



DOI: <http://dx.doi.org/10.1590/1807-1929/agriambi.v20n9p817-822>

## Irrigation management strategy for Prata-type banana

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### Key words:

*Musa* spp.  
crop evapotranspiration  
leaf area

### ABSTRACT

This study aimed to analyze different irrigation strategies in two cultivars of the banana crop. The study was conducted in four production cycles of 'Prata-Anã' and 'BRS Platina' bananas. The applied irrigation depths (ID) were obtained by the model  $ID = K \times LA \times ETo$ , where K is an empirical transpiration constant of 0.20; 0.35; 0.50 and 0.65 for the strategies 1, 2, 3 and 4, respectively; LA is the leaf area of mother and daughter plants of 'Prata-Anã' and ETo is the reference evapotranspiration. The strategy 5 was obtained according to the crop evapotranspiration,  $ETc = ETo \times Kc$ , where Kc is the crop coefficient. Drip irrigation system was used, with two laterals per plant row and emitters with flow rate of  $8 \text{ L h}^{-1}$ , spaced at 0.50 m. It was found that 'Prata-Anã' is more efficient than 'BRS Platina' in terms of water use and the model for irrigation management,  $ID = 0.35 \times LA \times ETo$ , is recommended to optimize water use by 'Prata-Anã' and 'BRS Platina' bananas, with increase in water use efficiency and maintenance of yield. The same model, with K coefficient equal to 0.50, makes it possible to obtain yield and water use efficiency equal to those obtained with irrigation management based on the ETc.

### Palavras-chave:

*Musa* spp.  
evapotranspiração da cultura  
área foliar

## Estratégias de manejo de irrigação para bananeira tipo Prata

### RESUMO

Objetivou-se, com o presente estudo, avaliar diferentes estratégias de irrigação para bananeiras 'Prata-Anã' e 'BRS Platina' em quatro ciclos produtivos. As lâminas de irrigação aplicadas (LA) foram obtidas pelo modelo  $LA = K \times AF \times ETo$  em que K é a constante empírica de transpiração de 0,20; 0,35; 0,50 e 0,65 para as estratégias 1, 2, 3 e 4, respectivamente; AF, área foliar das plantas mãe e filha da 'Prata-Anã' e ETo, evapotranspiração de referência. A estratégia 5 foi obtida conforme a evapotranspiração da cultura,  $ETc = ETo \times Kc$ , sendo Kc seu coeficiente. Utilizou-se o sistema de irrigação por gotejamento com duas laterais por fileira de planta, com emissores de  $8 \text{ L h}^{-1}$  espaçados 0,50 m totalizando 10 gotejadores por planta. Verificou-se que a 'Prata-Anã' é mais eficiente no uso da água cujo modelo para manejo de irrigação,  $LA = 0,35 \times AF \times ETo$  é indicado para otimizar o uso da água em bananeiras 'Prata-Anã' e 'BRS Platina' com aumento da eficiência de uso da água e manutenção da produtividade. O mesmo modelo possibilita com a constante K igual a 0,50, a obtenção de produtividades e de eficiência de uso da água iguais às obtidas com manejo de irrigação com base na ETc.



## INTRODUCTION

The Brazilian semi-arid region has high potential for banana production; however, rainfall scarcity and irregularities limit the production, which makes irrigation necessary. For Ravi et al. (2013), the limitation of water is a universal phenomenon and represents great obstacle in the production of banana.

With production of 6,902,184 t in 2013 (FAO, 2013), Brazil is the fifth largest banana producer in the world and this fruit is the second most-produced (ABF, 2015), with 66.54% of the production concentrated in the northeast and southeast regions of Brazil, where Bahia is the largest producer in the northeast (IBGE, 2015).

Banana yield tends to increase with the transpiration (Coelho et al., 2006), while monthly rainfall between 100 and 180 mm allows economically viable harvests (Costa et al., 2009). The values of 717 mm of rainfall and 2,438 mm of reference evapotranspiration are the most adequate for the production of banana in northern Minas Gerais (Borges et al., 2011).

The attention with the use of water requires from the irrigators, especially in the semi-arid region, the precision with irrigation management and the increase in precision leads to increment in irrigation efficiency (Santos et al., 2013; Santos & Martinez, 2013). Therefore, there is the need for studies with local specificity involving strategies that aim to facilitate irrigation management and its adoption by the producer.

Prata-type banana is the most widespread in Brazil, particularly in the semi-arid region, cultivated under irrigation. As a consequence of that and combined with the scarcity of studies that help the producer in a practical irrigation management and aim at the sustainability of water resources, this study aimed to analyze different irrigation strategies for two banana cultivars.

