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Water management of mombaça grass (*panicum maximum*) in sandy and loamy soil

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ABSTRACT: The objective of the present study was to assess the influence of irrigation management in the production of Mombaça grass in two distinct types of soil. The experimental material used was the *Panicum maximum* (Jacq.) cv. Mombaça, developed by Embrapa – *Centro Nacional de Pesquisa de Gado de Corte* (National Beef Cattle Research Center). Research took place in arched greenhouse located in the experimental area of the *Escola Superior de Agricultura* "*Luiz de Queiroz*", in Piracicaba-SP - Brasil. Two experiments using different types of soil (sandy and loamy) were conducted using a randomized block design, in a factorial (4x3) arrangement, with four levels of soil water depletion (15%, 30%, 45% and 60%) in three harvests, with four repetitions. The experimental unit consisted of a 21 L pot, with 0.30 m of depth and a surface area of 0.07 m^2. As results it was observed that the water use efficiency increased with the addition of water availability in the Nitosol. The grass showed sensitivity to water deficit, with higher production when irrigated with 30% depletion of available water capacity in both soils.
KEYWORDS: Irrigation; pastures; production; soil texture; water depth.

Manejo hídrico do capim-mombaça (*panicum maximum*) em solo arenoso e argiloso

RESUMO: O objetivo do presente estudo foi avaliar a influência do manejo da irrigação na produção de capim-mombaça em dois tipos distintos de solo. O material experimental utilizado foi o *Panicum maximum* (Jacq.) cv. Mombaça, desenvolvido pela Embrapa - *Centro Nacional de Pesquisa de Gado de Corte*. A pesquisa foi realizada em casa de vegetação em arco localizada na área experimental da Escola Superior de Agricultura "Luiz de Queiroz", em Piracicaba-SP. Dois experimentos utilizando diferentes tipos de solo (arenoso e argiloso) foram conduzidos em delineamento de blocos ao acaso, em arranjo fatorial (4x3), com quatro níveis de depleção de água no solo (15%, 30%, 45% e 60%) colheitas, com quatro repetições. A unidade experimental consistia em um vaso de 21 L, com profundidade de 0,30 m e área superficial de 0,07 m ^{2}. Como resultados observou-se que a eficiência do uso da água aumentou com a adição de disponibilidade de água no Nitossolo. O capim apresentou sensibilidade ao déficit hídrico, com maior produção quando irrigado com 30% de esgotamento da capacidade de água disponível em ambos os solos.
PALAVRAS-CHAVE: Irrigação; pastagens; Produção; textura do solo; profundidade da água.

INTRODUÇÃO

Brazil is the world's largest exporter of beef and has the largest commercial cattle herd in the world (USDA, 2016). Pastures compose the feeding basis of the Brazilian bovine herd, due to low production costs when compared to concentrated feed. As such, much of the meat and milk produced in the country come from herds kept at pasture (DIAS-FILHO, 2014).

Mombaça grass, or *Panicum maximum* Jacq. cv. Mombaça, is one of the most used forage grasses in animal production systems due to its good adaptability to tropical and subtropical climates, its elevated productive capacity and its high quality and nutritious value (SILVA et al., 2009). In Brazil, it is subject to the seasonal production of dry matter, a phenomenon known as production seasonality, with only 10% of its production occurring during the dry period (GOMES et al., 2011).

Production seasonality occurs due to low precipitation during the fall-winter period, and may be associated to temperatures inferior to 15ºC and to low photoperiods (WHITEMAN, 1980). In addition, this may take place in few regions in the country in which periods of water deficiency occur during the summer, known as 'short summers'.

Seasonal water deficiency is a limiting climatic factor for the production of grasses in the tropics that may be mitigated with the use of irrigation (Nabinger, 1996). With irrigation, water ceases to be the most limiting factor regarding fodder growth. Thus, production seasonality tends to decrease, and dry matter production becomes dependent on other factors, such as nutrient availability, aeration of the soil, genetic potential of the plants, solar radiation and temperature (CUNHA et al., 2008).

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Pasture irrigation has not been adequately conducted and, most of the time, excessive water application occurs, leading to environmental damage in the long run and inferior dry matter productivity, which impact on decreased pasture lifespans (ALENCAR et al., 2009).

