WATER CONSUMPTION ESTIMATE FOR MOMBAÇA AND *Cynodon* spp. **GRASSES IN EXCLUSIVE CROPPING AND OVERSEEDED WITH WINTER FORAGE**

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ABSTRACT: In order to improve irrigation water management practices, it is essential the precise estimation of evapotranspiration (ET). The crop coefficient (Kc) is the ratio between crop evapotranspiration (ETc) and reference evapotranspiration (ETo), and represents the effect of crop growth on water consumption. This work aimed to determine the Kc and ETc for *Panicum maximum* cv. Mombaça and *Cynodon* spp. in exclusive cropping and consorted in overseeding with oat and ryegrass during fall/winter seasons. This work was developed at ESALQ / USP, in Piracicaba (SP), using 4 experimental plots (Two for Mombaça and two for *Cynodon* spp., both in exclusive and overseeded cropping). At the center of each plot was placed a circular weighing lysimeter with a surface area of 1.17 m² and an automated system for data collection, composed by load cells, wires and a datalogger. During one year (February 2016 to February 2017), daily data of the lysimeter weight variation were collected, in order to calculate the forage water consumption, the Etc, and the Kc values. The meteorological data used to calculate ETo were obtained from automatic weather stations of INMET and ESALQ/USP, placed near to the experimental area. Mombaça grass in exclusive cultivation had the highest values of water consumption, with average ETc and Kc of 3.99 mm d^{-1} and 1.07, respectively. *Cynodon* spp. presented average ETc and Kc values of 3.57 mm d^{-1} and 0.96, respectively. The consortium of Mombaça grass with oat + ryegrass did not present high water intakes in the winter period, resulting in Kc values lower than in the exclusive cropping, with averages of 1.10 and 0.98, respectively. Otherwise, the consortium of *Cynodon* spp. + oat + ryegrass presented higher average values of Kc than the exclusive cultivation, 1.04 and 0,96, respectively.

KEYWORDS: irrigation, evapotranspiration, black oats and ryegrass

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ESTIMATIVA DO CONSUMO DE ÁGUA DOS CAPINS MOMBAÇA E *Cynodon* spp. **EM CULTIVO EXCLUSIVO E EM SOBRESSEMEADURA COM FORRAGEIRAS DE INVERNO**

RESUMO: Para melhoria das práticas de manejo da água na irrigação torna-se fundamental a estimativa precisa da evapotranspiração (ET). Da relação entre a evapotranspiração da cultura (ETc) e a evapotranspiração de referência (ETo) provém o coeficiente de cultura (Kc), representando o efeito do crescimento da cultura sobre o consumo de água. O objetivo deste trabalho foi determinar o Kc e ETc para os capins *Panicum maximum* cv. Mombaça e *Cynodon spp.* em cultivo exclusivo e consorciado em sobressemeadura com aveia e azevém no período de outono/inverno. O experimento foi conduzido na ESALQ/USP, em Piracicaba/SP, utilizando 4 parcelas experimentais (Duas para Mombaça e duas para Cynodon spp., ambos em cultivo exclusivo e em sobressemeadura). Ao centro de cada parcela foi posicionado um lisímetro circular de pesagem com superfície de 1,17 m² e equipado com um sistema automático de coleta de dados composto por células de carga, cabos e um datalogger. Durante um ano (fevereiro de 2016 a fevereiro de 2017) foram coletados dados diários da variação de peso dos lisímetros, de modo a calcular o consumo de água das forrageiras, a ETc e os valores de Kc. Os dados meteorológicos utilizados para cálculo da ETo foram obtidos a partir de estações meteorológicas automáticas do INMET e da ESALQ/USP, situadas em local próximo à área experimental. O capim Mombaça em cultivo exclusivo apresentou o maior consumo de água, com médias de ETc e Kc iguais a 3,99 mm dia^{-1} e 1,07, respectivamente. O *Cynodon spp.* apresentou médias de ETc e Kc de 3,57 mm dia^{-1} e 0,96, respectivamente. O consórcio de capim Mombaça com aveia + azevém não apresentou alto consumo de água no período de inverno, resultando em valores de Kc menores que no cultivo exclusivo, com médias 1,10 e 0,98, respectivamente. Por outro lado, o consórcio de *Cynodon* spp. com aveia + azevém apresentou valor médio de Kc maior que o cultivo exclusivo, 1,04 e 0,96, respectivamente.