## MATERIAL AND METHODS

The study was carried out in an orchard planted in March 2012 at spacing of 2.5 x 3.0 m in a Red Yellow Latosol, with medium texture, density of 1.60 and 1.59 kg dm<sup>-3</sup>; 0.648 and 0.610 kg kg<sup>-1</sup> of sand; 0.153 and 0.155 kg kg<sup>-1</sup> of silt; 0.198 and

0.235 kg kg<sup>-1</sup> of clay, in the layers of 0-0,15 and 0,15-0.30 m, respectively. The water contents retained at -10 and -1,500 kPa were 0.20 and 0.11 m<sup>3</sup> m<sup>-3</sup>, respectively. The experimental area in the Agriculture Sector of the Federal Institute of Bahia, Campus of Guanambi, is located in the Irrigation District of Ceraíma (14° 13' 30" S; 42° 46' 53" W, 545 m). The mean annual rainfall monitored in the area in historic series of thirty years is 680 mm and the mean temperature is 25.78 °C. Maximum and minimum temperatures and reference evapotranspiration, recorded approximately 100 m distant from the experiment, are presented in Figure 1.

The study was based on the evaluation of different irrigation strategies in the cultivation of 'Prata-Anã' (AAB) and 'BRS Platina' (AAAB) bananas, during four production cycles in order to define, according to the criteria of yield and water use efficiency, a model for irrigation management based on leaf area, empirical transpiration coefficient (K) and on the crop coefficient.

Two irrigation strategies were used, integrating five treatments: Strategy I: irrigation based on leaf area and empirical transpiration coefficient (K) according to the model:  $ID = K \times LA \times ETo$ , where ID is the applied irrigation depth corresponding to the volume applied per plant (L plant<sup>-1</sup>), K is a constant of 0.20, 0.35, 0.50 and 0.65 for the treatments 1, 2, 3 and 4, respectively; LA is the leaf area in m<sup>2</sup> of 'Prata-Anã' biweekly estimated based on the reading of length and width of the third leaf and total number of leaves in the mother plant in the first cycle, and in mother and daughter plants in the other cycles, according to Oliveira et al. (2013); ETo is the reference evapotranspiration daily determined along the cycle. Strategy II: full irrigation based on crop evapotranspiration with ETo obtained through the Penman-Monteith FAO-56 model, from the data recorded in an automatic weather station, and Kc is the crop coefficient for banana in northern Minas Gerais (Borges et al., 2011). The constants 0.20, 0.35, 0.50 and 0.65 for the strategy based on leaf area were selected according to the study of Oliveira et al. (2013), who evaluated the growth of 'Grande Naine' banana using the same model, with constants between 0 and 0.8, and observed that 0.57 showed the best fit. Thus, a coefficient higher than 0.65 was used in order to

