IV INOVAGRI INTERNATIONAL MEETING
XXVI CONIRD – CONGRESSO NACIONAL DE IRRIGAÇÃO E DRENAGEM
III SBS – SIMPÓSIO BRASILEIRO DE SALINIDADE

TROPICAL AND WINTER FORAGES IRRIGATED: BIOMETRIC AND PRODUCTIVE PARAMETERS

A. C. Sanches[1], D. P de Souza [2], F. L. F. de Jesus[3] F. C. Mendonça[4], R. G Maffei[5] E. P. Gomes[6]

ABSTRACT: The exploration of the productive potential of the pasture according to the climate can be the key to the ruminant production. However, it depends on the understanding and involvement with the use of forage and irrigation to promote increases in production. The research aimed to evaluate forage production, botanical composition, canopy height (CH) and leaf area index (LAI) of *Panicum maximum* cv. Mombaça and *Cynodon* spp. cultivated exclusively and in overseeded consortium with oat + ryegrass in the fall/winter period. The experiment was developed in an experimental area of ESALQ/USP, in Piracicaba-SP, between February 2016 and February 2017. The management of irrigation by sprinkler was supplementary to meet the humidity in the field capacity, always to 0.7 of the water availability factor. The experimental design was a randomized block design with 4 replicates. For all evaluated parameters, the Mombaça grass in exclusive cultivation was present among the best results. Total forage production (TFP) was higher for Mombaça grass compared to *Cynodon* spp. (59.3 and 30.2 Mg ha^{-1}, respectively); such behavior corroborates the mean LAI of 4.8 and 2.5 of Mombaça and *Cynodon* spp., respectively. *Cynodon* spp. presented higher number of stems than Mombaça with 12.22 and 7.99 Mg ha^{-1} of dry stem mass (DSM) respectively, which explains the low leaf-stem ratio (LSR) of *Cynodon* spp. Of 1.54. In the fall/winter period, the TFP of the exclusive and overseeded grasses, Mombaça was superior to the others with accumulate of 25.89 Mg ha^{-1}. The DSM was superior for *Cynodon* spp. and *Cynodon* spp. + [1]oats and ryegrass in relation to the others. Also in the winter period, the best LAI was Mombaça, followed by Mombasa + oats and ryegrass, of 4.8 and 4.5, respectively.

KEY WORDS: water consumption, height, dry matter, conventional sprinkler.

[1]Engenheiro Agrônomo, doutorando em Engenharia de Sistemas Agrícolas, ESALQ/USP, arthur_carniato@hotmail.com,
[2]Doutoranda em Engenharia de Sistemas Agrícolas, ESALQ/USP, dpdsouza@usp.br;
[3]Doutoranda em Engenharia de Sistemas Agrícola, ESALQ/USP, lamede10@yahoo.com.br;
[4]Professor Doutor, ESALQ/USP, fcmendon@gmail.com;
[5]Acadêmico do curso de Engenharia agronômica, ESALQ/USP, rodolfo.maffei@usp.br;
[6]Professor Doutor, UFGD/Dourados, edergomes@ufgd.edu.br;

