COEFFICIENT OF CULTURE (Kc) OF *Urochloa brizantha* cv. MARANDU IN TWO PRODUCTIVE SYSTEM

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ABSTRACT: The use of crop coefficient (Kc) take management irrigation efficient, its represent the water consumption of the plants. However, as for fodder plants, this knowledge is not well-founded**.** Because of this, this study aims to determine the water consumption of *Urochloa brizantha* cv. Marandu in single crop and black oats and Italian ryegrass in over-seeded cultivation, by means of weighing lysimeters. The experiment was carried out at the ESALQ/USP, both lysimeters were used throughout the experimental period (February to October 2016), one with exclusive culture and the other with overestimation in the month of May. The crop evapotranspiration (ETc) was calculated with the means of the weighting lysimeter variation and the reference evapotranspiration (ETo) determined by Penman-Monteith with data by meteorological stations present at the ESALQ/USP. Were determined Kc values every four days. There was differences between productive system. Water productivity in the fall/winter period was higher in consortium. Kc values varied between 0,30 and 1,24 (single crop in the summer), between 0,24 and 1,14 (single crop in winter) and between 0,33 and 1 (consortium).

KEYWORDS: Water consumption; over-seeded cultivation; evapotranspiration.

ESTIMATIVA DO COEFICIENTE DE CULTURA (Kc) DE *Urochloa brizantha* cv. MARANDU EM DOIS SISTEMAS PRODUTIVOS

RESUMO: A utilização do coeficiente de cultura (Kc) torna o manejo da irrigação facilitado e eficiente, por o mesmo representar o consumo de água de uma determinada espécie vegetal cultivável. No caso de plantas forrageiras, esse conhecimento ainda não está bem fundamentado. Por isso, objetivou-se determinar o consumo de água de *Urochloa brizantha* cv. Marandu em cultivo solteiro e consorciado com aveia preta e azevém, por meio de dois

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lisímetros de pesagem. Realizado na ESALQ/USP durante o período experimental de fevereiro a outubro de 2016, um dos lisímetros permaneceu com cultivo exclusivo e o outro recebeu sobressemeadura no mês de maio. A evapotranspiração de cultura (ETc) foi calculada com a variação de peso dos lisímetros e a evapotranspiração de referência (ETo) baseando em Penman-Monteith com dados de estações meteorológicas presentes no local. Foram gerados valores de Kc a cada 4 dias. Diferenças significativas foram observadas entre o cultivo solteiro e o sobressemeado. A produtividade da água no período outono/inverno foi maior no cultivo. Os valores de Kc variaram entre 0,30 e 1,24 (cultivo solteiro no verão), entre 0,24 e 1,14 (cultivo solteiro no inverno) e entre 0,33 e 1 (cultivo consorciado).

PALAVRAS-CHAVES: Consumo de água; sobressemeadura, evapotranspiração.

INTRODUCTION

Plants require water for maintenance of physiological processes, the water consumed is influenced primarily by the morphophysiological characteristics of the species (growing time and leaf area), amount of water the soil and atmospheric evaporative demand (ARTUR; GARCEZ; MONTEIRO, 2014).

A correct and accurate determination of water flux at the soil-plant-atmosphere interface is of fundamental interest for water management and for scientific research (SCHRADER et al., 2013). The monitoring of soil water changes, associated to the observation of the variation of the climatic elements, makes it possible to know and quantify the components of the water balance and to estimate the effective crop evapotranspiration, thus resulting in crop coefficients (Kc) (DE SOUZA et al., 2011).

The crop evapotranspiration (ETc) can be determined over short periods with electronic load cell systems, which, currently are used in almost all weighing lysimeters (ALLEN et al., 2011). Lot of research have demonstrated their efficiency in the determination of evapotranspiration, among them: De Souza, De Lima, Carvalho (2012); De Souza et al. (2011); Flumignan et al. (2012); Lena, Flumignan, de Faria (2011); Lena et al. (2016); Mariano et al. (2015); Nascimento et al. (2011); Silva, Folegatti, Villa Nova (2005).

There are few studies on Kc determination for tropical forages. Some papers were found, the *Panicum maximum*, cv. Tanzânia, Lourenço et al., (2001) Kc ranging from 0,35 in the initial phase to 1,25 in the final period, in Piracicaba, SP. Bueno et al. (2009) proposed mean values at 0,75, 0,83 and 1,04. One work with *Urochloa brizantha* cv. Piatã proposed Kc: 0,83 at 1,33 and the *Panicum maximum* cv. Mombaça, high values occur, de 0,96 a 1,54 (ANTONIEL et al., 2016).

