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MOMENTO DE IRRIGAR A GRAMA BATATAIS UTILIZANDO ÍNDICES DE ESTRESSE HÍDRICO

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1 RESUMO

O objetivo deste trabalho foi estudar o Índice de Estresse Hídrico Diário (IEH) da grama batatais para estabelecer um valor que determine o momento ideal para a irrigação. Foram avaliados dados meteorológicos do ambiente, índice de estresse hídrico da planta com o uso do termômetro digital infravermelho e potencial de água no solo. A pesquisa foi desenvolvida em área experimental do Departamento de Engenharia e Ciências Exatas da FCAV/UNESP-Câmpus de Jaboticabal, no período de inverno de 2019. Foi instalado um experimento contendo três tratamentos: T1 - sem irrigação, T2 - Irrigação efetuada de acordo com a soma da evapotranspiração da cultura e irrigada quando a reserva utilizável do solo atingiu o valor de 50% e T3 - irrigação efetuada de acordo com a soma da evapotranspiração da cultura mantendo o solo sempre na capacidade de campo. Foram efetuadas 16 leituras em cada tratamento, por meio da medição da temperatura da cobertura vegetal e da temperatura do ar, realizadas próximo ao meio-dia solar, com a utilização de termômetro infravermelho. As análises foram realizadas in loco. De acordo com os resultados encontrados, o valor médio do índice de Estresse Hídrico é de 8,8°C, para irrigar o tratamento T2.

Palavras-chave: manejo de água e solo; radiação solar; grama.

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THE TIME TO IRRIGATE A BATATAL GRASS USING WATER STRESS DAILY INDEX

2 ABSTRACT

With this study, the objective was to study the Water Stress Daily Index (WSDI) of batatal grass to establish a value that determines the ideal time for irrigation. They were evaluated environmental weather data, water stress index plants using an infrared thermometer, and water potential in the soil. The research was conducted in the experimental area of the Department of

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Engineering and Mathematical Sciences FCAV/UNESP Jaboticabal Campus, in the winter period of 2019. An experiment was installed containing two treatments: T1 - without irrigation, T2 - irrigation performed according to the sum of the culture evaporation and irrigated when the available water capacity of the soil reached 50%, and T3 - irrigation performed according to the sum of the culture evaporation keeping the soil always at field capacity. They were made 16 readings for each treatment by measuring the temperature of the vegetation cover and air temperature, held near solar noon, with the use of an infrared thermometer. The analysis was performed on the spot. According to the results, the average value of the WSDI is 8.8°C, to irrigate the T2 treatment.

Keywords: management of water and soil, solar radiation, grass.

3 INTRODUCTION

Grass production is highly important and has drawn attention for its use in large quantities in green areas, gardens, and sports fields (ALDRIGHI *et al*., 2020) . Brazil has approximately 75% of the known Paspalum species, including batatais grass (P. *notatum* Flugge) (PILLAR *et al*., 2009). It is widely used because it lasts for several years, is hardy, tolerant to winter and trampling, and can adapt to degraded soils (KISSMANN; GROTH, 1997). Forquilha grass (Paspalum *notatum*) is used to produce quality forage (SILVA; SILVA; OLIVEIRA, 2021).

For grass to thrive, it is important that irrigation be carried out efficiently, with a focus on optimizing water resources. In the specific case of grass irrigation, the use of water resources has been carried out without any scientific basis. (COAN *et al*., 2012).

Irrigation during the dry season is important for lawns to remain vigorous throughout the year. Owing to ongoing water use restrictions, it is necessary to optimize water use for lawn irrigation (ALDRIGHI *et al*., 2020) .

Good irrigation management provides plants with sufficient water to improve productivity and crop quality while minimizing water waste, nutrient leaching, and environmental degradation. Water should be applied in quantities that can be stored in the soil in the root zone layer to meet plant demand (SOUZA *et al*., 2011).

Controlled deficit irrigation is a strategy in which the irrigation depth is applied during the development period when the crop is least sensitive to water deficit. This alternative does not affect crop development and results in maximized water use efficiency (ALENCAR *et al*., 2009).