In order to adequately manage irrigation, it is necessary to correctly determine the amount of water that can be stored in the soil, the available water capacity (AWC). From the total AWC, only a fraction should be used in the attempt to avoid crop losses. Based on this, the concept of readily available water (RAW) for plants emerged. The fraction of AWC that determines RAW is referred to as the depletion factor of water in the soil (f), and varies from 0 to 1, according to the sensitivity of the crops to water deficit (ALLEN et al., 1998). The mentioned authors initially suggested that f = 0.6 for the irrigation of fodder species without water stress. When under crop evapotranspiration conditions above 5 mm d^{-1}, they propose an adjustment of the f value. Works regarding studies on the depletion factor for Mombaça grass were not found in literature.

In face of this, the objective of the present study was to generate information on the irrigation management of Mombaça grass, under the hypothesis that there is an optimum level of soil water depletion, which maximizes the plant's productivity in sandy and loamy soil conditions.

MATERIAL AND METHODS

Plant material

The experimental material used was the *Panicum maximum* (Jacq.) cv. Mombaça, developed by Embrapa – *Centro Nacional de Pesquisa de Gado de Corte* (CNPGC) (National Beef Cattle Research Center) in 1993 (AINFO, 2016). The plant exhibits a perennial cycle and is composed of approximately 13.4% protein. Under ideal conditions, it produces 33 Mg ha^{-1} of dry matter per year and is well adapted to tropical and subtropical climates (GOMES et al., 2011).

Localization, climatic monitoring and experimental design

Research took place in a 6.40 m x 22.50 m arched greenhouse located in the experimental area of the *Escola Superior de Agricultura* "*Luiz de Queiroz*", ESALQ/USP, in Piracicaba-SP – Brasil (22º42'S and 47º38'W) at an altitude of 540 m. Cultivation took place during the period between September 2014 and February 2015. The regional climate is tropical high-altitude (Cwa) according to the Köppen-Geiger classification (PEEL; FINLAYSON; MCMAHON, 2007), with the dry season occurring in the winter, and the average temperature during the coldest month below 18ºC, and in the hottest month, above 22 ºC.

Meteorological monitoring was carried out using a temperature and a relative air humidity sensor (Vaisala, HMP45C-L12), connected to a CR1000 datalogger (Campbell Sci.) that registered and stored data in a 30 minute interval.

Two experiments using different types of soil (sandy and loamy) were conducted using a randomized block design, in a factorial (4x3) arrangement, with four levels of soil water depletion (15%, 30%, 45% and 60%) in three harvests, with four repetitions. The experimental unit consisted of a 21 L pot, with 0.30 m of depth and a surface area of 0.07 m^2.

Physical-hydric characterization of the soils

The pots and their respective experiments were filled with Yellow Red Latosol ("*Sertãozinho*" series), of a sandy loam, and Red Nitosol ("*Luiz de Queiroz*" series), of a clay loam. The chemical characterization of the Latosol consisted in value of: pH = 5.7; P = 30 mg dm^{-3}; $K^{+,}$ Ca^{2+}, Mg^{2+}, H+Al, SB and CTC = 4.2; 29; 11; 20; 44.2 and 64.2 $mmol_c$ dm^{-3}, respectively; and V = 69%. Sand, silt and clay levels were of 710; 91 and 190 g kg^{-1}, respectively. The chemical characterization of the Nitosol consisted in value of: pH = 5.4; P = 4 mg dm^{-3}; $K^{+,}$ Ca^{2+}, Mg^{2+}, H+Al, SB and CTC = 2.8; 20; 7; 28; 29.8; 57.8, respectively; and V = 52%. Sand, silt and clay levels were of 293; 112 and 595 g kg^{-1}, respectively. The soils were collected at the 0-30 cm layer in areas located in the city of Piracicaba-SP. They were sieved in a 4.0 mm mesh, homogenized and air-dried.

According to recommendations by Raij et al. (1996), the Nitosol received 15 g of dolomitic limestone PRNT 100% per plot, in order to elevate base saturation to 70%. Two fertilizations were carried out: the first one during seeding, on 09/10/2014, with 10 g of single superphosphate per plot, only in the Nitosol group; and the second one at 15 DAE (days after emergence) with 5 g of urea and 5 g of potassium chloride per plot of either soil. At 15 DAE, thinning was performed, leaving two plants per plot.

