppercase in the row do not differ by Tukey test (5%).

throughout the day in the rainy season (Table 4); these results probably occurred due to the presence of trees of these systems that provided partial shade.

The plant adapt, degrading the chlorophyll to absorb less energy when subjected to a high light radiation. Contrastingly, the plants maintain high concentrations of chlorophyll to maximize the interception of light energy when subjected to a low light radiation (Nogueira *et al.,* 2005).

Martuscello (2009) evaluated *Brachiaria* spp. under shading levels and the SPAD of all *Brachiaria* spp. responded linearly and positively to shading level.

The SPADs of the *B. decumbens* in the SS and RS were similar in the dry season, which presents adverse conditions for plants. The *B. decumbens* in the ES had the worst SPAD, probably due the absence of trees in this area; the trees in the SS and RS shaded the plants, which may have contributed to the reduction of the *B. decumbens* transpiration, the interception of solar radiation can affect the microclimate pasture grows.

The water deficit is characterized as one of the environmental stresses responsible for changes in leaf pigments, by altering the chlorophyll and chlorophyll b ratio, and the chlorophyll and carotenoid ratio. This is used, to a lesser extent, to diagnose senescence under water stress conditions (Hendry and Grime, 1993).

CONCLUSIONS

The *Brachiaria decumbens* grown in silvopastoral management system had better ecophysiological efficiency for all evaluated variables, both in rainy and dry seasons, when compared to the other evaluated grazing management systems; consequently, this is a potential species for livestock production in this system.

The rotation system with regeneration of native *cerrado* vegetation proved to be a viable alternative in the livestock management, which provides good ecophysiological results for the *B. decumbens*.

The extensive system is not recommended as a grazing management system for *B. decumbens*, since it presented the worst results for the evaluated ecophysiological variables, and resulted in damage to the photosynthetic apparatus of the plants.

REFERENCES

Bolhar-Nordenkampf, H.R.; Long, S.P.; Baker, N.R.; Oquist, G.; Schreiber, U. & Lechner, E.G. (1989) – Chlorophyll fluorescence as probe of the photosynthetic competence of leaves in the field: A review of current instrument. *Functional Ecology*, vol. 3, n. 4, p. 497-514. http://dx.doi.org/10.2307/2389624

Carvalho, M.M.; Freitas, V.P. & Andrade, A.C. (1995) – Crescimento inicial de cinco gramíneas tropicais em um sub-bosque de angico-vermelho (*Anadenanthera macrocarpa* Benth.). *Pasturas Tropicales*, vol. 17, n. 1, p. 24-30.

Christen, D.; Schönmann, S.; Jermini, M.; Strasser, R.J. & Défago, G. (2007) – Characterization and early detection of grapevine (*Vitis vinifera*) stress responses to esca disease by in situ chlorophyll fluorescence and comparison with drought stress. *Environmental and Experimental Botany*, vol. 60, n. 3, p. 504-514. https://doi.org/10.1016/j.envexpbot.2007.02.003

Dias-Filho, M.B. (2006) – *Competição e sucessão vegetal em pastagens*. Belém: Embrapa Amazônia oriental.

Fagundes, J.L.; Fonseca, D.M.; Gomide, J.A.; Nascimento Junior, D.; Vitor, C.M.T.; Morais, R.V.; Mistura, C.; Reis, G.C. & Martuscello, J.A. (2005) – Acúmulo de forragem em pastos de *Brachiaria decumbens* adubados com nitrogênio. *Pesquisa Agropecuária Brasileira*, vol. 40, n. 4, p. 397-403. http://dx.doi.org/10.1590/S0100-204X2005000400012

Gonçalves, J.F.C.; Barreto, D.C.S.; Santos Junior, U.; Fernandes, A.V.; Sampaio, P.T.B. & Buckeride, M.S. (2005a) – Growth, photosynthesis and stress indicators in Young rosewood plants (Aniba rosaeodora Ducke) under different light intensities. *Brazilian Journal of Plant Physiology*, vol. 17, n. 3, p. 325-334. http://dx.doi.org/10.1590/S1677-04202005000300007