Irrigation management seeks to meet crop needs with the right measure. According to Gomes (2005), there are methods for defining irrigation management, the most commonly used of which are those based on soil or climate data. Plant water conditions can be determined by physiological measurements, such as leaf temperature (KIRKHAM, 2014).

The temperature difference between the plant canopy and the air is an indicator of the water status of crops such as corn, soybeans, wheat and cotton (LEBOURGEOIS *et al*., 2010). The infrared thermometer is used in studies of water relationships in the soil–plant–atmosphere system (MARAFON, 2012).

The use of water stress indices in crop development phases can act as an essential tool in irrigation management (TURCO; VIEIRA, 2021), preventing negative effects on plant development (BRUNINI; TURCO, 2018) .

Given the above, the objective of this work was to determine the water stress index for Gram-Bertani grass. Paspalum *notatum* Flüggé) by analyzing the crop canopy temperature and air temperature to determine when to irrigate the lawn under induced water deficit conditions.

4 MATERIALS AND METHODS

The research was conducted during the winter of 2019 at the experimental site of the Department of Engineering and Exact Sciences at UNESP/FCAV, Jaboticabal Campus, São Paulo. The site is located at an altitude of 575 m at the geographic coordinates 21°15'22" South and 48°18'58" West. The region's climate, according to the Köppem classification, is Cwa (subtropical). In this climate, summer is at least ten times rainier than winter, which is dry.

The treatments were designated as follows: T1 - no irrigation; T2 - irrigation carried out according to the sum of crop evapotranspiration and irrigated when the usable soil reserve reached 50%; and T3 - irrigation carried out according to the sum of crop evapotranspiration and always maintaining the soil at field capacity. For each treatment, four blocks were used, 4 m × 4 m, and each block had four replicates of 2 m × 2 m. At the end of each period, the leaf height from the thatch (transition area of the soil and partly above ground) was measured in the center of each replicate with a ruler graduating in cm.

Meteorological data for the entire experimental period were obtained from a Davis Instruments automatic meteorological station. The station is equipped with a data acquisition system (Vantage Pro Plus Wireless), which includes global solar radiation measurements via a sensor (Standard - model 6450), temperature and relative humidity (external sensor - model 7859), wind speed (Standard anemometer - model 7911), and rainfall (rain gauge - model 7852, Rain Collector). The solar radiation, air temperature, relative humidity and rainfall sensors were placed 1.5 m above the grass surface, and the wind speed sensors were placed 2 m above the grass surface.

Drip irrigation was carried out via 24 m long hoses (80 cm spacing) with drippers every 20 cm along their entire length. The system had a flow rate of 90 L h $^{-1}$.

The amount of water applied in treatments 2 and 3 was a function of the evapotranspiration (ET) value, which was obtained via the Penman–Monteith method (ALLEN *et al*., 2006) , Equation (1).

$$ EToPM = \frac{0{,}409\,\Delta\left(Rn - G\right) + \gamma\left(\dfrac{900}{T+273}\right)V\left(e_s - e\right)}{\Delta + \gamma\left(1 + 0{,}34V\right)} \qquad (1) $$

In which,
EToPM - reference evapotranspiration, in lawn, mm d $^{-1}$;
Rn - net radiation, MJ m $^{-2}$ d $^{-1}$;
G - soil heat flux, MJ m $^{-2}$ d $^{-1}$;
T - average air temperature, °C;
V - average wind speed at 2 m height, ms $^{-1}$;
(e_s - e) - vapor pressure deficit, kPa;
Δ- vapor pressure curve, kPa °C $^{-1}$;
γ - psychrometric constant, kPa °C $^{-1}$;
900 - conversion factor.

In treatment 2, irrigation was carried out when the soil's available water capacity, which is the usable reserve in mm, reached 50% (BRUNINI; TURCO, 2018) . In treatment 3, irrigation was carried out when the soil moisture reached the field capacity value (θ_{cc}), and the soil was maintained at approximately 25% moisture (FARIA *et al*., 2012).