Soil water retention curves were obtained from the Soil Laboratory of the ESALQ/USP Biosystems Engineering Department, using the tension table and Richards Chamber methods. The Latosol exhibited field capacity humidity (Θ_{fc}) of 21% and permanent wilting point humidity (Θ_{pwp}) of 10%, resulting in an 11% available soil water capacity (AWC). The Nitosol exhibited Θ_{fc} of 34% and Θ_{pwp} of 23%, also resulting in an 11% AWC, although in a higher humidity range. Soil density was calculated at 1.42 Mg m^{-3} and 1.12 Mg m^{-3}, respectively, for Latosol and Nitosol. Regarding soil water tension, field capacity was calculated at 10 kPa, and the permanent wilting point, at 1500 kPa.

Water management

Irrigation monitoring was controlled by the gravimetric method, individualized by each treatment, by way of a 10 g precision digital scale. Soil humidity measurements were taken daily. Using the critical humidity readings for each treatment, the necessary water replacement in order to elevate soil humidity to field capacity was calculated (Table 1), and irrigation was performed using a test tube.

The pots were maintained, by way of daily irrigation, with humidity approximate to that of field capacity during 30 days. Following this period, 0.30 m high trimming was carried out in order for plant standardization, and the treatments relative to moment of irrigation commenced.

Table 1. Water depths and volumes applied to the plots, according to the proposed levels of depletion, identical for either type of soil.

Depletion levels	AWC (cm^3cm^{-3})	Depth (mm)	Volume (L)
0.15	0.11	4.95	0.35
0.30	0.11	9.90	0.70
0.45	0.11	14.85	1.05
0.60	0.11	19.80	1.40

Measured variables

Initial harvesting took place on 12/15/2014, followed by a second harvest on 01/15/2015 and a third on 02/27/2025, when the plants reached approximately 1.0 m of height, totaling development periods of 26, 30 and 42 days, respectively.

Dry matter (DM) and fresh matter (FM) of the aerial portion were calculated in the three harvestings. Paper bags containing the gathered plants were put in a forced-air circulation greenhouse, at 65ºC ± 1ºC. The samples were maintained in the greenhouse until they exhibited constant mass, which was determined afterwards using a precision analytical balance.

Watering frequencies (WF) were obtained by counting the intervals between two consecutive irrigations. The total water depth applied per treatment was calculated, based on the number of irrigations performed.

Water use efficiency (WUE) was determined by calculating the ratio between the produced dry matter in each harvest and the amount of water used in that period (PIETERSE et al., 1997). The denominator of Equation 1 represents the total volume of water per plot, utilized by the fodder, in each growth period.

$$\mathrm{WUE} = \frac{\mathrm{MS}}{\mathrm{L}} \qquad (1)$$

WUE – Water use efficiency, kg m^{-3};
DM - Dry mass of the aerial portion produced in the period, kg $plot^{-1}$; and
L – Water volume used during the production period, m^3 $plot^{-1}$.

Data analysis

The variables underwent variance analysis; the water depletion effect on the soil was analyzed statistically by polynomial regression (linear and quadratic) according to its significance by the F Test, using the ASSISTAT statistical program, version 7.6 betas (SILVA; AZEVEDO, 2009).

RESULTS AND DISCUSSION

Within the greenhouse, the maximum registered temperature was of 48.6ºC at 23 days after emergence (DAE) of the plants, and the minimum temperature was of 9.8ºC, at around 10 DAE; the latter is considered critical to the development of the studied fodder species, but since it was of short duration, it possibly did not affect plant growth. The maximum and minimum levels of relative average daily humidity were of 91.3% and 38.8%, respectively. Externally, the maximum registered temperature was of 38.6ºC, and the minimum, of 10.4ºC; the maximum relative average of humidity was of 99.9%, while the minimum was of 50.8%.

The Mombaça grass fresh mass (FM) results, in the three harvestings, according to water depletion in both Latosol and Nitosol, are shown in Figure 1. FM production adjusted satisfactorily to the quadratic polynomial model according to the soil water depletion levels, in the three harvestings, regarding the plants cultivated in Nitosol. The maximum calculated values occurred at the 29.7%; 30.8% and 32.8% levels of soil water depletion, corresponding to 120, 118 and 352 g in the 1st, 2nd and 3rd harvests, respectively.