Gonçalves, M.C.; Vega, J.; Oliveira, J.G. & Gomes, M.M.A. (2005b) – Sugarcane yellow leaf virus infection leads to alterations in photosynthetic efficiency and carbohydrate accumulation in sugarcane leaves. *Revista de Fitopatologia Brasileira*, vol. 30, n. 1, p. 10-16. http://dx.doi.org/10.1590/S0100-41582005000100002

Hendry, G.A.F. & Grime, J.P. (1993) – *Methods in comparative plant ecology – a laboratory manual*. London, Chapman & Hall, 252 p.

Koeppen, W. (1948) – *Climatologia: estúdio de los climas de la Tierra*. México, Fondo de cultura económica, 496 p.

LABGEO/LABMET (2002) – *Atlas do maranhão*. 2ª ed. São Luís, GEPLAN/LABGEO/UEMA, 39 p.

Martuscello, J.A.; Jank, L.; Gontijo, M.M.; Laura, V.A. & Figueiredo, D.D.N.V. (2009) – Produção de gramíneas do gênero *Brachiaria* sob níveis de sombreamento. *Revista Brasileira de Zootecnia*, vol. 38, n. 7, p. 1183-1190. http://dx.doi.org/10.1590/S1516-35982009000700004

Minolta (1989) – *Manual for chlorophyll meter SPAD 502*. Osaka: Minolta, Radiometric Instruments divisions.

Naumann, J.C.; Young, D.R. & Anderson, J.E. (2008) – Leaf chlorophyll fluorescence, reflectance, and physiological response to freshwater and saltwater flooding in the evergreen shrub, *Myrica cerifera*. *Environmental and Experimental Botany*, vol. 63, n. 1-3, p. 402-409. http://dx.doi.org/10.1016/j.envexpbot.2007.12.008

Nogueira, R.J.; Araújo, E.L.; Willadino, L.G. & Cavalcante, U.M.T. (2005) – *Estresses ambientais: danos e benefícios em plantas*. Recife, Imprensa Universitária, 500 p.

Ogaya, R.; Penuelas, J.; Asensio, D. & Llusià, J. (2011) – Chlorophyll fluorescence responses to temperature and water availability in two co-dominant Mediterranean shrub and tree species in a long-term field experiment simulating climate change. *Environmental and Experimental Botany*, vol. 73, p. 89-93. http://dx.doi.org/10.1016/j.envexpbot.2011.08.004

Oukarroum, A.; El Madidi, S.; Schansker, G. & Strasser, R.J. (2007) – Probing the responses of barley cultivars (*Hordeum vulgare* L.) by chlorophyll a fluorescence OLKJIP under drought stress and re-watering. *Environmental and Experimental Botany*, vol. 60, n. 3, p. 438-446. https://doi.org/10.1016/j.envexpbot.2007.01.002

Strasser, R.J.; Srivastava, A. & Tsimilli-Michael, M. (2000) – The fluorescence transient as a tool to characterize and screen photosynthetic samples. *In*: Mohanty, p. & Yunus, p. (Eds.) – *Probing photosynthesis: mechanism, regulation and adaptation*. London, Taylor and Francis, p. 443-480.

Swiader, J.M. & Moore, A. (2002) – SPAD-chlorophyll response to nitrogen fertilization and evaluation of nitrogen status in dryland and irrigated pumpkin. *Journal of Plant Nutrition*, vol. 25, n. 5, p. 1089-1100. http://dx.doi.org/10.1081/PLN-120003941

Vieira, D.A.; Portes, T.A.; Stacciarini, E. & Teixeira, J.B. (2010). Fluorescência e teores de clorofila em abacaxizeiro cv. Pérola submetida a diferentes concentrações de sulfato de amônio. *Revista Brasileira de Fruticultura*, vol. 32, n. 2, p. 360-368. http://dx.doi.org/10.1590/S0100-29452010005000061