PALAVRAS-CHAVE: irrigação, evapotranspiração, aveia preta e azevém

INTRODUCTION

Livestock and dairy farming, and agriculture tend to a complete for areas. So, a farmer may

see pasture irrigation as a technology that enables to increase the stocking rate and, also, the efficiency in that production system (Barbosa et al., 2015).

The high pasture yield during the rainy/hot season, and the low yield during the dry/cool season, or even during drought periods in the rainy season, is defined as a production seasonality (Antoniel et al., 2016; Koetz et al., 2017; Sanches et al., 2017). The main factors affecting that seasonality are: soil and plant water deficiency, solar radiation, photoperiod, and temperature (Barbosa et al., 2015). When the last three factors are not limiting, the pasture irrigation emerges as an alternative for increase the forage yield, supplying the soil water deficit and maximizing the plant yield potential (Oliveira et al., 2016).

Thus, the crop water consumption depends on the energy demand of the atmosphere, on the soil moisture, and on the plant resistance to lose water to the atmosphere (Oliveira et al., 2013), known and recommended by FAO as the crop evapotranspiration (ETc) (Pereira et al., 2015). The methods commonly used in ETc estimations are based on soil water balance, turbulent vortex correlations and Bowen ratio energy balance method (Silva et al., 2015).

One of the methods for soil water balance is lysimetry (Allen et al., 2011). The basic device of this method is the lysimeter, a tank the enables to measure water inlets and outlets (drainage lysimeters), or the weight variation (weghing lysimeters). In both the cases, the objective is to determine the soil moisture variation occurred in the lysimeter, known as the crop evapotranspiration (ETc) (Bilibio et al., 2017). So, with ETc and the estimation of reference evapotranspiration (ETo), it is possible to calculate the crop coefficient (Kc), as shown by Allen et al. (1998). With the Kc values for each phase of the crop phenological cycle, it is possible to estimate ETc with meteorological data (Zheng et al., 2012).

The research works related to pasture crops show that ETc may have high, with Kc values higher than 1.0 (Barbosa et al., 2015; Antoniel et al., 2016; Santana et al., 2016; Sanches et al., 2017). Sanches et al. (2017) worked with tropical forage crops of three genera (*Panicum*, *Brachiaria, and Cynodon*), during the crops formation period, and observed a wide range on the Kc, with values that reached 1.7 to *Panicum maximum* cv. Mombaça.

Thus, this work aimed to propose values for the crop coefficient (Kc) of two tropical forage crops, single cropped or consorted with winter forage crops.

MATERIAL AND METHODS

The experiment was carried out from February 2016 to February 2017, at an experimental area of the Biosystems Engineering Department of "Luiz de Queiroz" College of Agriculture – ESALQ/USP, in Piracicaba/SP (Latitude 22º 42' 14.6" S; Longitude 47º 37' 24.1" W; altitude 546 m amsl.). According to Köppen's Classification, the regional climate is defined as Cwa (Pereira et al., 2016). According to the Brazilian Classification of Soils (Santos et al., 2013), the soil of the experimental area is defined as 'Nitossolo Vermelho Latossólico Eutroférrico', with 48.6% clay, 32.5% silt, and 18.9% sand.