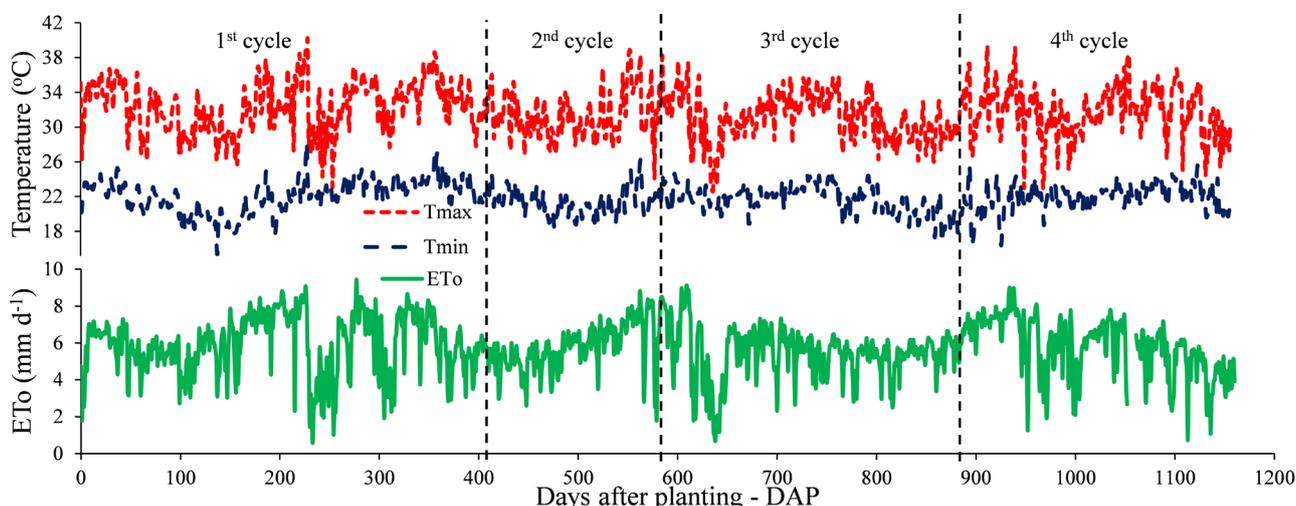


Figure 1. Maximum temperature (Tmax), minimum temperature (Tmin) and reference evapotranspiration (ETo) during four production cycles of 'Prata-Anã' and 'BRS Platina' bananas

apply an irrigation depth greater than the  $ET_c$  and three lower coefficients were used to increase water use efficiency.

The four cycles, five irrigation strategies and two cultivars were arranged in a randomized block design in a split-split plot scheme ( $4 \times 5 \times 2$ ), with three replicates and nine plants evaluated in each experimental plot.

Irrigation was daily performed using a pressure-compensating drip system, with two laterals per plant row and drippers with flow rate of  $8 \text{ L h}^{-1}$  spaced by 0.50 m, totaling 10 emitters per plant. Crop evapotranspiration ( $ET_c$ ) in mm, for the irrigation management in treatment 5, was calculated by the product between  $ET_o$  and the crop coefficient.

The times of irrigation per day used in the irrigation management of the orchard during the experiment in the treatments 1, 2, 3 and 4 were calculated using Eq. 1 and, in treatment 5, Eq. 2, adopted by Santos et al. (2014; 2015) and Neves et al. (2013). When there were rainfalls, they were subtracted from the  $ET_c$  in order to obtain the time of irrigation ( $T_i$ ), in  $\text{h d}^{-1}$ .

$$T_i = \frac{ID}{n \times q \times Ea} \quad (1)$$

$$T_i = \frac{ET_c \times E1 \times E2 \times K1}{n \times q \times Ea} \quad (2)$$

where:

- n - number of emitters plant<sup>-1</sup>;
- q - emitter flow rate,  $\text{L h}^{-1}$ ;
- Ea - application efficiency (decimal), adopted value of 90%;
- E1 - spacing between banana rows, m;
- E2 - spacing between plants in the row, m; and,
- K1 - location coefficient.

The location coefficient (K1) was determined through the highest value between the percentage of wetted area and the shaded area. From 140 to 274 days after planting (DAP), K1 ranged from 0.71 to 0.75 and, after 275 DAP, the leaf area covered 100% of the surface, resulting in K1 of 1.

In the first cycle, the plants of all treatments received full irrigation until 141 DAP; after this period, the irrigation strategies started being applied (Figure 2). According to Figure

2, the duration of the second cycle is lower compared with the others. Harvest was used to separate one cycle from the other; however, at the harvest of the first cycle, the daughter plant was already in development, which explains the lower duration of this cycle. In addition, there was small occurrence of rainfall at the end of the second cycle, since it coincided with the drought period of the region.

The harvested bunches were weighed, analyzed and quantified as total bunch yield and net yield, disregarding the rachis. Water use efficiency (WUE) was calculated for all treatments considering the ratio between total bunch yield and the gross water depth applied for each treatment, according to Silva et al. (2009) and Santos et al. (2014; 2015).

Yield and WUE data were subjected to analysis of variance and a follow-up analysis of the interactions, according to their significance. The means of these variables were compared by Tukey test ( $p < 0.05$ ) for all factors.

Based on the results of these four production cycles, it was possible to determine the empirical transpiration coefficient that best fitted to the model for the estimation of water demand by 'Prata-Anã' and 'BRS-Platina' bananas, with data of leaf area and  $ET_o$ . The coefficient was selected considering the results of the statistical analyses for yield and water use efficiency.

## RESULTS AND DISCUSSION

The behavior of leaf area along the four cycles is presented in Figure 3. Leaf area was determined in the mother plant in the first cycle and daughter and mother plants of 'Prata-Anã' banana in the other cycles, which justifies the lower leaf area in the first cycle (Figure 3). From the point of view of rational irrigation water management, this is an interesting proposal, because the crop coefficient is constant and, in this model, there is the monitoring of the change in leaf area, as observed in Figure 3, which may represent water saving.