Soil-based management allows us to characterize soil water storage. Soil water storage has upper and lower limits, called the field capacity and permanent wilting point, respectively. The ideal limit between field capacity and the permanent wilting point depends on several factors, including the crop, the irrigation system, and the management strategy adopted. This limit is called the water availability factor (f) or safety factor, whose proportion is defined according to the economic value and sensitivity of the crop to water deficit. An "f" factor of 0.4 means that plants can consume up to 40% of all available soil water without significantly reducing their productivity (ALENCAR *et al*., 2009). In this study, an f factor of 0.5 was adopted for Treatment 2. According to Alencar *et al*. (2009), batatais grass can consume up to 50% of all available soil water without affecting its development.

To determine when to irrigate treatments 2 and 3, a tensiometer (vacuum gauge) was installed in each block at a depth of 0.10 m, with the purpose of monitoring the behavior of the soil water matrix potential (critical soil moisture) (FARIA *et al*., 2012). The equation for determining the soil water matrix potential is given by Equation 2:

$$\Psi m = -12{,}6\,h + h_1 + h_2 \qquad (2)$$

where:
Ψ_m - soil water matric potential (cmca);
h - height of the mercury column (cm);
h_1 - height of the mercury tank in relation to the ground surface (cm);
h_2 - tensiometer installation depth (cm).

For a depth of 0.10 m, the soil water matric potential was converted into moisture via the mathematical model of the soil water retention curve presented by Van Genuchten (1980), Equation 3, considering that for field capacity moisture (θ_{cc}), the soil water tension is 103.32 cmH2O, and the current moisture (θ_A) is obtained daily with water tension from tensiometer readings.

$$\theta_A = \theta_r + \frac{(\theta_s - \theta_r)}{[1+(\alpha * |\psi_m|)^n]^m} \qquad (3)$$

where:
Θ_A - current humidity (cm $^{-3}$ cm $^{-3}$);
Θ_r - residual moisture (cm $^{-3}$ cm $^{-3}$);
Θ_S - saturated soil moisture (cm $^{-3}$ cm $^{-3}$);
Ψ_m - soil water matric potential (cmca);
α, n and *m* - adjustment coefficients generated by the van Genuchten model (1980).

Table 1 shows the values of the physical–hydraulic characteristics of the soil at the location where the experiment was conducted and the values of the empirical constants used in Equation 3.

Table 1. Physical-hydric characteristics of the soil at the site where the experiment took place and values of the empirical constants used in the van Genuchten equation (1980).

P (m)	θ_{CC} (cm ^{3} cm $^{-3}$)	θ_{PMP} (cm ^{3} cm $^{-3}$)	*Ds* (g cm $^{-3}$)	*n*	*α*		θ_S (cm ^{3} cm $^{-3}$)	θ_r (cm ^{3} cm $^{-3}$)
0.1	0.3799	0.297	1.13	12.7127	0.1383	0.0178	0.539	0.297

P = depth. θcc - soil moisture at field capacity; θ_{PMP} - soil moisture at the permanent wilting point; *Ds* - soil bulk density; θs - saturated soil moisture; θr - residual soil moisture; *α*, *n* and *m* - adjustment coefficients generated by the model (Van Genuchten, 1980).

The available soil water capacity (*CAD*), readily available soil water (*AFD*) and available soil water reserve (RAD_f) were also calculated via the following equations:

$$CAD(mm) = (\theta_{CC} - \theta_{PMP}) * Z \qquad (4)$$

$$AFD(mm) = 0{,}5 * CAD \qquad (5)$$

$$RAD_f(mm) = (CAD - AFD) \qquad (6)$$

where:
θ_{CC} - soil moisture at field capacity (potential of 103.32 cm H_2O), cm^3 cm^{-3};
θ_{PMP} - soil moisture at wilting point (matric potential of 15498.41 cm H_2O), cm^3 cm^{-3};
Z - effective depth of the root system of the batatais grass (0.10 m).

To evaluate the daily water stress index (DSI) of potato grass in treatments T1, T2, and T3 , daily measurements were taken close to solar noon, with one reading for each replicate. This measurement simultaneously measured the temperature of the vegetation cover and the ambient air temperature via a portable digital infrared thermometer, FLUKE, model 62 MAX+, and a mercury thermometer (accuracy ± 0.1°C), respectively. On days of precipitation, strong winds, and/or cloudy weather intercepting the flow of direct solar radiation, readings were avoided, according to the limitations of the device and the methodology.