The forage crops studied were *Cynodon* spp. and *Panicum maximum* cv. Mombaça, single cropped and overseeded during the fall/winter period with black oat (*Avena strigosa* cv. Embrapa 29 - Garoa) and ryegrass (*Lolium multiflorium* cv. BRS). The experiment had four plots, each one with 12 m x 12 m, with a weighing lysimeter in its center. The plots, the cropping period, their respective crops and cropping systems were: Plot 1 - *P. maximum* cv. 'Mombaça', from Feb 12th, 2016 to Feb 13th, 2017, with 12 cutting cycles (12 CC); Plot 2 - *Cynodon* spp., from Feb 19th, 2016 to Feb 15th, 2017, with 14 CC; Plot 3 - *P. maximum* cv. 'Mombaça' + black oat + ryegrass, from May 6th, 2016 to Sept 22th, 2016, wtih 4 CC; and *Cynodon* spp. + black oat + ryegrass, from Apr 30th, 2016 to Oct 14th, 2016, with 6 CC.

The irrigation system proposed by conventional sprinkler with previously established irrigation interval was based on a limit of 70% of the moisture of the field capacity. In this way, the irrigation depth (ID) to be applied was determined by the difference between the volumetric moisture in the field capacity (θfc) and the current volumetric moisture (θi), multiplied by the effective root depth (Z), equal to 400 m. The moisture at the field capacity (θfc) was considered as the humidity corresponding to the value of Ψm = 0.06 bar. The values of θi were estimated by means of the soil water retention curve, obtained with the aid of a Richards extractor in the Laboratory of Soils and Water Quality of ESALQ/USP and adjusted by the Genuchten equation (Van Genuchten, 1980):

$$\theta i = 0,268 + \left[\frac{(0,4934 - 0,2938)}{\left[1+(0,113\Psi_m)^{1,3211}\right]^{0,2431}} \right]; (R^2=1,00 \text{ e } P<0,01) \qquad (1)$$

Where:

θi = Current volumetric humidity (cm³ cm^{-3})

Ψ_m = Potential current matrix of soil water (bar).

To calculate the reference evapotranspiration (ETo), it was estimated from the combined data of 3 meteorological stations: ESALQ / USP meteorological station and the INMET automatic station located at Latitude 22º 42 '11.3 "South and Longitude 47º 37' 24.3" West , And the automatic station of Fazenda Areão of ESALQ / USP located Latitude 22º 42 '01.1 "South and Longitude 47º38' 39.8" West. Observed meteorological data were analyzed using the Reference Evapotranspiration Calculator (REF-ET 4.1) using the methodology proposed by FAO 56 (Allen et al., 1998):

$$ETo = \frac{0.408s(RB-H)+\frac{\gamma 900U_2(es-ea)}{T+273}}{S+\gamma(1+0.34U_2)} \qquad (2)$$

Where,

ETo – reference evapotranspiration (mm.day^{-1});

RB – radiation balance (MJ.m^{-2}.dia^{-1});

H – heat flow to the soil (MJ.m^{-2}.day^{-1});

γ – Psychrometric constant (0,063 kPa ºC^{-1});

U_2 – wind speed at 2 m height (m.s^{-1});

es – vapor saturation pressure (kPa);

ea – current vapor pressure (kPa);

T – average air temperature (ºC);

s – change in vapor pressure as a function of air temperature (kPa ºC^{-1}).

In the calculation of crop evapotranspiration (ETc) weighed lysimeters were used. Each lysimeter was composed of a rigid PVC circular box, with a volume of 500 liters, an upper diameter of 1.22 m, a lower diameter of 1.0 m and a height of 0.58 m, a weighing system with load cells, a Water collection and drainage system and a masonry structure for installation in the soil. For estimating crop evapotranspiration (ETc), it was calculated through the inputs and outputs by weight difference of the lysimeter system, using the following equation:

$$ETc = Vsto + P + I - Vdra \qquad (3)$$

Em que,

ETc – crop evapotranspiration (mm.h^{-1});

$Vsto$ – storage variation (mm.h^{-1});

P – precipitation (mm.h^{-1});

I – irrigation (mm.h^{-1});

Vdra – Drain variation (mm.h^{-1});

Based on the daily values of crop evapotranspiration (ETc), reference evapotranspiration (ETo) and the relation between the two, the values of the crop coefficient (kc) were obtained for the forage during the collection cycles (regrowth), according to equation 6:

$$Kc = \frac{ETc}{ETo} \qquad (4)$$

Where:

Kc = crop coefficient (dimensionless);

ETc = crop evapotranspiration (mm d^{-1});

ETo = reference evapotranspiration (mm d^{-1})

The results were processed through the MS Excel spreadsheet with mean Kc data in a 6 day scale for the exclusive and overseeded Cynodon grass and 8 day scale for exclusive and overseeded Mombaça grass.