FORRAGEIRAS TROPICAIS E DE INVERNO IRRIGADAS: PARÂMETROS BIOMÉTRICOS E PRODUTIVOS

RESUMO: A exploração do potencial produtivo da pastagem em função do clima pode ser a chave para a produção ruminantes. No entanto, depende do entendimento e envolvimento com o uso da forrageira e da irrigação para promover acréscimos na produção. A pesquisa teve por objetivo avaliar a produtividade de forragem, a composição botânica, altura do dossel forrageiro (ADF) e o índice de área foliar (IAF) de *Panicum maximum* cv. Mombaça e *Cynodon* spp. cultivados exclusivos e em consorciado sobressemeado com Aveia + Azevém no período de outono/inverno. O experimento foi desenvolvido em área experimental da ESALQ/USP, em Piracicaba-SP, entre fevereiro de 2016 a fevereiro de 2017. O manejo da irrigação por aspersão foi suplementar para atender a umidade na capacidade de campo, sempre a 0,7 do fator de disponibilidade de água. O delineamento experimental foi o de blocos ao acaso com 4 repetições. Para todos os parâmetros avaliados o capim Mombaça em cultivo exclusivo esteve presente entre os melhores resultados. A produtividade total de forragem (PTF) foi superior para o capim Mombaça em relação ao *Cynodon* spp. (59,3 e 30,2 Mg ha^{-1}, respectivamente), tal comportamento corrobora o IAF médio de 4,8 e 2,5 da Mombaça e *Cynodon* spp., respectivamente. O *Cynodon* spp. apresentou maior quantidade de colmos em relação a Mombaça com 12,22 e 7,99 Mg ha^{-1} de massa seca de colmo (MSC), respectivamente, isto explica a baixa relação folha/colmo (RFC) do *Cynodon* spp. de 1,54. No período outono/inverno, a PTF dos capins exclusivos e sobressemeados, a Mombaça foi superior aos demais com acumulado de 25,89 Mg ha^{-1}. Já a MSC foi superior para o *Cynodon* spp. e o *Cynodon* spp. + aveia e azevem em relação aos demais. Ainda no período de inverno, o melhor índice de IAF foi da Mombaça exclusiva e Mombaça + aveia e azevem, de 4,8 e 4,5, respectivamente.

PALAVRAS CHAVE: consumo de água, altura, matéria seca, aspersão convencional.

INTRODUCTION

A great challenge for human society is to produce enough food to feed a growing population, and that production is highly dependent on the expansion of irrigated agriculture (LIU, 2011). However, the use of innovative practices that increase water use efficiency is an obstacle (LIU, 2011; LEVIDOW et al., 2014).

In recent years, the increasing use of technologies has allowed to increase productivity in cattle, which is dependent on techniques that improve the main food resource – pastures (SOARES et al., 2015). Also, in a climate that favors their growth, the key to ruminant production is in the diet from forages, being grazed or cultivated (MORRIS; KENYON, 2014; CHOBTANG et al., 2017a, 2017b).

The irrigation of pastures appears as a promising thing, in the periods of drought, where the forage plants present a marked seasonality, which reflects in the livestock production (MOCHEL FILHO et al., 2016). Studies comparing the productivity of irrigated and non-irrigated pastures indicate increases in average daily accumulations between 25 and 55 kg ha^{-1} day^{-1} with irrigation (GOMES et al., 2015b; SANCHES et al., 2015, 2016, 2017; DANTAS et al., 2016). Forage production throughout the year does not constantly meet animal requirements, and irrigation alone, despite mitigating, does not eliminate the seasonality of production (SANCHES et al., 2015). Thus, the consortium between summer and winter forages can optimize fodder production in the Hibernal period by extending the period of pasture utilization as well as improving its quality (SILVEIRA et al., 2015).

The objective of this study was to evaluate the productivity, botanical composition and biometric parameters of the Mombasa and *Cynodon* spp. grass in annual exclusive cultivation, and overgrowth with Oat + ryegrass during autumn/winter.

MATERIALS AND METHODS

The study was conducted in the Department of Biosystems Engineering of the "Luiz de Queiroz" School of Agriculture - ESALQ / USP, in an experimental area, Piracicaba/SP (Latitude 22º 42' 14.6" South and Longitude 47º 37' 24.1" West, Height de 546 m). The climate of the region according to the classification of Köpen is of the type Cwa - Subtropical or tropical of altitude (PEREIRA et al., 2016), and its characteristics are presented in Figure 1 in the experimental year (February 2016 to February 2017).