There is variation in Kc year, due to the influence of the elements climbers and their interaction with a plant. Voltolini et al. (2009) emphasize the need to know Kc of fodder according to physiological stage and growing region, aim of irrigation efficiency.

It is necessary to establish some indicators to evaluate the results obtained with the irrigation and know the effects of water consumption on plants. One of the indicators of water production (PA), an express qualification or a performance of a productive system, being the ratio of a input (evapotranspiration) and another output (production) (PURCELL; CURREY, 2003; NEAL; FULKERSON; HACKER, 2011).

The knowledge of ETc values throughout the productive cycle becomes fundamental for the efficiency of the irrigated productive systems. Thus, the objectives of this study was to evaluate the water consumption of *Urochloa brizantha* cv. Marandu in single crop and intercropped with black oats and Italian ryegrass, by means of weighing lysimeters, to determine crop coefficients for different periods and forage water productivity in each cutting cycle.

MATERIAL AND METHODS

The experiment was carried out in the Escola de Superior de Agricultura "Luiz de Queiroz" (ESALQ/USP) In two parcels with individual size of 144 m², each with a lysimeter weighing in the center, with an area of 1,17 m² and depth of 0,58 m. Constructive details of lysimeters are in Sanches et al., (2016). Around the plots, there were other lysimeters, experiments irrigated or rainfed with tropical forages and set-aside.

The soil is classified Eutrophic Red Nitosol (SANTOS et al., 2013). The experimental plots were prepared for the planting of *Urochloa brizantha* cv. Marandu, by conventional soil preparation (plowing and harvesting), pH correction and soil fertility, planting of seeds, control of invasive plants, irrigation and fertilization with nitrogen after each forage cut.

The irrigations were applied by sprinkler system, whenever necessary. Figure 1 shows the irrigation events and the temperature, precipitation and net radiation data recorded in the ESALQ weather stations. To estimate the reference evapotranspiration (ETo), the Penman-Monteith model was used, according to the FAO 56 (ALLEN et al., 1998, 2006).

Previously, calibrations of the lysimeter and automatic drainage weighing systems were done. The electrical signals of the lysimeters (mV) load cells were converted to mass (kg) by means of the calibration curves, inserted by means of computer system programming in the data logger, with a similar process done for the drainage system. Data were measured at 10 second intervals and three types of averages were stored: 15 minutes, hourly and daily.

The model data logger was CR1000 (Campbell Scientific® Inc. Logan Utah, USA). Used the computer program PC200W (Campbell Scientific® Inc. Logan Utah, USA) To export the data.

To obtain more precision in measuring the mass variation of each lysimeter and to relate it to the inputs (Rain and Irrigation) and water outputs (Drainage), with mean every 15 minutes. The mass variations between the measurements were calculated, excluding the values referring to periods when expressive rainfall (R) occurred, which caused imprecision of the data due to the time required for the stabilization of the weight of the lysimeters (CAMPECHE et al., 2011; SCHRADER et al., 2013).

Data were also excluded where evapotranspiration was high within the range of 15 minutes (above 0,20) mm characterized by the presence of hot air masses brought by the wind in the North, Northwest and West directions, and a few days also in the Southwest direction (follow land in some times). The surrounding areas in this sense are rainfed, fallow or uncovered areas, by the movement of air masses.

For the calculation of crop evapotranspiration (ETc), all daily values were used. The mass variations were converted directly into volume (1 kg = 1 L) and divided by the lysimeter area (1,17 m^2) to be transformed into mm h^{-1}. After that, the consumption data were added to each daily interval by comparing with the calculated ETo in order to obtain the crop coefficient (Kc).

Considering the two experimental plots, three cycles were performed in the months of February to April 2016, characterizing the hot period of the year (late summer and early autumn), and the remaining cycles from May to October 2016 (autumn, winter And early spring). Four cycles had individual duration of 40 days and were of single crop of *Urochloa brizantha* cv. Marandu; and five cycles of Marandu palisadegrass over-seeded with black oats (*Avena strigosa* Schreb.) and Italian ryegrass (*Lolium multiflorum* L.), at variable day intervals, according to the development of winter forages. During the experimental period there was interruption in the data acquisition of the lysimeters due to climatic rain, being inactive and without the presence of data.

The total forage yield (PTF) as determined by the sum of leaf and stem mass, at the end of each crop cycle, cut at 0,15 from the soil level. By means of this, it was possible to calculate the average daily forage accumulation (AMDF) and the water productivity (PA).