RESULT AND DISCUSSION

During the whole experimental period, rainfall was 1457.6 mm with application of 477.8 mm of water through irrigation, where it was possible to observe a large decrease in temperature in the fall / winter period with a large accumulation of Days with temperatures lower than 12ºC limiting the growth of tropical forages. Mombasa presented mean values of Kc = 1.07 and ETc = 3.99 during the experimental period. In the period comprised of autumn and winter the average Kc was 1.08 and 1.10 and in the spring and summer it was 0.95 and 1.12, respectively, according to Table 1.

Table 1. Kc values for the exclusive cultivation of M grass. Piracicaba / SP, 2016/17.

	Mombasa in exclusive cultivation (from 12/02/2016 to13/02/2017)											
	Autumn cycles			**Winter cycles**			**Spring cycles**			**Summer cycles**		
Cycle	**2º**	**3º**	**4º**	**5º**	**6º**	**7º**	**8º**	**9º**	**10º**	**11º**	**12º**	**1º**
Kc$_m$	1,05	1,18	1,03	1,17	1,08	1,02	0,92	0,93	0,99	1,04	1,10	1,22
ETc$_{accum}$	156,2	160,6	118,8	112,3	139,4	107,2	105,4	102,4	93,6	125,1	105,1	139,5
ETo$_{accum}$	150,1	139,5	116,7	98,3	142,5	116,0	120,7	119,9	96,2	122,0	95,0	123,3

Legend: Kc$_m$ = Mean Kc of the cycle, ETc$_{accum}$ = ETc accumulated in the cycle, ETo$_{accum}$ = ETo accumulated in the cycle.

The Kc data obtained in the winter cycles were close to 1 (Table 2), whereas, in the autumn, the water consumption recorded was lower than the ETo, resulting in mean Kc_s of less than 1.

Table 2. Kc values for the exclusive cultivation of Cynodon grass. Piracicaba / SP, 2016/17.

Cycles	Cynodon in exclusive cultivation (from 19/02/2016 to 14/02/2017)													
	Autumn cycles			Winter cycles			Spring cycles				Summer cycles			
	2º	3º	4º	5º	6º	7º	8º	9º	10º	11º	12º	13º	14º	1º
Kc_m	0,85	0,79	0,94	1,01	1,01	0,98	0,94	0,90	0,94	1,05	0,99	1,14	1,04	0,91
ETc_{accum}	95,7	84,0	104,3	71,7	94,5	105,6	136,2	80,0	75,6	84,7	96,9	70,1	85,4	120,9
ETo_{accum}	113,6	108,3	117,0	70,1	98,3	116,0	147,1	92,0	85,7	83,5	99,7	67,5	83,7	109,1

Legend: Kc_m = Mean Kc of the cycle, ETc_{acum} = ETc accumulated in the cycle, ETo_{acum} = ETo accumulated in the cycle.

For both, Mombasa grass and Cynodon grass, it is observed that the Kc did not obtain different results with the seasons, ETc decreases in the winter as it is possible to observe but the ETo also followed the same route. However, water consumption decreases because daily evapotranspiration was reduced in the fall / winter period (Table 1 and 2), and Muniz et al. (2014) state that crop evapotranspiration suffers from seasonal variation dependent on radiation Available during the period.

During the experiment of Mombasa grass in consortium with Oat + Ryegrass, a system malfunction occurred in lysimeter 2, compromising ETc and Kc data from 06/15/2016 to 07/20/2017. The ETc, ETo and Kc mean values of the experimental period were: 3.01 mm d $^{-1}$, 3.10 mm d $^{-1}$ and 0.96, respectively (Table 3).

