AGRONOMIC PERFORMANCE OF ELEPHANT GRASS CULTIVARS UNDER IRRIGATION: A SYSTEMATIC REVIEW

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ABSTRACT. Elephant grass (*Pennisetum purpureum* Schum) is a grass species native to Africa, mainly used as forage resource. The search for adequate species and irrigation can be an alternative to increase yield and year-round availability of this forage in the Cerrado. Studies on irrigated elephant grass in the literature are still rather scarce. This review aimed to update information on the agronomic performance of elephant grass cultivars under irrigation. Methods: Articles referring to the topic irrigation of elephant grass were searched at the databases *ScienceDirect, Scopus* and *Agris*. In April 2018, two independent researchers searched at these databases considering all articles in English without restriction of year. At the three databases, a total of 357 articles were selected and downloaded, 316 of which were excluded and 41 were thoroughly read. At the end, three articles were considered in the systematic review. The best results were obtained in the period from June to October, when evapotranspiration and temperature were higher. In the second article, salinity caused reductions in vegetation index, leaf area, plant height and chlorophyll. In the last article of the review, the results were satisfactory with the use of irrigation, resulting in increased grass yield, generating greater availability of feed to cattle. With the present study it is possible to conclude that elephant grass can be a good alternative for cattle feed production, but some factors may limit its growth and development.

Key words: irrigation, watering, drip, *Pennisetum purpureum*

DESEMPENHO AGRONÔMICO DE CULTIVARES DE CAPIM-ELEFANTE SOB IRRIGAÇÃO: UMA REVISÃO SISTEMÁTICA

RESUMO. O capim-elefante (Pennisetum purpureum Schum) é uma espécie nativa da África, usada principalmente como recurso forrageiro. A busca por espécies e irrigação adequadas pode ser uma alternativa para aumentar a produtividade e a disponibilidade o ano todo dessa forragem no Cerrado. Estudos sobre capim-elefante irrigado na literatura ainda são bastante escassos. Esta revisão teve como objetivo atualizar informações sobre o desempenho agronômico de cultivares de capim-elefante sob irrigação. Métodos: Os artigos referentes ao tópico irrigação de capim-elefante foram pesquisados nas bases de dados ScienceDirect, Scopus e Agris. Em abril de 2018, dois pesquisadores independentes pesquisaram nessas bases de dados, considerando todos os artigos em inglês sem restrição de ano. Nas três bases de dados, um total de 357 artigos foram selecionados e baixados, 316 dos quais foram excluídos e 41 foram lidos exaustivamente. Ao final, três artigos foram considerados na revisão sistemática. Os melhores resultados foram obtidos no período de junho a outubro, quando a evapotranspiração e a temperatura foram maiores. No segundo artigo, a salinidade causou reduções no índice de vegetação, área foliar, altura das plantas e clorofila. No último artigo da revisão, os resultados foram satisfatórios com o uso da irrigação, resultando em aumento da produção de gramíneas, gerando maior disponibilidade de ração para o gado. Com o presente estudo, é possível concluir que o capim-elefante pode ser uma boa alternativa para a produção de ração, mas alguns fatores podem limitar seu crescimento e desenvolvimento.

Palavras-chave: irrigação, rega, gotejamento, Pennisetum purpureum

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INTRODUCTION

Brazil has in most of its regions two well-defined seasons, which are the drought period, from April to September, and the rainy period, from November to March, the latter of which is favorable to forage growth. Water deficit causes many losses for forage crops. In the dry period, forage production stagnates due to the lack of rains, and the use of irrigation and its adequate management are required to avoid production losses (Mistura et al., 2007).

For Vitor et al. (2009), forages are the most practical and economical way of feeding cattle, being the support basis of the Brazilian livestock farming. In other countries such as Vietnam there was an expressive increase in beef and milk production from 100,000 tons in 2001 to 290,000 tons of live weight in 2011. The increase of the country's population was one of the reasons for the increment in the demand for higher-yielding forages, and several genera have been studied, including *Pennisetum purpureum* Schum (Xuan ba et al., 2013).

Elephant grass (*Pennisetum purpureum* Schum) is a forage which has stood out due to its high yield, with excellent characteristics of adaptation to different types of soil, high biomass production, being well adapted to intensive grazing systems (Cóser et al., 2007). Studies conducted by Waramit & Chaugool (2014) highlight that elephant grass is tall (most cultivars) and has high yield, being a grass species of hot climates such as that of Thailand. In this country, there has been increasing interest in its use to produce bioenergy due to its vigorous biomass production and easy adaptability.