According to the analysis of variance (Table 1), there was interaction ( $p < 0.05$ ) between irrigation strategies and cultivars, and between cycle and irrigation strategies for bunch yield. On the other hand, for WUE there was interaction between cycle and irrigation strategies and independent effect for cultivars.

According to the analysis in Figure 4A, which shows the main yield of the four cycles for 'Prata-Anã' and 'BRS Platina' bananas, the use of irrigation strategies based on leaf area with K equal

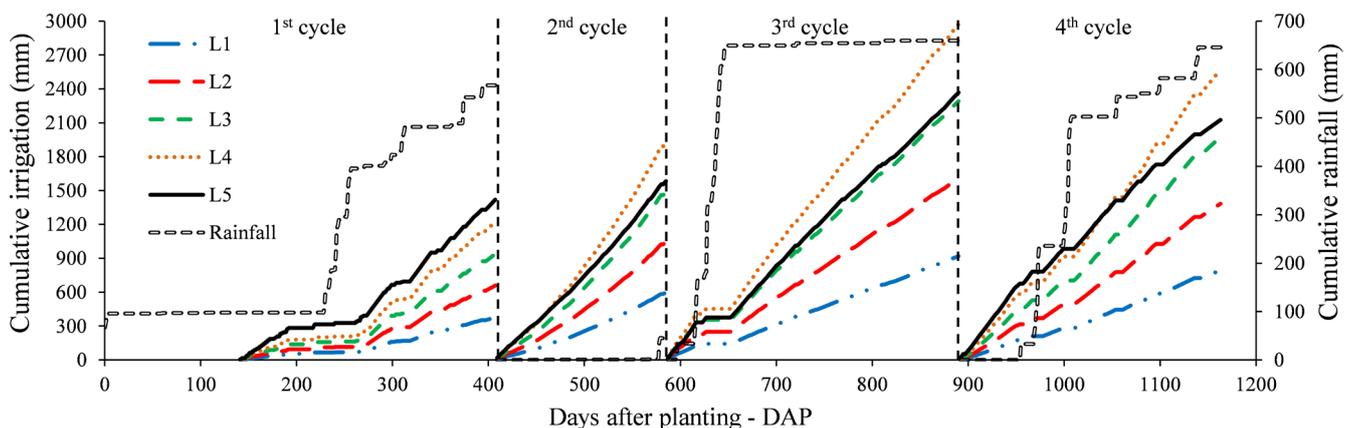


Figure 2. Cumulative irrigation and rainfall for irrigations based on leaf area (L1, L2, L3 and L4) and  $ET_c$  (L5)

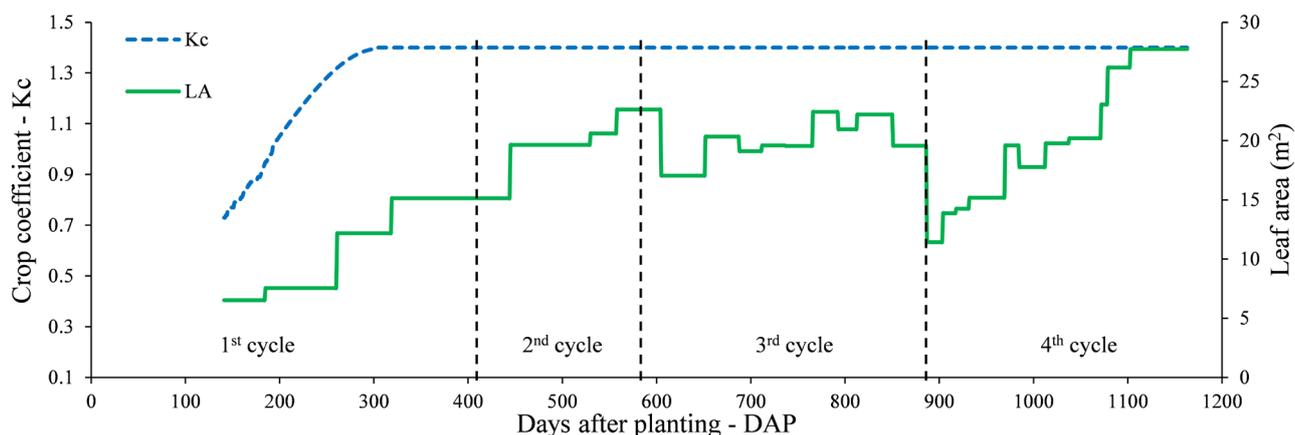


Figure 3. Leaf area (LA) (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> cycle) and crop coefficient (Kc) of 'Prata-Anã' banana