With regard to the Latosol group, in the first harvest, the reduction of FM production was linear, with maximum and minimum values of 68.8 and 18.6 g, respectively, at 15% and 60% water depletion levels. In the second harvest, the same variation was not significant, probably due to the high variation coefficient of 63%, with an average of 65 g. In the third harvest, the results were quadratic, with maximum production of 210.3 g at 34.7% water depletion (Figure 1).

The reduction in growth, in response to the decrease in soil water, may be attributed to reduced photosynthetic activity, caused by stomata closure (Taiz; Zeiger, 2009). The point of maximum production of fresh mass was at approximately 30% of water depletion in Latosol and 35% in Nitosol. In conditions of higher soil humidity, aeration deficiency may have occurred, causing root hypoxia and, consequently, limiting the development of the plant's aerial portion.

A quadratic variation in DM production was observed following the increment of water stress implemented in both soils, caused by the increase in soil water depletion. The calculated water depletion levels in the Latosol, which promoted maximum production of DM, were 37.0%; 31.1%; and 33.4% in the 1st, 2nd and 3rd harvestings, respectively. In the Nitosol, the levels were 29.0%; 34.2% and 34.0% in the 1st, 2nd and 3rd harvests, respectively (Figure 2).

Figure 1. Fresh mass of the aerial portion of Mombaça grass in three harvestings due to water depletion in Latosol and Nitosol.

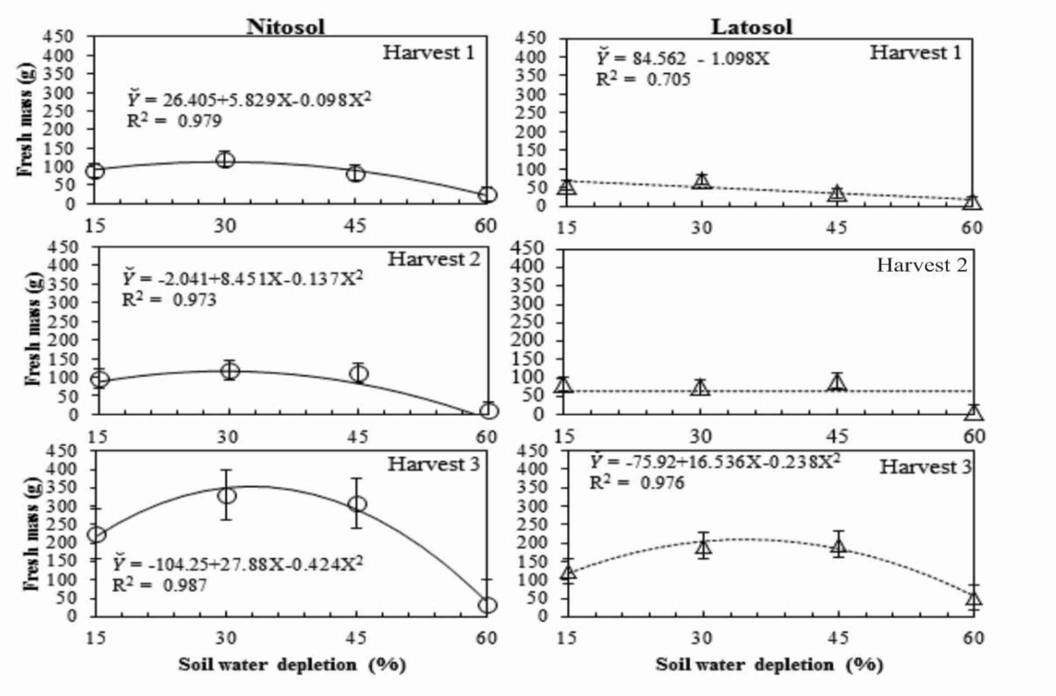
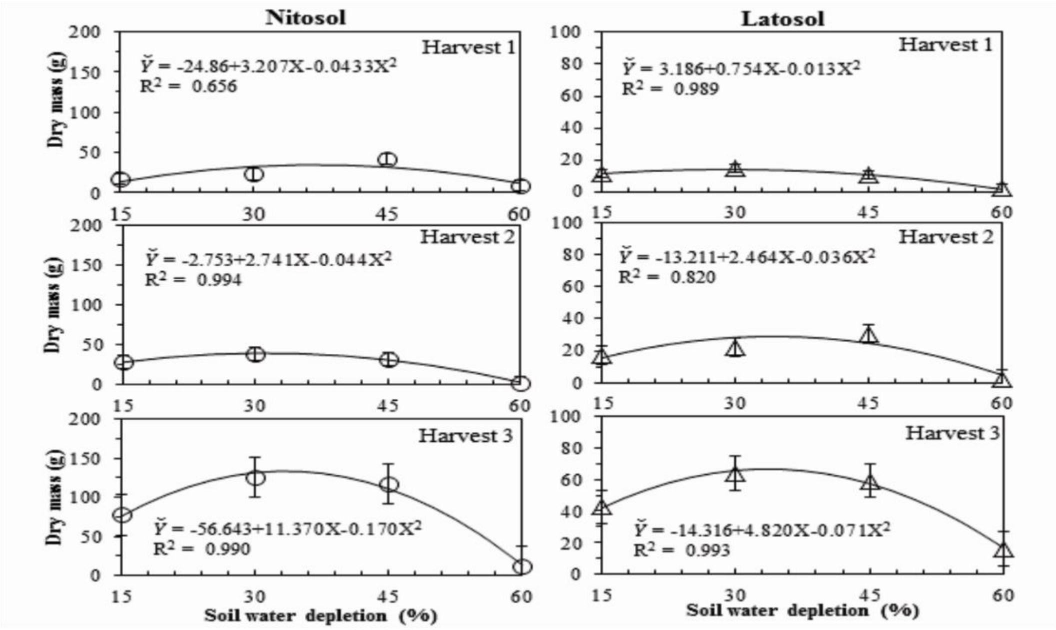