RESULTS AND DISCUSSION

Figure 2A shows the data of ETo and ETcA1 and ETcA2 determined during the experimental phase with the aid of the weighing lysimeters. The highest ETc values were 5,18 and 5,19 mm day^{-1} for lysimeters A1 and A2 respectively. Bueno et al. (2009) studied Tanzania grass for similar periods of analysis, but with longer cycles, obtaining the highest average of 6,65 mm day^{-1}. It is observed that the data were superior to those of the cited authors, possibly because they worked with daily data differently from the cited authors, who used averages of ten days.

In another study with Tanzania grass in Montes Claros/MG, or one year of the cycle, evapotranspiration determined by weighing lysimeter ranged from 1,98 at 7,21 mm day^{-1} (BARBOSA; OLIVEIRA; FIGUEIREDO, 2015). Considering that the lower values measured in lysimeters A1 and A2 were 1,18 and 1,28 mm day^{-1} respectively, the data corroborate with the values found by the cited authors.

Both lysimeters presented similar behavior in evapotranspiration accumulation, however it can be seen in Figure 2.B. The Area 2 (508 mm) had higher cumulative evapotranspiration compared to A1 (485 mm). Such behavior was already expected and was proved in this experiment, mainly caused by the difference in composition between the plots. Comparing the accumulated ETc and using the equation of the graph presented in Figure 3, an average water consumption of 5,06% higher in area A2 was estimated.

In addition, there was higher forage production in the over-seeded cultivation (M+OB+R) during the seasonal period (autumn/winter), (Table 1), with one cycle more cutting than in A1, being smaller cycles, being smaller cycles because the harvest point before the Marandu palisadegrass in single crop.

In addition, the higher accumulated evapotranspiration for the over-seeded pastures can be explained by the difference between the average daily forage accumulation (AMDF) between the experimental areas (Table 1). Most of the increase in AMDF is due to leaves, consequently there is an increase in leaf area and water consumption in the lysimeter of A2.

In cycle 4 (5th at 13th July), considered as the first cycle of autumn-winter, when the black oat and Italian ryegrass were implanted. Initially over-seeded (M+BO+R) had less accumulation compared to the single crop (M), and the total forage productivity (PTF) for the M exceeded that of the M+BO+R on 171,5 in kg ha^{-1} (Table 1). The black oat and Italian ryegrass in this period were in establishment, with greater representation of oats in production. This fact is in agreement with Carvalho et al. (2011) and Olivo et al. (2010), The authors observed that the highest peak of forage production of Italian ryegrass occurs later than that of black oats, usually from July to September.

In the other cycles, the M+BO+R had greater accumulation in relation to the M, increasing sharply from the fifth to the sixth cycle, due to the expressive presence of Italian ryegrass and explaining the greater total evapotranspiration in this area. The difference in AMDF fell in the seventh cycle due to the reduction of the black oat population.

Analyzing water productivity (kg DM m^{-3}) In Table 1 the cycles presented differences. The sixth cycle (24th Jul. at 1st Sep.) differs from all cycles, characterizing the seasonality of production (lower productivity) and consequent reduction of PA. The next cycle (2nd Sep. at 11th Oct.) Also showed seasonality effect, however, it had higher PA results.

The cycles M+BO+R reached productive levels per consumption similar to the summer and early autumn (single Marandu palisadegrass) cycles. Artur, Garcez e Monteiro (2014) studied the water productivity of the Marandu palisadegrass in a pot experiment, finding values between 1,07 e 2,27 kg m^{-3}. Molden et al. (2010) estimated the standard water productivity (PA) for wheat ranging from 0,2 a 1,2 kg m^{-3}. Rawnsley et al. (2009) Studied different irrigation slides in the perennial Italian ryegrass culture and observed an PA the 1,10 kg m^{-3} for 100% ETo.

In Table 2 the crop coefficients (Kc) determined with the weighing lysimeter data are presented, according to the possible cultivation cycles to be calculated. The lowest values of Kc found in the daily calculation were 0,24 (A1) and 0,30 (A2). Considering the averages presented, the minimum Kc was 0.60, approximating that observed by Gargantini et al. (2005) for the Mombaça grass (0,73).

It is observed that the maximum Kc reached for each cycle occurred on different days and with varied amplitude. It was observed that the first cycle of A2 (1,41) had its peak higher than A1 (1,24). Comparing with experimental Kc data on tropical forages obtained from several studies, maximum values of 1,04 to 1,25 for Tanzania grass, 1,04 to 1,54 for Mombaça grass and 1,33 for *Urochloa brizantha* cv. Piatã (LOURENÇO et al., 2001; GARGANTINI et al., 2005; BUENO et al., 2009; ANTONIEL et al., 2016). In this way, the values found in this experiment are within this range.