Table 1. Analysis of variance

Source of variation	DF	Bunch Yield			Water Use Efficiency		
		MS	F	Significance	MS	F	Significance
Block	2	28.324	6.68	0.0031	16.739	6.46	0.0037
Cycle	3	1694.452	399.47	0.0000	170.977	65.96	0.0000
Error (A)	6	4.242			2.592		
Irrigation	4	28.428	5.59	0.0011	1088.086	667.97	0.0000
Irrigation x cycle	12	13.136	2.59	0.0121	8.218	5.04	0.0000
Error (B)	32	5.081			1.629		
Cultivar	1	67.118	11.27	0.0017	20.107	4.60	0.0380
Cultivar x cycle	3	11.575	1.94	0.1381	4.474	1.02	0.3921
Cultivar x irrigation	4	14.742	2.48	0.050	7.265	1.66	0.1775
Cultivar x irrigation x cycle	12	7.704	1.29	0.2601	4.754	1.09	0.3953
Residual	40	5.955			4.368		
Coefficient of variation			13.022			14.269	

DF-Degree of freedom; MS-Mean square

to 0.20 caused yield reduction only for 'Prata-Anã', compared with the irrigation based on Kc. For 'BRS Platina', there was yield reduction in plants irrigated based on the K coefficient of 0.35, 0.50 and 0.65. Additionally, the yields are similar between both cultivars, only differing in the irrigation with K equal to 0.36 and Kc, for which 'Prata-Anã' produced more than 'BRS Platina'. The higher yield probably promoted higher WUE in 'Prata-Anã', compared with 'BRS Platina', because the irrigation depth applied in both cultivars was the same (Figure 4B).

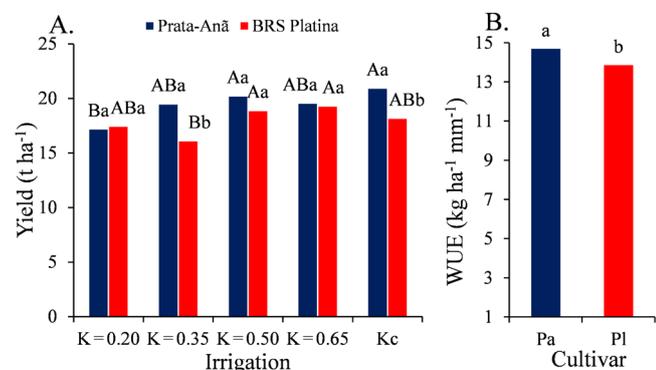
The means of yield and WUE for the banana cultivars 'Prata-Anã' and 'BRS Platina' under the different irrigation strategies in the four production cycles are presented in Table 2. Only in

the fourth cycle the irrigation based on ETC (Kc) promoted higher bunch yield compared with irrigation based on leaf area using K of 0.20, 0.35 and 0.65. The mean yield between the cultivars 'Prata-Anã', mother, and 'BRS Platina', daughter, is not a characteristic of differentiation between them; the values were very close and varied along the production cycles and in the same planting area (Donato et al., 2009; Marques et al., 2011).

In the evaluation of yield of 'Prata-Anã' banana intercropped with leguminous species and subjected to different irrigation depths in Pentecoste, CE, Barbosa et al. (2013) observed that the application of 50% of ETC (390.7 mm) combined with the rainfall (1,095.9 mm) did not cause yield reduction compared with 125% of ETC in the first production cycle, corroborating the results of the present study in the first cycle.

Yield increased from the first to the fourth cycle (Table 2). On the other hand, WUE was higher for plants irrigated based on leaf area and K equal to 0.20 and, for all irrigation strategies, WUE was higher in the fourth cycle. The reduction in WUE is explained by the higher gross water depth applied (Figure 2) as the constants K and Kc increased. The higher WUE obtained in the strategies 1 and 2 may be related to the small change between yields for the different irrigation strategies for 'Prata-Anã' and 'BRS Platina' bananas, which are considered as moderately responsive to the increase in irrigation depth (Azevedo & Bezerra, 2008).