The IEH calculation was performed via the difference between the average temperature of the vegetation cover (T_s in °C) and the air temperature (T_a in °C), as proposed by Idso, Jackson and Reginato (1977) and Jackson, Reginato and Idso (1977):

$$IEHC = T_s - T_a \quad (7)$$

where:
IEH - daily water stress index (°C);
T_s - average temperature of vegetation cover (°C);
T_a - average air temperature (°C).

The mean IEH data were subjected to analysis of variance via the F test followed by the application of the Tukey test (p <0.05).

5 RESULTS AND DISCUSSION

Table 2 shows the Tukey test of means for the leaf height variable (cm). Leaf height differed significantly between the periods of 170--180, 198--206, 208--216 and 221--227 (Julian day) for the T1, T2 and T3 treatments. During the period 184--194, there was no difference in leaf height between T2 and T3, which differed from that in the T1 treatment.

During the research period, the average leaf heights of the grass from the thatch (soil transition area and part of the area) of the T1, T2 and T3 treatments were 5.1 cm, 5.8 cm and 6.3 cm, respectively (Table 2). During this period, the grass initially grew at a slow pace, and in winter, the grass entered vegetative dormancy, saving energy to withstand the cold days, which caused the grass to show almost no growth.

Table 2. Analysis of variance (mean squares) and means of leaf heights (cm) in treatments T1, T2 and T3 during the study period.

Julian Day	IEHC		
FOOT	T1	T2	T3
170 to 180 *	3.8 c	4.0 b	4.3 a
184 to 194**	4.9 b	5.4 a	5.7 to
198 to 206***	5.8 c	6.3 b	6.9 a
208 to 216****	5.8 c	6.5 b	7.2 a
221 to 227*****	5.4 c	6.6 b	7.4 a

PE = periods studied. Averages followed by the same letters do not differ from each other, according to the Tukey test (P < 0.05). * CV = 5.2%. ** CV = 5.3%. *** CV = 5.1%. **** CV = 5.2%. ***** CV = 5.3%.

T3 presented the lowest average value of the daily water stress index (5.8°C) compared with the other treatments during the analyzed period, indicating that the irrigation regime without induced water deficit conditions presented a lower IEH for the batatais grass than did Treatment 2, but under an induced water deficit regime , the average IEH was 8.8°C. Treatment T1 presented the highest IEH value (13.7°C) for potato grass under a water deficit regime, due to being in the rainfed area (Figure 1).

With the decrease in leaf transpiration, there is an increase in canopy temperature due to the greater concentration of energy in the form of sensible heat. Thus, the leaf temperature becomes higher than the air temperature (BRUNINI; TURCO, 2016), thus explaining the behavior of the water stress index, which varies between 8.8 and 5.8°C for treatments T2 and T3.

Figure 1. Water stress index (WSI).