For Italian ryegrass Kc from 0,95 for initial phase, 1,05 for the mean period and 1,00 for the final stage (ALLEN et al., 1998). For the wheat crop, Lena et al. (2016) established as mean for the initial period: 0,7; cycle middle: 1,5 and 0,6 for the final, study with Londrina/PR. Another study with wheat in three years in northern China obtained Kc values ranging from

0,35 to 0,8 for the initial period, 1,01 to 1,04 for the middle and from 0,53 to 0, 98 for the end (GAO et al., 2014). In this work, the Kc for the M+BO+R cultures did not exceed.

Thus, we can recommend the use of Kc values for the summer and early fall and winter/autumn seasons, when using overestimation, in irrigated areas. When the Marandu palisadegrass plants were in the process of seasonality of production the maximum Kc reached was 1,14 (Table 2). In this same cycle, the PA was 1,18 kg m^{-3} (Table 2), his clarifies that the single grass at this time is demanding in water, but its use is not efficient because it produces little dry matter in relation to water demand.

CONCLUSION

Marandu palisadegrass with black oats and Italian ryegrass showed higher water consumption than the single Marandu palisadegrass during the seasonal period.

The water productivity achieved in over-seeded systems is similar to single Marandu palisadegrass crops during seasons with no single productive seasonality.

The Kc for Marandu palisadegrass for the summer and early autumn period ranged from 0,30 a 1,24. For the winter period in single tropical pasture Kc values of Kc de 0,24 a 1,14, and Marandu palisadegrass plus black oat and Italian ryegrass of 0,33 a 1.

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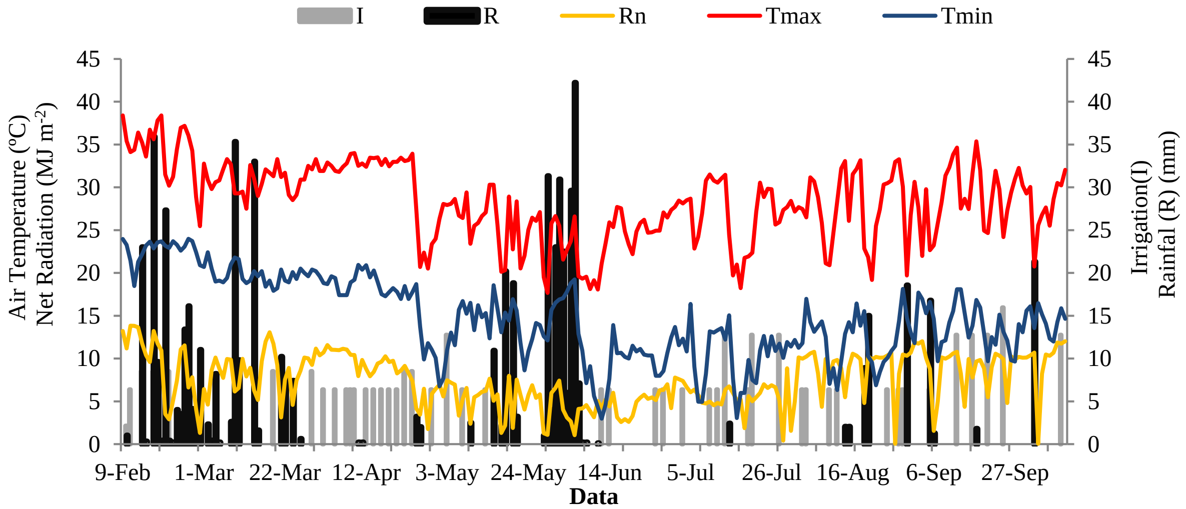

Figure 1. Meteorological datas (Rainfall-R, Net radiation-Rn., air temperature maximum -Tmax. and minimum-Tmin.), and Irrigations -I during experimental in Piracicaba/SP, 2016.