Figure 2. Production of dry mass of the aerial portion of Mombaça grass in three harvestings due to water depletion in Latosol and Nitosol.



The highest DM values were obtained in the third harvest, at an approximate 34% soil water depletion level, corresponding to 133.05 g in the Latosol and 66.48 g in the Nitosol. Extrapolating the DM productions acquired in the plots, the Latosol exhibited productivity of 19 Mg ha^{-1}, and the Nitosol 9.50 Mg ha^{-1} during the average harvest period (approximately 42 days), indicating optimal productivity.

Müller et al. (2002), regarding rotational and irrigated pastures of Mombaça grass in Bahia, obtained dry mass production of 4.96 Mg ha^{-1} in the spring, with an average resting period of 40 days, and of 3.96 Mg ha^{-1} in the winter, with an average resting period of 88 days. According to the mentioned authors, the main limiting climatic variables of forage production were the minimum air temperature and the water availability in the soil.

Under low soil water availability conditions, several metabolic processes of plants may occur, such as stomata closure and reduced photosynthesis and transpiration (PORTES et al., 2006); these phenomena tend to reduce cell elongation and, thus, plant growth, development and production.

The calculated water use efficiency (WUE) values for the four levels of water depletion in both of the studied soils are shown in Table 2. In the Latosol, the depletion levels did not allow the clear observation of WP. On the other hand, regarding the Nitosol, the obtained results suggest higher WP with the increment of soil water availability (f = 0.15). When evaluating the efficiency of the use of water in sugarcane farming, cultivated in Yellow Argisol and submitted to dry farming and irrigation in Pernambuco, Oliveira et al. (2011) also observed an increment in WP with the use of irrigation.

Table 2. Water productivity regarding dry matter of Mombaça grass due to water depletion in Latosol and Nitosol.

Soil water depletion (%)	Total WUE (kg m^{-3})			
	1st Harvest	2nd Harvest	3rd Harvest	Total
	Latosol			
60	2.04	1.80	5.64	9.48
45	5.16	2.26	5.92	13.34
30	1.82	2.09	5.50	9.41
15	2.65	2.92	6.25	11.82
	Nitosol			
60	1.86	0.88	2.73	5.47
45	2.65	1.88	1.57	6.10
30	3.55	1.20	3.77	8.52
15	1.81	2.41	5.20	9.42

A different result was obtained by Cunha et al. (2008), which, while studying three levels of irrigation (50%, 75% and 100% of AWC) of Tanzania grass, cultivated in Yellow Red Latosol, observed that the 50% irrigation level showed greater WUE when compared to the other irrigation levels. In other words, the higher the water availability, the lower the WUE of the grass. Similar behavior to that observed by these authors was described by Lourenço (2004), who registered WUE values of 2.9; 2.7 and 2.1 kg m^{-3} in irrigation depth treatments of 50%, 75% and 100% of the crop's evapotranspiration, respectively, in Tanzania grass fertilized with 110 kg ha^{-1} $harvest^{-1}$ of N.