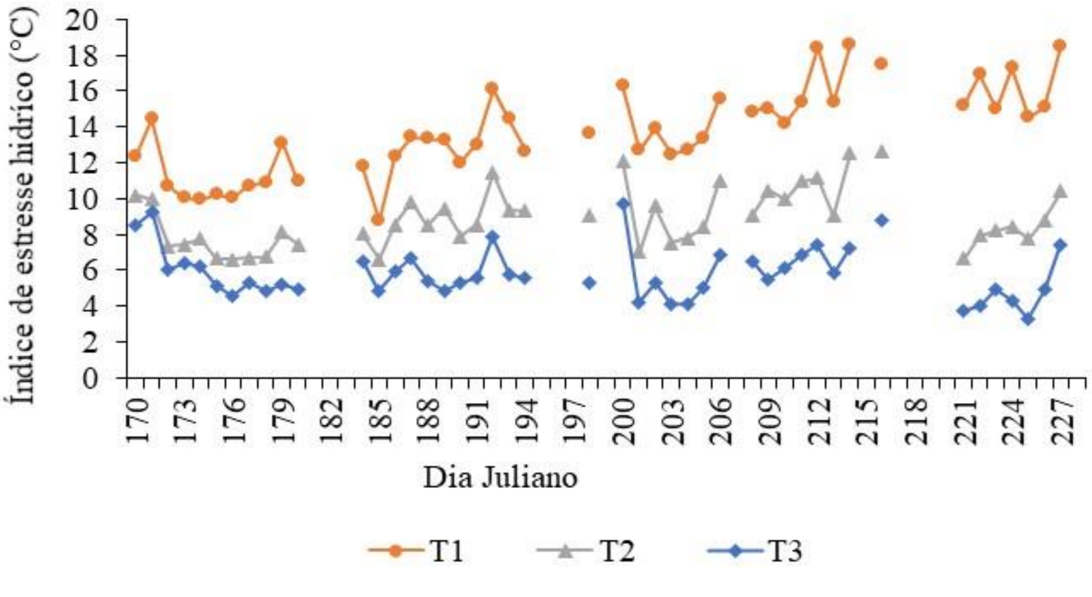


Table 3 shows the average water stress indices for the periods studied in the treatments. T1 , T2 and T3. The T1 treatment presented the highest average water stress index, followed by the T2 and T3 treatments. The index used to determine crop water deficit is the crop water stress index (CWI). The CWI is estimated from the difference between canopy temperature (T_s) and air temperature (T_a) (IDSO; JACKSON; REGINATO, 1977; JACKSON; REGINATO; IDSO, 1977).

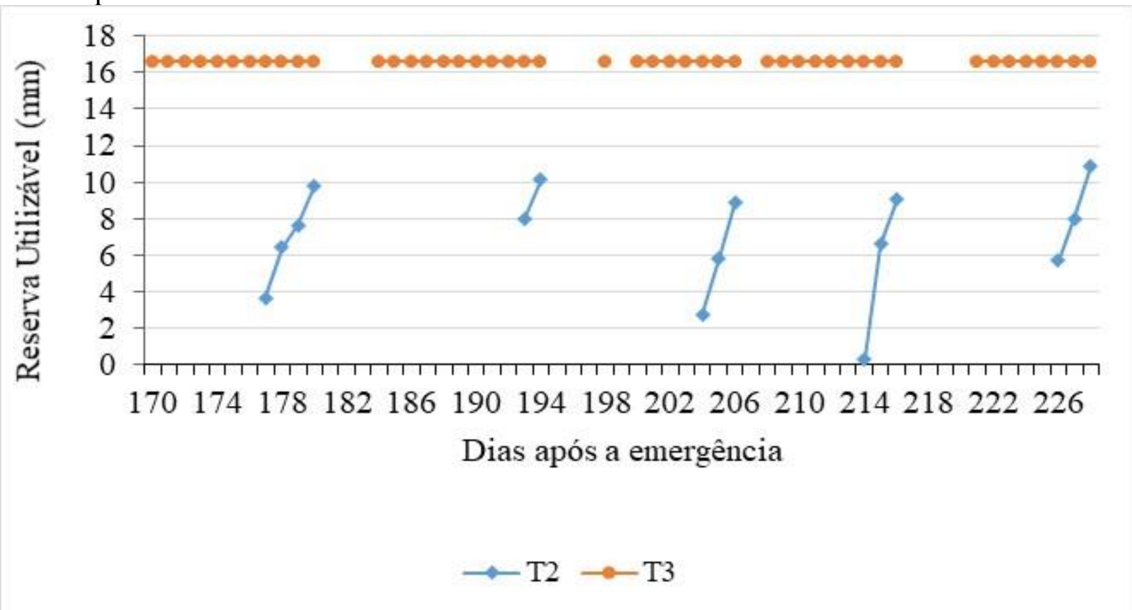
Table 3. Analysis of variance (mean squares) and means of water stress indices (IEHC) (°C) in treatments T1, T2 and T3 during the periods studied.

Julian Day	**IEHC**		
FOOT	T1	T2	T3
170 to 180 *	11.2 a	7.7 b	6.0 c
184 to 194**	12.8 a	8.9 b	5.9 c
198 to 206***	13.9 a	9.1 b	5.6 c
208 to 216****	16.2 a	10.7 b	6.8 c
221 to 227*****	15.7 to	8.3 b	4.7 c

PE = periods studied. Averages followed by the same letters do not differ from each other, according to the Tukey test ($P < 0.05$). * CV = 5.2%. ** CV = 7.7%. *** CV = 6.1%. **** CV = 5.5%. ***** CV = 6.6%.