Elephant grass irrigation has been studied as an option to minimize the stagnation of its production in the drought periods and dry spells in the rainy period. Such deficit causes losses and there are few studies addressing that. If irrigated and well managed, elephant grass shows increased yield and quality. Mota et al. (2011) observed significant effects of irrigation on the yield of tropical forages. Losch (1996) states that water is the essential component of plant cells and is present in most metabolic processes. Its deficit causes damage to plants. Moreover, turgor pressure and diffusion of solutes between cells are necessary for the maintenance and survival of this grass, and water is required for these processes to occur.

In the last years, there has been an expressive increase in beef and milk production in Brazil and in other countries, leading to the search for cultivars with higher yields. This systematic review aimed to evaluate the agronomic performance of elephant grass cultivars under irrigation as a parameter for other researchers, because there is little research on this topic.

MATERIAL AND METHODS

Methods

Protocol

This systematic review was registered at the *International Prospective Register of Systematic Reviews*, conducted according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) [26], for identification, selection, eligibility and inclusion of articles.

Research strategy and eligibility criteria

In April 2018, two independent researchers searched in English for articles published at the databases *ScienceDirect*, *Agris* and *Scopus*, considering all years, without restriction. The articles were downloaded and saved in a folder for subsequent analysis in *Mendeley* software.

We have included articles with the following characteristics: (a) irrigation, (b) watering, (c) elephant grass, and (d) *Pennisetum purpureum*.

Exclusion criteria were: (a) articles not related to elephant grass; (b) irrigation performed with other genera; (c) articles containing incomplete data; (d) elephant grass not irrigated. Article search strategy and key words used are presented in Chart 1.

CHART 1. Search strategy

Additional file 1: search strategy. The search terms used in *ScienceDirect*, *Agris* and *Scopus* were: (“irrigation" or "drip" or "watering") and ("elephant grass" or "pennisetum purpureum").

Reviewing process

After performing the strategy of search at the databases (Figure 1), duplicated articles were removed. Two reviewers (VNL and EAS) selected the titles and abstracts of all articles found, reading them and, consequently, including them in the systematic review. Included articles were thoroughly read in order to determine their eligibility. In case of disagreement, a third evaluator was asked to read the articles.

Data extraction, quality appraisal and synthesis

From the selected articles, the following data were extracted: authors, publication year, sample size, type of irrigation used, genus *Pennisetum purpureum* Shum, analyzed variables, method used for the analyses and results.