Table 3. Kc values for the Mombasa grass overseeded in consortium with Oat + Ryegrass. Piracicaba, SP, 2016.

Cycles	Mombasa cultivated in consortium (from 06/05/2016 to 22/09/2016)			
	Autumm	Winter		
	1º	2º	3º	4º
Kc_m	0,96	----	0,93	1,00
ETc_{accum}	106,1 mm	----	88,8 mm	117,7 mm
ETo_{accum}	116,7 mm	89,0 mm	101,6 mm	126,3 mm

Legend: Kc_m = Mean Kc of the cycle, ETc_{accum} = ETc accumulated in the cycle, ETo_{accum} = ETo accumulated in the cycle.

In the intercropped and overseeded crop of the Mombasa with Oat + Ryegrass the height of the residue (post-cut) was reduced to 15 cm to facilitate the insertion of the winter forage in the middle, however, it was observed that there was a damage to the growth of the Mombasa (Table 3), and ETc accumulated during the winter period was always lower than ETo, unlike Mombasa in

exclusive cultivation that showed higher intakes in the 5th and 6th cycles of winter.

The interaction between Mombasa and winter forages (Oat + Ryegrass) was not synergistic and thus resulted in negative results both in water consumption and production, the literature points out several studies with overseeded of winter forages in pastures, however they are in their Most of the genus *Cynodon* spp. (Gomes et al., 2015, Sanches et al., 2015), in which they present significant morphogenic differences.

As occurred in the Mombasa consortium (lysimeter 2), the electrical system presented problems in lysimeter 4 from climatic weather, with no data in the period from 06/29/2016 to 07/20/2017, as presented in Table 4.

Table 4. Kc values for the Mombasa grass overseeded in consortium with Oat + Ryegrass. Piracicaba, SP, 2016.

	Cynodon cultivated in consortium (from 30/04/2016 to 14/10/2016)					
	Autumm	Winter				Spring
Ciclos	1st	2nd	3th	4th	5th	6th
Kc$_m$	1,04	1,02	----	1,03	1,01	1,01
ETc$_{accum}$	113,9 mm	59,8 mm	----	65,0 mm	87,8 mm	160,0 mm
ETo$_{accum}$	116,2 mm	62,0 mm	60,2 mm	65,5 mm	96,8 mm	162,1 mm

Legend: Kc$_m$ = Mean Kc of the cycle, ETc$_{accum}$ = ETc accumulated in the cycle, ETo$_{accum}$ = ETo accumulated in the cycle.

The Cynodon consortium in Oat + Ryegrass showed a good synergism that caused the cycles during the winter to be shortened due to the fast growth of Oat and Ryegrass providing 2 cycles more cutting (harvest) than the Mombasa grass, not suppressing the winter forages that lasted until the first week of October. Sanches et al., (2015) also obtained prolonged winter forage yields, in this case, the overseeded oat in Tifton 85, obtaining yields until the beginning of November when the main grass suppressed the oats.

The overseeded Cynodon showed evapotranspiration of the crop close to the ETo which led to Kcs close to 1, the characteristics of this consortium may have contributed to such values, since are small grasses and total cover of the soil resemble the batatais grass (*Paspalumnotatum*) used as the grass for the calculation of ETo.

CONCLUSIONS

Mombasa grass in exclusive cultivation presented the highest water consumption, the Mombasa consortium with Oat + Ryegrass did not present high water consumption and Kc during

the period was lower than the exclusive grass.

The Cynodon in exclusive cultivation presented Kc averages close to 1, and the Cynodon consortium with Oat and Ryegrass presented higher Kcs in the winter than the exclusive one.

In general, the seasons of autumn / winter and spring / summer did not strongly influence Kc, since ETo decreases in autumn / winter. However, ETc was higher in spring / summer than in autumn / winter.

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