The watering frequencies and depths applied according to the treatments are shown in Table 3. It can be noted that, during the third harvesting period, the frequencies were generally lower than in the first period. This may be due to the elevated temperatures registered within the greenhouse; and the improved development of the plants, due to the longer interval between harvests.

Table 3. Applied watering depths and frequencies due to water depletion in Latosol and Nitosol during the three harvests, and the total.

SWD (%)	Water depth (mm) and Watering frequency [ ] (days)			
	1st Harvest	2nd Harvest	3rd Harvest	Total
	Latosol			
60	59.4 [8.67]	39.6 [15.5]	59.4 [12.0]	158.4 [12.06]
45	118.8 [3.25]	282.1 [1.62]	326.7 [1.63]	727.6 [2.17]
30	178.2 [1.45]	207.9 [1.47]	306.9 [1.16]	693.0 [1.36]
15	89.1 [1.45]	148.5 [1.04]	163.3 [1.10]	400.9 [1.20]
	Nitosol			
60	19.8 [26.0]	118.8 [5.17]	178.2 [4.0]	316.8 [11.7]
45	59.4 [6.50]	297.0 [1.55]	326.7 [1.41]	683.1 [3.15]
30	59.4 [4.34]	198.0 [1.55]	287.1 [1.24]	544.5 [2.38]
15	89.1 [1.45]	99.0 [1.55]	163.3 [1.10]	351.4 [1.37]

SWD= Soil water depletion

Regarding both soils, the total water depth applied showed an increase from the 15% to the 45% depletion, and a decrease from the 45% to the 60% depletion. This behavior closely corroborates with the obtained dry mass results. During the third harvest, regarding the Latosol, the maximum calculated water depth was of 344.5 mm, corresponding to 35.37% soil water depletion; while in the Nitosol, the maximum calculated depth was of 324.2 mm, related to 38.43% depletion.

Allen et al. (1998) initially suggest that f = 0.6 for the irrigation of forage species without water stress. Under conditions of crop evapotranspiration (ETc) greater than 5 mm d^{-1}, the authors recommend an adjustment of the "f" value as follows: f = 0.6 + 0.04 (5 – ETc). Considering the cycle of the last interval as being equivalent to 42 days, the average daily evapotranspiration was of 8.20 mm d^{-1} and 7.72 mm d^{-1}, respectively, for the Latosol and the Nitosol. Therefore, according to Allen et al. (1998), the maximum suggested depletion levels for the referred demands would be of 0.47 and 0.49 for Latosol and Nitosol, respectively. In the present study, the maximum productions of FM and DM were obtained with "f" close to 0.30, and when the depletions were greater, production reduced. In conclusion, Mombaça grass exhibited sensitivity to water deficit, when compared to other fodder species, responding better to frequent watering.

CONCLUSIONS

Mombaça grass exhibited sensitivity to water deficit. The level of approximately 30% of soil water depletion provided greater dry mass production in both types of soil. The efficiency in water use increased with the water availability in the Nitosol.

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REFERENCES

AINFO – Sistema de Gestão do Acervo Documental e Digital da Embrapa. 2016.

ALENCAR, C. A. B. DE; CUNHA, F. F. DA; MARTINS, C. E; CÓSER, A. C.; ROCHA, W. S. D. DA; ARAÚJO, R. A. S. Irrigação de pastagem: atualidade e recomendações para uso e manejo. **Revista Brasileira de Zootecnia**, Viçosa, v. 38, p. 98-108, 2009.

ALLEN, R. G.; PEREIRA, L. S.; RAES, D.; SMITH, M. **Crop evapotranspiration**: Guidelines for computing crop water requirements. Rome: FAO, 1998. 300 p. (Irrigation and Drainage Paper, 56).