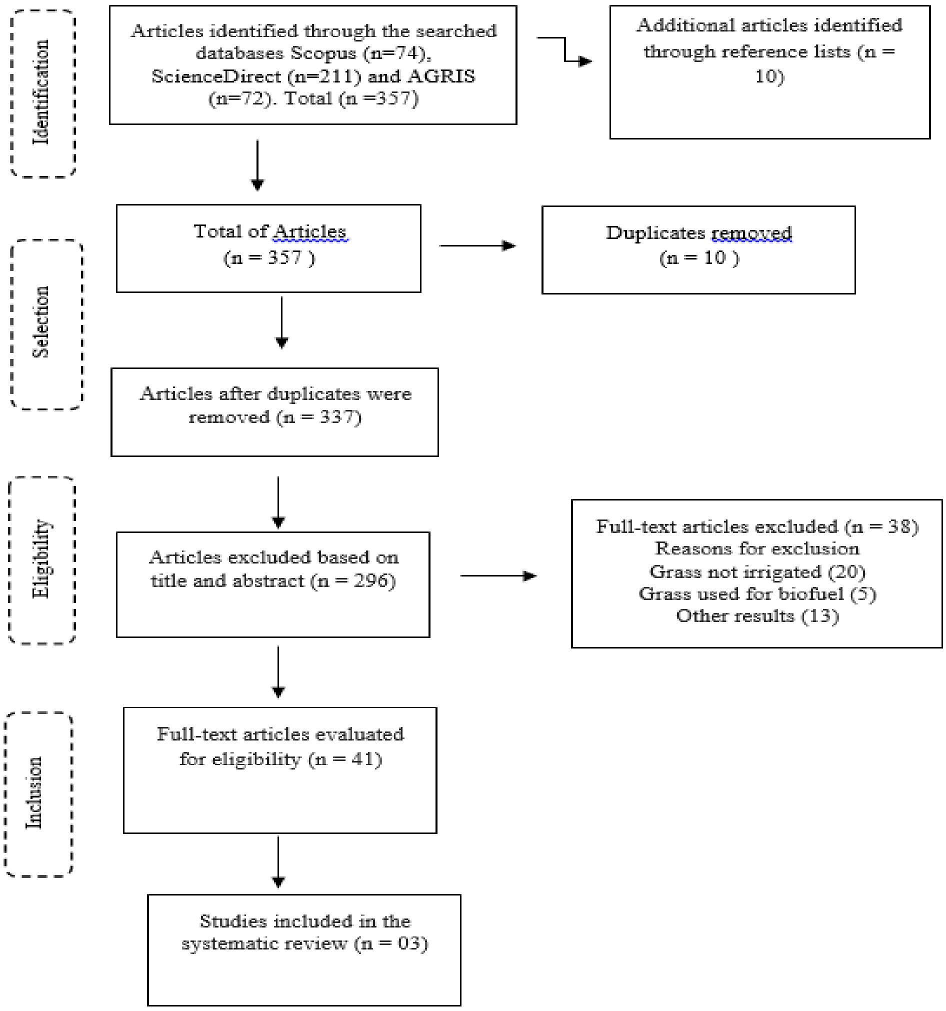

FIGURE 1. Flowchart of the reviewing process

RESULTS

The search performed at the three databases *Agris*, *Scopus* and *ScienceDirect* identified a total of 357 articles. After removing duplicates, titles and abstracts, 41 articles were left and these were thoroughly read. Three of them were included in this review. Both reviewers agreed upon the included articles.

Data extraction in this study consisted in the collection of the most important data by the two reviewers, considering those, which directly impacted the systematic review, for instance, expected results and conclusion. Subsequently, they were fully included in the systematic review.

After thorough analysis of the articles, three articles met the requirements and were included in the systematic review. The most common reasons for exclusion of articles were: elephant grass not irrigated; use of elephant grass for biofuels; irrigation with other grass genera.

TABLE 1. Results of the evaluations of the three articles included in this review

Author (s)	Valencia-Gica; Yost & Porter	Wang, et al	Rambau; Fushai; Baloyi
Title	Biomass production and nutrient removal by tropical grasses subsurface drip-irrigated with dairy effluent	Biophysical properties and biomass production of elephant grass under saline conditions	Productivity, chemical composition and ruminal degradability of irrigated Napier grass leaves harvested at three stages of maturity
Year	2012	2002	2016
Experimental site	Waianae (Hawaii)	Imperial Valley Research Center in Brawley, (California)	University of Venda (Thohoyandou)
Irrigation	Drip	Furrow	Use of pipes to field capacity
Cultivar	Banagrass	Elephant grass	Napier grass
Plant and soil variables	GBP; NR High application rates of dairy effluent CP; ADF; NDF; Fe; Mn; Zn and Cu.	Characterizing the effects of salinity. CSR; T; LAI; CC; AS; GBP.	Production DM; CP; ADL; ADF; NDF; P; K; Ca; Mg; S, Cu; Zn; Mn; Fe.
Method	Periodic analysis Kjeldahl ANKOM Filter Bags Fe, Mn, Zn and Cu (applied as fertilizer from April 2005). Zn November 2005 Mn, Fe May 2006.	Electromagnetic inductance meter Remote sensing Multi-Spectral Radiometer Infrared Thermometer LICOR LAI-2000 Plant Canopy Analyzer SPAD meter readings Total fresh weight measured on a scale immediately after each cut.	NT and NL were counted and grass height and longest leaf length (cm) were measured. Method of Van Soest et al. (1991) for ADL, ADF and NDF. Determination with inductively coupled plasma optical emission spectrometry (ICP-OES) (SOP, 2005).
Continued table 1 **Results**	There was a difference ≠ in DM yield between grass species and between irrigation rates. ≠ Between species in NR capacity. CP (> 150 g kg). NDF varied from 570 to 620 g kg. ADF varied from 320 to 360 g kg. Tissue concentration and absorption of other nutrients Levels ↓. Supplemental foliar micronutrient application led to adequate levels. P. purpureum and B. mutica obtained higher absorption (P <0.01) of N, P and K.	ES ↓ CSR LAI. ↑ T, ↑ salt content, significant ↓ in transpiration. ↓ PH with increase of salinity from control to 25 dS m^{-1} treatment. ↓ PH of elephant grass due to salinity. ↓ CC, as salinity increased.	↑ LL per plant and PH differed (p <0.01) at the three stages. NT vs LPP n≠ (p> 0.05). BIO 6.08 ton/ha. ED ↓ with maturity, when rate of passage ↑ from 2% to 8% for DM and CP. NDF and ADF contents decreased from early to intermediate and increased in the late stage. There was effect on Ca, Na and Zn (p <0.05), as well as on Cu and K (p <0.01). There was no effect (p> 0.05) on Mg, P, Mn and Fe at the three maturity stages; Mg increased from 1.82 to 2.29 g / kg, while K, Na, P and Cu decreased from 19.94 to 16.09 g / kg, 0.63 to 0.37 g / kg, 1.34 to 1.08 g / kg and 9.51 to 6.78 mg / kg.