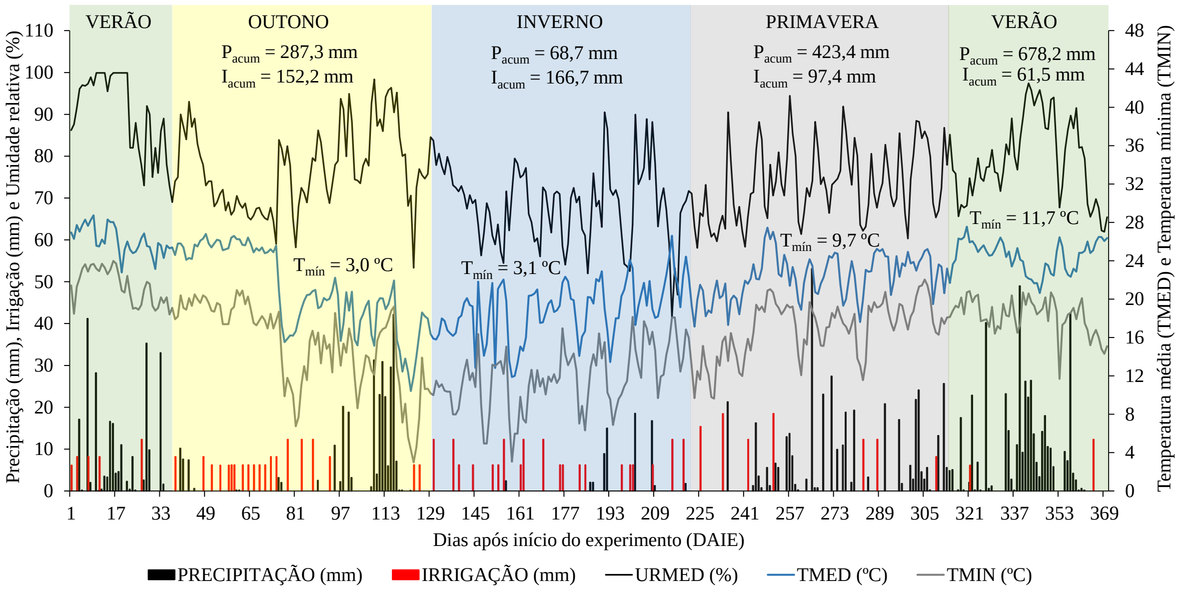

Figure 1. Precipitation values (mm), relative humidity (%), minimum temperature (ºC) and average temperature (ºC) during the experimental period, from 02/2016 to 02/2017. Piracicaba / SP. Legend: Pacum = accumulated rainfall in the period, Iacum = accumulated irrigation in the period, Tmin = lower temperature presented in the period.

The soil of the experimental area is classified as red nitosol latosolic eutroferric (SANTOS et al., 2013). The basic fertilization was performed according to Raij et al. (1997) and depending on the chemistry and particle size analysis (Table 1). During the experiment, there were nitrogen fertilizations fractionated with urea after each cycle / cut, dosage of 80 and 50 kg ha^{-1} $cycle^{-1}$ o N in the spring-summer period and in autumn-winter, respectively.

Table 1. Chemical and granulometric analysis of the soil of the experimental area in the 0-20 cm layer, 20-40 cm layer. Piracicaba / SP, 2015.

Layer	pH	P	K	Ca	Mg	H+Al	Al	CEC	Sand	Silt	Clay
(cm)	$CaCl_2$	mg dm^{-3}	cmol$_c$ dm^{-3}					cmol$_c$ dm^{-3}	(%)	(%)	(%)
0 – 20	5,3	72	0,94	3,9	1,8	3,1	0,2	9,74	35,7	19,2	45,1
20 – 40	4,9	31	0,44	1,3	1,0	4,2	0,2	6,94	29,3	18,7	52,0

P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; H + Al = potential acidity; Al = exchangeable aluminum; CEC = cation exchange complex.