CUNHA, F. F.; SOARES, A. A.; MANTOVANI, C. E.; SEDIYAMA, C. G.; PEREIRA, O. G.; ABREU, F. V. de S. .Produtividade do capim tanzânia em diferentes níveis e frequências de irrigação. **Acta scientiarum Agronomy**, Maringá, v. 30, n. 1, p. 103-108, 2008

Dias-Filho, M. B. **Diagnóstico das pastagens no Brasil**. Belém-PA: Embrapa Amazônia Oriental, 36 p. 2014

GOMES, R. A.; LEMPP, B.; JANK L.; CARPEJANI, G. C.; MORAIS, M. G. Características anatômicas e morfofisiológicas de lâminas foliares de genótipos de *Panicum maximum*. **Pesquisa Agropecuária Brasileira**, Brasília, v. 46, n. 2, p. 205-211, 2011

LOURENÇO, L. F. **Avaliação da produção de capim-tanzânia em ambiente protegido sob disponibilidade variável de água e nitrogênio no solo**. Piracicaba: ESALQ, 2004. 77p.

MÜLLER, M. S.; FANCELLI, A. L.; DOURADO-NETO, D.; GARCIA A.; OVEJERO, R. F. L.. Produtividade do *Panicum maximum* cv. Mombaça irrigado, sob pastejo rotacionado. **Scientia Agricola**, Piracicaba, v. 59, n. 3, p. 427-433, 2002

NABINGER, C. Princípios da exploração intensiva de pastagens. In: PEIXOTO, A.M.; MOURA, J.C.; FARIA, V.P. (Eds.) Produção de bovinos a pasto. In: SIMPÓSIO SOBRE MANEJO DA PASTAGEM, 13., Anais... Piracicaba: Fundação de Estudos Agrários "Luiz de Queiroz" (FEALQ) p. 15-96. 1996

OLIVEIRA, E. C. A. DE; FREIRE, F. J.; OLIVEIRA, A. C. DE; NETO, D. E. S.; ROCHA, A. T. DA; CARVALHO, L. A. Produtividade, eficiência de uso da água e qualidade tecnológica de cana-de-açúcar submetida a diferentes regimes hídricos. **Pesquisa Agropecuária Brasileira**, Brasília, v. 46, n. 6, p. 617-625, 2011

PEEL, M. C.; FINLAYSON, B. L.; MCMAHON, T. A. Updated world map of the Köppen-Geiger climate classification. **Hydrology and Earth System Sciences Discussions**, v. 4, n. 2, p. 439-473, 2007.

PIETERSE, P. A.; RETHMAN, N. F. G.; VAN BOCH, J. Production, water use efficiency and quality of four cultivars of *Panicum maximum* Jacq. at different levels of nitrogen fertilization. **Tropical Grassland**, Brisbane, v. 31, n. 2, p. 117-123, 1997.

PORTES, M. T.; ALVES, T. H.; SOUZA, G. M.. Water deficit affects photosynthetic induction in *Bauhinia forficata* Link (Fabaceae) and *Esenbeckia leiocarpa* Engl. (Rutaceae) growing in understory and gap conditions. **Brazilian Journal of Plant Physiology**, Campos dos Goytacazes, v. 18, n. 4, p. 491-502, 2006

RAIJ, B. VAN; CANTARELLA, H.; QUAGGIO, J. A.; FURLANI, A. M. C. **Recomendações de adubação e calagem para o Estado de São Paulo**. Campinas: IAC. 285 p. (Technical Bulletin 100). 1996

RICHARDS, L. A. Physical conditions of water in soil. In: Black, C. A. (ed.) **Methods of soil analysis**. Madison: American Society of Agronomy. p.128-152. Agronomy 9, Part 1. 1965

SILVA, A. G; FRANÇA, A. F. S.; MIYAGI, E. S.; MELLO, S. Q. S.; FERREIRA, J. L.; CARVALHO, E. R. Frações proteicas do capim-mombaça submetido a doses de nitrogênio em duas alturas de corte. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, Belo Horizonte, v. 61, n. 5, p. 1148-1155, 2009

SILVA, F. DE A. S.; AZEVEDO, C. A. V. Principal Components Analysis in the Software Assistat-Statistical Attendance. In: WORLD CONGRESS ON COMPUTERS IN AGRICULTURE, 7, Reno-NV-USA: American Society of Agricultural and Biological Engineers, p. 393-396. 2009

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 4 ed. São Paulo: Artmed, 2009. 820p.

USDA. USDA Foreign Agricultural Service. 2016. Available at: <http://apps.fas.usda> Accessed in: August/2016.

WHITHEMAN, P.C. **Tropical Pasture Science**. New York: Oxford University Press, 392p. 1980.