Abbreviations: (in alphabetic order Accumulation of salinity (AS), acid detergent fiber (ADF), acid detergent lignin (ADL), biomass (BIO), calcium (Ca), canopy spectral reflectance (CSR), chlorophyll content (CC), copper (Cu), crude protein (CP), difference (≠), dry matter (DM), effective degradability % (ED), effects of salinity (ES), gram (g), grass biomass production (GBP), hectares (ha), higher than (>), high or increase (↑), iron (Fe), kilogram (kg), leaf area index (LAI), leaf length (LL), lower than (<), low or reduction (↓), magnesium (Mg), manganese (Mn), neutral detergent fiber (NDF), no difference (n≠), number of leaves (NL), number of leaves per plant LPP), number of tillers (NT), nutrient removal (NR), phosphorus (P), plant height (PH), potassium (K), sulfur (S), and temperature (T).

SYNTHESIS OF RESULTS

The characteristics of the included studies are shown in Table 1. The evaluations conducted in the first article were: biomass production, nutrient removal, high application rates to tropical grasses under subsurface drip irrigation with dairy effluent, neutral detergent fiber (NDF), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu).

In the second study, the following evaluations were conducted: characterization of salinity effects on biophysical variables such as canopy spectral reflectance, temperature, leaf area index, chlorophyll content and cumulative effect of salinity on biomass production of elephant grass.

The characteristics evaluated in the last article included were: dry matter (DM); crude protein (CP); acid detergent lignin (ADL); acid detergent fiber (ADF), neutral detergent fiber (NDF), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe).

DISCUSSION

Our study is one of the few, if not the first, to systematically review the agronomic performance of elephant grass cultivars under irrigation. In relation to the results of the articles included in this review, differences were observed in some of the variables analyzed. In the results analyzed by (Valencia-Gica & Yost and Porter, 2012), tropical grasses irrigated with effluent produced large quantities of dry matter. The best results were obtained in the period from June to October, when evaporation and temperature were higher and irrigation provided favorable conditions for biomass production by the cultivars.

The same authors found low concentrations of N, P and K in plant tissues, compared to the adequate levels for growth and development. The low levels of N in plant tissues indicate high demand of this cultivar during its development stage. This may also be due to the harvesting frequency carried out in the experiment. N levels in soil were also low. Among the grasses, *Pennisetum purpureum* and *Brachiaria mutica* usually showed the highest absorption of N, P and K, especially with the irrigation rate equivalent to 2 ½ of potential evapotranspiration (ETp).

A study conducted with *Brachiaria brizantha* used irrigation and N fertilization. The authors observed that the variables plant height and number of leaves were positively influenced by the interaction between irrigation and N doses. The combination between irrigation and fertilization increased the leaf area index of the cultivar and, consequently, its yield (Lopes et al., 2011).

Another study with elephant grass found increase in its dry matter. When water depths and N doses were applied, the highest value of dry matter (6,445.72 kg ha^{-1} $year^{-1}$) was obtained with irrigation equivalent to 100% evapotranspiration and N dose of 500 kg ha^{-1} $year^{-1}$. The worst result (2,539.08 kg ha^{-1} $year^{-1}$) was observed with application of 0% evapotranspiration and N dose of 100 kg ha^{-1} $year^{-1}$ (Mota et al., 2011).

In the evaluations of nutrient removal, there were differences between the tropical grasses. The cultivar *Pennisetum purpureum* consistently removed the largest quantities ($P < 0.05$) of N (94%) and P (82%) among the irrigated grasses for 0.5 ETp. Among the grasses which received the rate of 2 ½ ETp, *B. mutica* removed the largest percentage of nutrients applied (62% N and 23% P), but these values were not significantly different from the N and P percentages removed by the other grasses (Valencia-Gica & Yost and Porter, 2012)).