The usable soil water reserve in the monitored layer from 0 to 0.10 m corresponds to 16.58 mm. By observing the data in Figure 2, one can follow the behavior of soil water during periods of induced water deficit, which corresponds to 50% of the usable reserve, for treatment T2 in the studied periods. On the basis of the average water stress indices for treatment T2 presented in Table 3 and the average values of available soil water in Figure 2, the ideal time to irrigate is when the average water stress indices reach 8.8°C. The results obtained in Treatment 2 agreed with those of Alencar *et al*. (2009) reported that controlled deficit irrigation does not affect crop development and results in maximized water use efficiency .

Figure 2. Average values of water available in the soil up to 0.10 m deep during the study period for treatments T2 and T3.

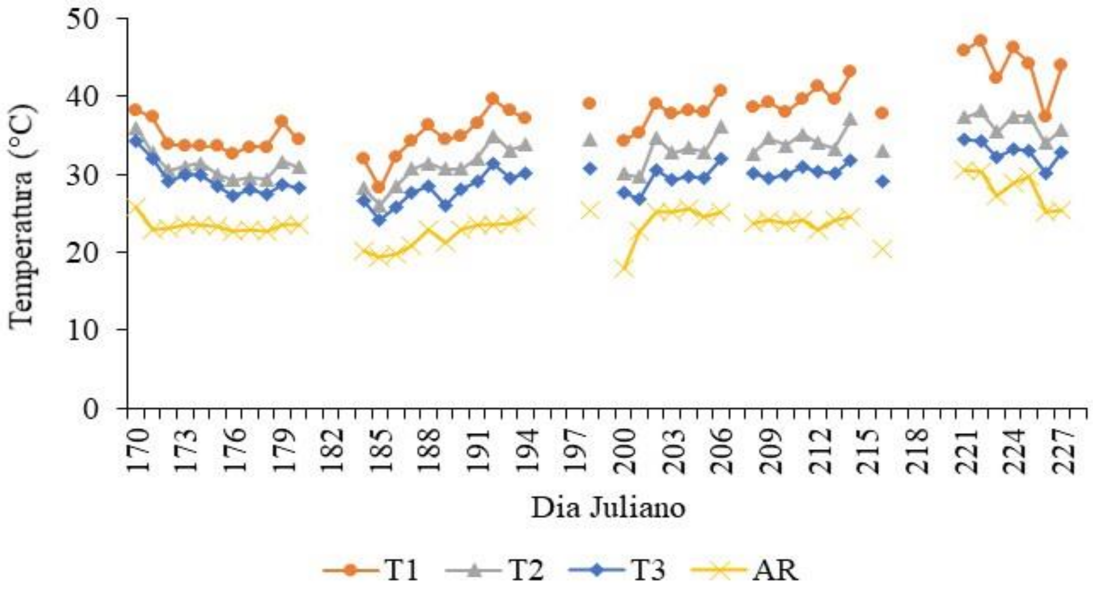


Compared with the average air temperature (23.9°C), Treatment 1 resulted in a higher average canopy temperature (37.5°C), which can be attributed to Batatais grass being in a water deficit condition, that is, in the rainfed area. Treatments 2 and 3 presented average canopy temperature values of 32.7°C and 29.7°C, respectively (Figure 3).

The results obtained in this study corroborate those of Lebourgeois *et al.* (2010), who reported that the lower the plant canopy temperature is relative to the air temperature, the lower the water deficit. Canopy temperature is one of the best indicators of plant health and has been successfully used for irrigation management. Continuous monitoring of canopy temperature via infrared sensors can provide real-time information on crop water status (ZONTA *et al*., 2018).

The crop canopy temperature can be obtained via infrared thermography. According to Mendonça (2005), objects on the Earth's surface emit infrared radiation, which depends on the object's temperature and radiation-emitting capacity, known as emissivity. Infrared thermography allows the temperature of plant leaf surfaces to be obtained through the infrared radiation emitted by the plant.

Figure 3. Vegetative canopy temperature and air temperature, in °C.



6 CONCLUSIONS

The time to irrigate Batatais grass is when the average water stress index values reach 8.8°C , with the grass at approximately 50% of its available water capacity. This alternative does not affect the growth of Batatais grass, maximizing water use efficiency.

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