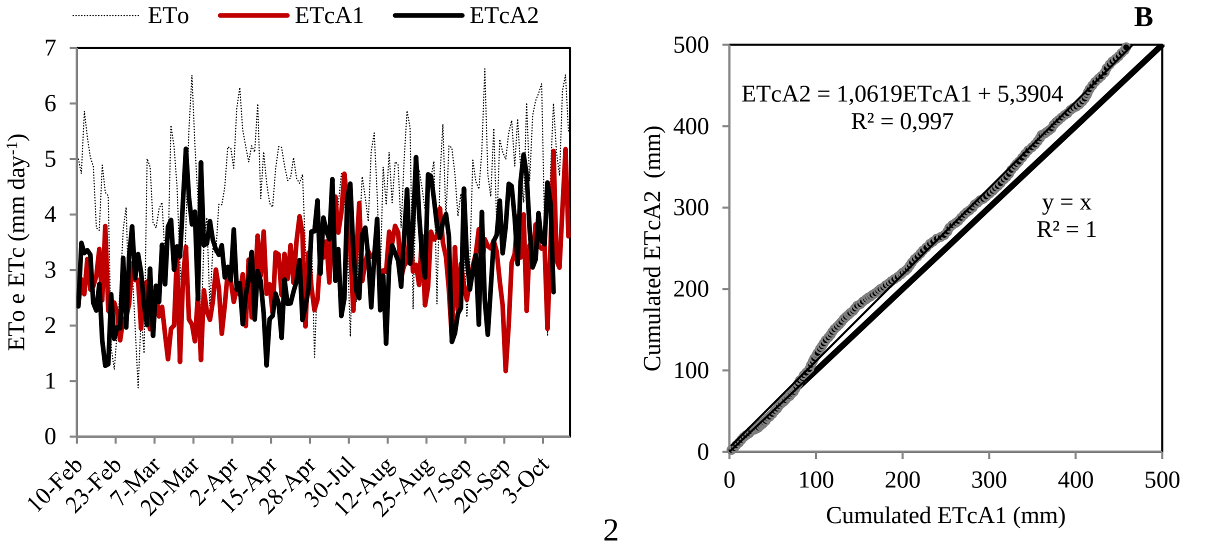

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Figure 2. A. Reference evapotranspiration (ETo) and crop evapotranspiration (ETc) measured in lysimeters (A1 and A2). **B.** Cumulative ETc linear correlation (ETcA1 x ETcA2).

Table 1. Total forage yield (PTF), dairy mean forage accumulated (AMDF), crop evapotranspiration (ETc) and water productive (PA) over the climatic seasons.

Climatic seasons	Growing	Date		PTF Kg ha^{-1}	AMDF Kg ha^{-1} day^{-1}	ETc mm day^{-1}	PA Kg m^{-3}
summer	M	11-Feb	9-Mar	1708,30	61,01	74,06	2,31
late summer/early autum	M	10-Mar	6-Apr	2542,90	90,82	65,56	3,88
autum	M	7-Apr	4-May	2307,13	82,40	83,93	2,75
	M	5-May	13-Jun	1998,83	49,97	------------	
	M+BO+R	5-May	13-Jun	1827,37	45,68	------------	
late autum/early winter	M	14-Jun	23-Jul	1318,70	32,97	-------------	
	M+BO+R	14-Jun	11-Jul	1735,87	62,00	-------------	
winter	M+BO+R	12-Jul	4-Aug	2748,90	98,18	-------------	
	M	24-Jul	1-Sep	1617,30	40,43	136,57	1,18
	M+BO+R	5-Aug	5-Sep	2554,80	91,24	107,55	2,38
late winter/early spring	M	2-Sep	11-Oct	2570,50	64,26	127,35	2,02
	M+BO+R	5-Sep	7-Oct	2476,80	88,46	113,35	2,19

*M- Marandu palisadegrass; M+BO+R – Marandu + Black Oat + Italian ryegrass

Table 2. Crop coefficients estimated with weighting lysimeter over the climatic seasons, Kc_i –initial, Kc_{m1} and Kc_{m2} – middle 1st and 2nd, Kc_f – final.

Climatic seasons	Growing	Date		Kc_i	Kc_{m1}	Kc_{m2}	Kc_f
summer	M	11-Feb	9-Mar	0,63	1,01	1,24	0,74
	M			0,61	0,84	1,41	0,77
late summer early autum	M	10-Mar	6-Apr	0,60	0,57	0,67	0,48
	M			0,94	1,02	0,99	0,52
autum	M	7-Apr	4-May	0,59	0,61	0,78	0,99
	M			0,51	0,49	0,64	1,26
winter	M	24-Jul	1-Sep	1,14	0,72	0,75	0,78
	M+BO+R	5-Aug	5-Sep	0,71	0,78	1,00	0,65
late winter early spring	M	2-Sep	11-Oct	0,68	0,58	0,64	0,74
	M+BO+R	5-Sep	7-Oct	0,66	0,65	0,83	0,83

*M- Marandu palisadegrass; M+BO+R – Marandu + Black Oat + Italian ryegrass