The forages used were Cynodon spp and *Panicum maximum* cv. Mombasa in exclusive and overhang cultivation with winter forages *Avena strigosa* cv. Oat meal Embrapa 29 (Garoa) + *Lolium multiflorium* cv. Ryegrass BRS in the fall / winter period. The experiment was conducted with 4 treatments and 4 replicates, totaling 16 experimental plots. Treatment 1 with Mombaça grass from 12/02/16 to 2/13/17 with 12 collection cycles (12 CC), Treatment 2 with Cynodon from 02/19/16 to 2/15/17 with 14 CC, treatment 3 with Mombaça grass with oats + ryegrass from 5/6/16 to 9/22/16 with 4 CC and treatment 4 Cynodon with oats + ryegrass from 4/30/16 to 4/14/16 with 6 CC. The CC were variable for each forage, and the total number of CDC was dependent on each one. In the winter forages the experiment period was dependent on the persistence of oats and ryegrass in the field, variable in each of the consortiums with Mombasa and Cynodon.

The layer of irrigation (LI) to be applied was determined by the ratio of the volume consumed by the lysimeter (liters) and area of the same (m²), with effective depth (Z) equal to 600 mm. The irrigation interval previously established was based on a limit of 70% of the water availability factor (Θ 70 = humidity at 70%). The moisture at the field capacity (θ_{cc}) was considered as the humidity corresponding to the value of $\Psi m = 0.06$ bar. The values of current moisture (Θi) were estimated by means of the soil water retention curve, obtained in the Laboratory of Soils and Water Quality of ESALQ / USP and adjusted by equation:

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

Where:
Θi = current volumetric humidity (cm³ cm-3)
Ψm = current matrix potential of water in the soil (bar).

The collection cycles were fixed for the exclusive crops of Mombaça and Cynodon at 21 and 28 days after the cut (DAC) in spring / summer and 33 and 40 DAC in autumn / winter, respectively. The post-cut height (residue) was adopted according to literature of 30 cm for Mombasa (SIMONETTI; MARQUES; COSTA, 2016) and 10 cm for the Cynodon (SANCHES et al., 2017). For the consortium through the overhang, the cut cycles were variable as a function of the winter forage growth measured with LAI 2000 (LI-COR Biosciences). The cutting and harvesting procedure was repeated until the extinction of oats + ryegrass in the pastures.

In the laboratory, in the exclusive cultures, samples of Mombasa and Cynodon were submitted to botanical separation (leaf, stem and dead material), then sent to a forced air circulation oven (65º for 72 hours) and the dry matter Of forages: TFP (total forage production), LP (leaf production), SP (stem production), DMP (Dead material production). In the overgrown cultures, the samples were separated, the Mombat being separated from the Oat + Azevém and the Cynodon separated from the Oat + Azevém. Thus, TPOR (total production of oats + ryegrass), POLR (production of oat leaves + ryegrass) and POSR (production of oat stems + ryegrass) were determined, the dead material was not identified .

At the end of the cycle, leaf area index (LAI) and forage height canopy (CH) were also evaluated. To carry out the evaluation of the IAF, the table sensor Licor 3000C (electronic optical planimeter developed in Nebraska, USA) the area (cm² g^{-1}) was determined by reading the area (cm²) in the sensor divided by the dry mass (g) of the tiller (COSTA et al., 2016). With the specific area the IAF was determined according to the equation:

$$\mathrm{IAF} = \mathrm{A_e} * \mathrm{Prod}; \quad (2)$$

Where;
IAF = index of leaf area (dimensionless);
Ae = specific area ($cm^2\ g^{-1}$);
Prod = forage production ($g\ cm^2$);

The experimental design was randomized blocks with 4 replicates. The experimental data were submitted to analysis of variance and when significant the means were compared through the Tukey test ($p \leq 0.05$) with the aid of the SAS statistical tools for Windows 7 and assistat 7.7 (FRANCISCO; CARLOS, 2016).

RESULTS AND DISCUSSION

For the overall comparison between the 4 treatments, the mixed-model procedure (ProcMix) of the SAS software with multi-factor adjustments (Tukey-Kramer) was used, in which it presented the following results:

Table 2. Mean data per cycle of TFP, LP, SP, DMP, CH and LAI. Piracicaba / SP, 2016/17.