The grasses *Brachiaria mutica*, *Pennisetum purpureum*, *Pennisetum atratum* and *Cynodon nlemfuensis* had high yields under drip irrigation and produced high biomass levels, which were higher than the values commonly found in the literature. Among the grasses, *B. mutica* and *P. purpureum* produced the highest dry matter yields and demonstrated high potential to absorb nutrients from the effluent (Valencia-Gica & Yost and PorteR, 2012). These grasses were shown to be excellent options for forage production and for maximizing the reuse of dairy effluents. This type of irrigation contributes to reducing the build-up of effluents in lagoons and, in turn, the risk of overflow and water contamination.

Results presented by (Wang et al., 2002), included in this review, were related to the increase in irrigation water salinity. There was increase in salinity and reduction in canopy reflectance in the near-infrared region (NIR) for harvest. In the period of faster growth, the maximum reflectance in the NIR was about 80% in the control plot. The largest difference occurred at the bands 830 and 900 nm. Lowest NIR reflectance was found on July 17 and October 18, when the maximum NIR reflectance reached only about 50%. This result occurred because there was more dry matter per leaf area unit, due to the reduced growth of cell expansion. Based on the reflectance measurement at the bands 830 and 660 nm, there were large reductions in the simple ratio vegetation index (SRVI), which was more sensitive than other indices in reflecting salt stress, with salinity increments from 5 to 10 dS m^1 and 20 to 25 dS m^1.

The same authors found consistent reductions in plant height and leaf area index with the increase of salinity from the control to the treatment of 25 dS m^{-1}. Such degree of reduction was related to the severity of the salt stress. Size reduction is consistent with the reduced SRVI calculated from the reflectance measurements.

The total of chlorophyll per plant is directly linked to the photosynthesis rate; the higher this content, the greater the increment in biomass production. The study of (Wang et al., 2002) found reduction in dry biomass yield with the increase of salinity at the level of 5 dS m^{-1}, which occurred between July and August, when the biomass tends to dry due to the high temperatures. Because of the increase in salinity from 10 to 15 dS m^1 or higher levels, there was a greater reduction in the biomass of the cultivars.

Conducting a study with Brachiaria, some authors observed that the chlorophyll content by the SPAD index was high in treatments with water volume equivalent to 80% field capacity and a positive response to N doses with increase of 0.0718% for every kg of N. On the other hand, for the lowest water volume, 40% field capacity, the SPAD index increased by 0.0370% in response to every kg of N (Alves et al., 2008).

The total chlorophyll of the plant was also reduced by the salt stress. Salinity reduced the elephant grass canopy reflectance in the NIR, which resulted in the reduction of the vegetation index. Yield was reduced by more than half when salinity increased from 5 to 25 dS m^1. However, the high rate of biomass production can also justify it as a viable forage crop to grow under conditions of high temperatures (Wang et al., 2002).

Rambau et al, (2016) verified that the growth parameters of the cultivar Napier at its three maturity stages did not show significant differences for leaf length per plant and plant height. The number of tillers and number of leaves did not differ either. The longest leaf length per plant, plant height, number of leaves per plant and number of tillers increased with grass maturity. The cumulative biomass production was equal to 6.8 tons / ha over 12 weeks of growth.

In a comparison between Mombasa grass and Napier grass, greater proportion of leaves was found in the former. Such difference is attributed to the expression of tillering in each cultivar, due to the axillary and basal tillering of Napier, which elongates its stalk. By contrast, Mombasa grass has more basal tillering, which imparts greater proportion of leaves (Garcia et al., 2011).

The authors recommended the cultivation of Napier grass for ruminant feed. The results indicated that the harvesting stage is critical to obtaining high-quality forage. For Napier, the forage should be harvested in the correct period in order to maintain its high content of nutrients and the degradability of DM and protein. However, in-vivo studies are necessary to evaluate the effect of the change on the nutritive value, maturity, specific digestibility of nutrients and animal performance (Rambau et al., 2016).

The authors concluded that the grass which received adequate fertilization and irrigation increased its yield and availability for cattle feed. Napier grass was recommended by the authors, being a continuous food supply to ruminants. This grass decreased its production in saline environments, and salinity reduced its canopy reflectance in the near-infrared region, which resulted in reduction of the vegetation index (RAMBAU et al., 2016; WANG et al., 2002; (Valencia-Gica & Yost and Porter, 2012).

With this study, it is possible to conclude that elephant grass has high yield and can be an excellent alternative for cattle feed production, but some factors, such as salinity, may limit its growth and development. To avoid such limitation, this cultivar should be correctly managed.