The results of the present study corroborate those of Oliveira et al. (2013), who concluded that it is possible and viable the alternative irrigation management using data of leaf area, ETC and empirical coefficients for the estimation of



Different uppercase letters on the bars differ ( $p < 0.5$ ) by Tukey test for the irrigation strategies and different lowercase letters differ for the cultivars

Figure 4. Bunch yield of 'Prata-Anã' and 'BRS Platina' bananas for the different irrigation strategies (A). Water use efficiency (WUE) for the cultivars 'Prata-Anã' (Pa) and 'BRS Platina' (PI) during four production cycles (B)

Table 2. Means of bunch yield and water use efficiency of 'Prata-Anã' and 'BRS Platina' bananas, for irrigations based on leaf area (K) and ETc (Kc) in four production cycles

Irrigation	Yield (t ha <sup>-1</sup> )				Water use efficiency - WUE (kg ha <sup>-1</sup> mm <sup>-1</sup> )			
	1 <sup>st</sup> cycle	2 <sup>nd</sup> cycle	3 <sup>rd</sup> cycle	4 <sup>th</sup> cycle	1 <sup>st</sup> cycle	2 <sup>nd</sup> cycle	3 <sup>rd</sup> cycle	4 <sup>th</sup> cycle
K = 0.20	9.00 A d	14.88 A c	20.83 A b	24.56 C a	23.79 A b	24.94 A b	22.67 A b	31.01 A a
K = 0.35	9.33 A c	14.84 A b	22.45 A a	24.60 C a	14.17 B b	14.20 B b	13.96 B b	17.78 B a
K = 0.50	9.59 A d	17.08 A c	22.87 A b	28.73 AB a	10.21 C b	11.46 BC b	9.98 C b	14.55 C a
K = 0.65	10.02 A d	18.00 A c	22.77 A b	26.98 BC a	8.17 CD ab	9.33 C ab	8.49 C b	10.50 D a
Kc	10.01 A c	17.23 A b	20.12 A b	30.90 Aa	7.05D c	10.88 C b	7.66 C bc	14.54 C a

Means followed by different letters, uppercase in the columns for irrigation strategies and lowercase in the rows for the production cycles, differ ( $p < 0.05$ ) by Tukey test for each variable

crop water demand. Therefore, based on a combined analysis of yield and WUE, i.e., maintenance of yield and increase in WUE, in the present study, the proposed model can be used for Prata-type banana with K coefficient of 0.50 and gross water depth of approximately 939, 1,490, 2,291 and 1,975 mm in the first, second, third and fourth cycles, respectively. In 'Grande Naine' banana, Oliveira et al. (2013) reported that the best crop development was obtained with transpiration coefficient (K) of 0.57 and irrigation depth estimated at 1,247 mm cycle<sup>-1</sup>.

D'Albuquerque Júnior et al. (2013) observed that the highest yields and fruit quality of 'FHIA-18' banana in the second and third cycles in the state of Piauí occurred in plants subjected to water depths between 800 and 1,200 mm per cycle. In Pentecoste-CE, Azevedo & Bezerra (2008) reported that the yields of 'Prata-Anã' and 'Pacovan' bananas linearly increase with the irrigation depth, and 'Pacovan' was the most productive in the first production cycle, in which the water depths varied from 1,883.7 to 3,747.1 mm, with mean yields of 15.50 and 17.80 t ha<sup>-1</sup> for 'Prata-Anã' and 'Pacovan', respectively. In the present study, the increase in yield with the applied amount of water was observed only in the fourth cycle. Based on these results, the importance of conducting studies during various cycles subjected to different irrigation depths to obtain consistent results is observed, because the banana crop increases its vigor and yield until the fourth production cycle (Donato et al., 2009).

From the point of view of the sustainability of water resources, with maintenance of yield, it is viable to use the irrigation model based on leaf area, because it increases WUE, which is essential nowadays, when water limitation is a universal phenomenon and represents great obstacle in banana production (Vanhove et al., 2012; Ravi et al., 2013; Muthusamy et al., 2014; Kissel et al., 2015), especially in semi-arid regions of tropics and subtropics (Surendar et al., 2013), more subject to climatic alterations. This increase in WUE is related to the control of the applied water depth according to the water demand of the crop with certain leaf area. The use of the crop coefficient is constant from the first cycle on (Figure 3) and leaf area changes according to crop development, local climatic factors, thinning and other cultural practices in all cycles, which estimates, with greater accuracy, the water depth to be applied, avoiding the application of water beyond the requirement in periods in which the leaf area is lower.

## CONCLUSIONS

1. Using the model  $ID = LA \times K \times ET_c$  with K coefficient equal to 0.35 allows to obtain profitable yields with increase in water use efficiency.

2. Using the model  $ID = LA \times K \times ET_c$  with K coefficient equal to 0.5 allows to obtain yield and water use efficiency equal to those obtained in irrigation management based on ETc.

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