	TFP (kg ha^{-1})	LP (kg ha^{-1})	SP (kg ha^{-1})	DMP (kg ha^{-1})	CH (m)	LAI
Mombasa	4941 A	4175 A	666 A	100 A	91,3 A	4,8 A
Mom + O + R	3009 B	2149 B	753 A	107 AB	61,4 B	4,3 B
Cynodon	2154 C	1151 C	873 A	130 A	27,8 D	2,5 C
Cyn + O + R	1873 C	1108 C	750 A	15 B	44,3 C	2,9 C

Legend: TFP = total forage production, LP = leaves production, SP = stem production, DMP = dead material production, H = canopy height, LAI = leaf area index.

The highest average leaves and forage yield of the Mombasa grass correspond to the highest leaf area indexes (LAI). Turning TFP into daily accumulation we have 162.4; 86.0; 82.6 and 66.9 kg ha^{-1} day^{-1} of dry mass for exclusive and intercropped Mombasa, exclusive and intercropped Cynodon, respectively. In irrigated cultivation with nitrogen fertilization between August and December, Mochel Filho et al. (2016) Obtained total forage yield of 141.5 kg ha^{-1} day^{-1} of the Mombaça grass in Parnaíba/PI, yields slightly lower than those found at work. Silva et al. (2009) observing rates of daily accumulation of dry mass of Mombasa found results higher than 200 kg $ha^{-1}dia^{-1}$ for days of the month of January in Araras/SP.

With irrigation at rates of daily forage accumulation in *Cynodon* cv. Tifton 85 for Sanches et al. (2016) where 102,7 Kg $ha^{-1}day^{-1}$ in an experiment in the northwest of Paraná, higher values than the one found in the experiment. Likely justification is due to the grass being implanted months before the experiment and still be a probable mixture between Tifton and the star grass (less productive than the previous one).

In relation to plant height, the oat bran consortium with ryegrass in Mombasa showed an intermediate mean value of 61.4 (Table 2), due to the lower cut management of 15 cm, in the attempt to establish the winter forage. The average height of the 91.3 cm exclusive Mombasa corroborates the literature data (SILVA et al., 2009; SIMONETTI; MARQUES; COSTA, 2016).

For the other results we used the software Assistat 7.7 (FRANCISCO; CARLOS, 2016). The accumulated production during the seasons for summer forages (Mombasa and Cynodon) are presented in Table 3. The highest TFP presented were present in spring / summer for both Cynodon and Mombasa, corroborating Aguirre et al., (2016) which found higher dry matter yields in spring / summer with Coast Cross grass, corresponding to 61.5% of the Total production of the year. Spring / summer co-operated with approximately 60% of Cynodon TFP, Sanches et al., (2016) Found 71% of the production of a Cynodon irrigated in spring / summer in an experiment carried out in Mariluz-PR, collaborating with the idea of bigger productions in the hot seasons of the year.

Table 3. Mean data of TFP, LP, SP and LAI accumulated during the year between seasons for exclusive Mombasa and exclusive Cynodon. Piracicaba / SP, 2016/17.

		Fall	Winter	Spring	Summer	Average	CV%
TFP	Mombaça	13138,6 aB	12752,9 aB	15645,1 aAB	17756,6 aA	14823,3 a	4,97
	Cynodon	5512,9 bB	6584,3 bB	10876,6 bA	7181,0 bB	7538,7 b	15,44
	Average	9325,8 B	9668,6 B	13260,8 A	12468,8 A	11181,0	---
LP	Mombaça	10862,6 aA	10833,8 aA	14177,5 aA	14228,8 aA	12525,7 a	7,31
	Cynodon	2774,8 aA	3762,9 aA	5656,5 aA	3924,6 aA	4029,7 b	16,24
	Average	6818,7 C	7298,4 BC	9917,0 A	9076,7 AB	8277,7	---
SP	Mombaça	2029,8 aB	1301,5 bB	1362,7 bB	3304,3aA	1999,6 b	11,39
	Cynodon	2297,6 aB	2256,0 aB	4929,7 aA	2732,8 aB	3054,0 a	19,89
	Average	2163,7 B	1778,8 B	3146,2 A	3018,6 A	2526,8	---
LAI	Mombaça	5,29 aAB	4,76 aB	6,59 aA	6,67 aA	5,83 a	6,83
	Cynodon	2,51 bA	2,41 bA	2,89 bA	2,31 bA	2,53 b	15,44
	Average	3,90 AB	3,59 B	4,74 A	4,49 AB	4,18	---

Legend: TFP = total forage production, LP = leaf production, SP = stem production, LAI = leaf area index. Note Capital letters for lines and lower case letters for columns.