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REFERENCES

XUAN BA, N; LANE, P. A; PARSONS, D. Forages improve livelihoods of smallholder farmers with beef cattle in South Central Coastal Vietnam. v. 1, 2013, p. 225–230. Disponivel em: http://www.tropicalgrasslands.info/index.php/tgft/article/view/92.

ALVES, J. de S; PIRES, A. J. V; MATSUMOTO, S, S. N;FIGEUEIREDO, M. P; RIBEIRO, G. S. Características morfológicas e estruturais da brachiaria decumbens stapf . submetida a diferentes doses de nitrogênio e volumes de água. Revista Acta Veterinária Brasílica, v.2, n.1, 2008. p. 1–10. Disponivelem:https://periodicos.ufersa.edu.br/index.php/acta/article/view/599.

CÓSER, A. C. MARTINS, C. E; DERESZ, F; FREITAS, A. F; PACIULLO, D. S. C; ALENCAR, C. A. B de. et al. Produção de forragem e valor nutritivo do capim-elefante, irrigado durante a época seca. n. 1, 2007, p. 1625–1631. Disponivel em: http://www.scielo.br/pdf/pab/v43n11/23.pdf.

GARCIA, C. D. S; FERNANDES, A. M; FONTES, C. A. C. A. de A. et al. Desempenho de novilhos mantidos em pastagens de capim-elefante e capim-mombaça Performance of steers raised on pastures of Elephant and Mombasa grasses. Revista Brasileira de Zootecnia. 2011, p. 403–410. Disponivel em: http://www.scielo.br/pdf/rbz/v40n2/23.pdf.

MOTA, V. J. G; ROCHA JÚNIOR, V. R; REIS, S. T. dos; SALES, E. C. J. de; OLIVEIRA, F. G. de; GOMES, V. M. et al. Lâminas de irrigação e doses de nitrogênio em pastagem de capim-elefante no período chuvoso no norte de Minas Gerais, 2011. p.908–922. Disponivel em: http://revistas.ufba.br/index.php/rbspa/article/view/2361/1160.

MISTURA, C; FONSECA, D. M. da; MOREIRA, L de M. Fangundes, J. L; MORAIS, R. V; QUEIROZ, A. C. de. et al. Efeito da adubação nitrogenada e irrigação sobre a composição químico-bromatológica das lâminas foliares e da planta inteira de capim-elefante sob pastejo. *Revista Brasileira Zootecnia*. v.36 no.6 Viçosa Nov./Dec. 2007. Disponivel em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S151635982007000800002&lng=en.
LOSCH. A. *Physiology*. v. 57, 1996. p. 1–2.

LOPES, W. B; CARVALHO, G. G. P. de; PATÊS, N. M. da S. et al. Dinâmica, produção e qualidade da *Brachiaria brizantha* submetida a regime hídrico e adubação nitrogenada. *Revista Brasileira de Saúde e Produção Animal* [online], v.12, n.1, 2011. p.43-58.

RAMBAU, M. D.; FUSHAI, F.; BALOYI, J. J. Productivity, chemical composition and ruminal degradability of irrigated Napier grass leaves harvested at three stages of maturity. v. 46, n. 4, 2016. Disponivel em: http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S037515892016000400008.

VITOR, C. M. T; FONSECA, D. M da; CÓSER, A. C. et al. Produção de matéria seca e valor nutritivo de pastagem de capim-elefante sob irrigação e adubação nitrogenada, *Revista Brasileira de Zootecnia.* v. 38, n. 3, 2009. p.435-442. Disponivel em: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S151635982009000300006.

WANG, D; POSS, J. A; DONOVAN, T. J; SHANNON, M. C; LESH, S. M. Biophysical properties and biomass production of elephant grass under saline conditions. 2002. p. 447–456.

Disponivel em: https://www.sciencedirect.com/science/article/abs/pii/S0140196302910165?via%3Dihub.

WARAMIT, N; CHAUGOOL, J. Napier grass: a novel energy crop development and the current status in Thailand. J. ISSAAS Int. Sociedade Southeast Asia Agricola, Science. 20, 2014. p. 139-150.Disponivelem:http://agris.fao.org/agrissearch/search.do?recordID=PH2014000950.

VALENCIA-GICA, R. B., YOST, R. S; PORTER, G. Biomass production and nutrient removal by tropical grasses subsurface drip-irrigated with dairy effluent. *Grass and Forage Science*, September 2012, p. 337–349. Disponivel em: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1365-2494.2011.00846.x.