During the seasons Mombasa and Cynodon did not present significant differences for the production of leaves, nevertheless for general average the Mombasa was superior. In the high parameter Cynodon presented the highest yields of the same in winter and spring, with a higher overall average that may have been contributed by its morphological characteristics of cespitoso growth with tiller launch with stolons, being a characteristic feature of high stem yields of this genus (GOMES et al., 2015a; AGUIRRE et al., 2016; SANCHES et al., 2016, 2017).

The highest TFP and LP presented occurred in the exclusive Mombasa, and it was observed that there was no positive interaction between the overlapping consortium of Ova with Azevém in Mombasa (Table 4). During the experiment it was observed that some type of allelopathy could have occurred between the species, not occurring a good synergism between both species. Cavalli et al. (2016) observed allelopathic effect of black oats and ryegrass on the plant and root growth of the Sudan grass in an experiment conducted in São José do Cedro / SC.

Table 4. Productive and biometric data in the winter period for the treatments. Piracicaba, SP, 2016.

	TFP (kg ha^{-1})	LP (kg ha^{-1})	SP (kg ha^{-1})	DMP(kg ha^{-1})	CH (m)	LAI
Mombaça	12752,9 a	10833,8 a	1301,5 b	617,6 a	82,6 a	4,8 a
Mom + O + R	9612,7 b	6249,0 b	2956,3 a	407,5 ab	62,0 b	4,5 a
Cynodon	6584,3 c	3762,9 c	2256,0 ab	565,4 a	25,7 d	2,4 b
Cyn + O + R	7283,4 c	4392,4 c	2854,6 a	36,5 b	43,4 c	2,9 b
CV (%)	10,60	13,00	19,07	48,28	4,09	11,39

Legend: TFP = total forage production, LP = leaves production, SP = stem yield, DMP = dead material production, CH = forage canopy height, LAI = leaf area index.

The exclusive and oversized Cynodon presented the smallest TFP and LP, without statistically differentiating between them. The ova overgrowth with ryegrass in the Cynodon, although numerically superior, did not obtain a significant result, corroborating Gomes et al. (2015a) who did not find significant effects of Cynodon cv. Tifton 85 with oat bran. Differently, Sanches et al. (2015) obtained significant positive results in Oat overestimation with Tifton 85. The amount of dead matter was lower for the Owen consortium with Azevém in Cynodon, presenting low amount of dead material in relation to the others. This shows the good synergism between the different forages that also produced a good amount of TFP with high yields of stem, being compatible the consortium. Neres et al. (2012) discuss the importance of forage compatibility, and in their experiment they obtained problems regarding the height of the overgrown crop (pigeon pea) that promoted shading in the Cynodon.

CONCLUSIONS

1. Mombasa grass presented the highest forage yields with TFP and LP of 59.3 and 50.1 Mg ha^{-1} year^{-1} with the highest leaf area indexes.

2. For grasses in exclusive crops, spring / summer showed higher yields in relation to autumn / winter.

3. The Cynodon in exclusive cultivation presented a great accumulation of stem, mainly in winter and spring.

4. The overlapping consortia of oats with ryegrass in the tropical grasses did not have a significant effect on them, and in the winter period, Mombasa in exclusive cultivation presented the most productive among them.

ACKNOWLEDGEMENTS

To the Foundation for Research Support of the State of São Paulo - FAPESP, for the aid granted to the regular research project nº 2012 / 23002-6.

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