academicJournals

Vol. 11(36), pp. 3425-3432, 8 September, 2016
DOI: 10.5897/AJAR2016.11460
Article Number: 4299DED60336
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Irrigation under different soil surface wetted areas and water depths for banana cv. Grand Naine

Eugênio Ferreira Coelho[1]*, Marcelo Rocha dos Santos[2], Édio Luis da Costa[3], Sérgio Luiz Rodrigues Donato[2] and Polyanna Mara Oliveira[4]

[1]Agricultural Engineering, Embrapa Mandioca e Fruticultura, C.P. 07, Cruz das Almas, BA, Brazil.
[2]Agricultural Engineering, Instituto Federal Baiano *Campus* Guanambi, C.P 009. Zona Rural, Distrito de Ceraíma, Guanambi, BA, Brazil.
[3]Agricultural Engineering, Universidade Federal de São João Del-Rei, Campus de Sete Lagoas. Rod. MG 424 - km 47, CEP: 35701970 - Sete Lagoas, MG, Brazil.
[4]Agricultural Engineering, Epamig Norte. Rodovia MGT 122 km 155, Zona Rural, CEP: 39527-000 Nova Porteirinha – MG, Brazil.

Received 20 July, 2016; Accepted 17 August, 2016

The use of different water depths and soil surface soil surface wetted areas by micro-sprinkler irrigation systems results different wetted soil volumes and evapotranspiration conditions, which may cause changes in fruit production quality and quantity. The objective of this study was to evaluate yield, fruit physical characteristics and leaf area of banana cv. Grand Naine under different irrigation depths and soil surface wetted areas in Northern Minas Gerais State, Brazil. The experiment was conducted in the period 2003 to 2006, involving three production cycles of 'Grand Naine' banana with planting spacing of 3.0 m × 2.7 m irrigated by micro-sprinklers. The experimental design was a randomized block with four replicates in a split-plot arrangement with three soil surface wetted areas in the plot and five irrigation depths as subplots. The irrigation levels were taken as fractions of crop evapotranspiration (ETc): 0.70; 0.85; 1.00; 1.15 and 1.30 ETc, and the soil surface wetted areas (Wa) were: Wa 1 of 10.17 m^2, with emitter of 20 L h^{-1} and radius of throw of 1.8 m; Wa 2 of 23.74 m^2, with emitter of 63.6 L h^{-1} and radius of throw of 2.7 m and Wa 3 of 28.26 m^2, with emitter of 60 L h^{-1} and radius of throw of 3.0 m. Central fruit diameter and mean weight, leaf area and yield of 'Grand Naine' banana were not influenced by irrigation depths. On the other hand, smaller soil surface wetted area causes reduction in central fruit length and weight, leaf area and yield of 'Grand Naine' banana.

Key words: *Musa spp*., irrigation management, soil surface wetted area.

INTRODUCTION

Brazil is in the fifth position in the global ranking of banana production and, according to FAOSTAT (2015), in 2014, the production was 6,946,567 tons, with emphasis for the northeast and southeast regions, which account for 66.91% of the production (IBGE-SIDRA, 2016). The state of Minas Gerais is the second largest

*Corresponding author. E-mail: eugenio.coelho@embrapa.br. Tel: +55 (75) 33128021.

producer in the southeast region, with 47.48% of the production concentrated in its northern portion (IBGE-SIDRA, 2016), a semi-arid region, recently identified by the trademark “Região do Jaíba”, constituted for characterization as an area of geographic indication for the production of quality fruits.

In the Brazilian semi-arid region, the mean annual rainfall is lower than 800 mm, with irregularity of spatial and temporal distribution and aridity index between 0.2 and 0.5. Since the water requirement of the banana crop is higher than the natural rainfall and with regular distribution, the use of irrigation becomes necessary to fulfill water needs during the periods of water deficit in the soil even in humid regions (Vanhove et al., 2012; Ravi et al., 2013; Muthusamy et al., 2014; Kissel et al., 2015). However, it is necessary to attempt for precision of irrigation mainly in semiarid regions of tropics and subtropics more subjected to climate changes (Surendar et al., 2013, 2015).

Micro-sprinkler irrigation has been predominant in the localized irrigation of banana in the production centers of the semi-arid region. There are different micro-sprinklers available in the market, in terms of both structure and nominal flow rate. Flow rates are related to the radius of throw and, consequently, the generated soil surface wetted area. The soil surface wetted area is associated with the region of root development; the higher it is, the greater the lateral expansion of the root system. However, larger soil surface wetted diameters also imply greater areas under evaporation, with reduction of application efficiency. Rocha (2009) evaluated the effect of the percentage of soil surface wetted area on physiological, production and fruit quality variables of ‘Tahiti’ lime (transpiration, stomatal conductance and leaf temperature) and observed no differences in these aspects for the evaluated soil surface wetted area percentages.

The knowledge on the water requirement of the banana crop has increased in the last years and results have been found for different climate conditions (Coelho et al., 2013; Silva; Bezerra, 2009; Montenegro et al., 2008; Teixeira et al., 2002) for different cultivars in different physiographic regions. However, considering micro-sprinkler irrigation as the trickle system most used in the production centers of irrigated banana in Brazil, studies that associate levels of irrigation water and soil surface wetted area for water application by micro-sprinklers are scarce.

The emitter radius of throw determines soil surface wetted area, which is dependent upon its flow rate and pressure. The emitter precipitation intensity, in turn, depends on their physical characteristics. The wetted area on the soil surface due to the application of water is a determinant factor in the mean moisture content of the wetted volume and in its dimensions, with implications on root distribution, on water and nutrient uptake and also on soil water losses through evaporation and percolation. Farmers usually do not know which emitter to choose for optimal production and market offers types with different flow rates. Moreover, morphological, production and fruit quality factors of the banana crop may be influenced by the soil surface wetted area, in isolation or in interaction with the applied water depths. This study aimed to evaluate the effect of different irrigation water depths and soil surface wetted areas applied by a micro-sprinkler system on yield, fruit physical characteristics and on leaf area of ‘Grand Naine’ banana during three production cycles in Northern Minas Gerais, Brazil.

MATERIALS AND METHODS

The experiment was carried out in the Northern Unit of the Agricultural Research Company of Minas Gerais - EPAMIG, in the municipality of Nova Porteirinha, Minas Gerais State, Brazil (Figure 1). The area is inserted in the Brazilian semi-arid region, at the geographical coordinates of 15° 46' 38.98"S, 43 17' 22.06" W and altitude of 537 m, and its climate is Aw, according to Köppen’s classification. The soil of the experimental area was classified as dystrophic Red Yellow Latosol and its physical-hydraulic characteristics are presented in Table 1.

The experiment was conducted from 2003 to the beginning of 2006, comprehending three production cycles of ‘Grand Naine’ banana, with planting spacing of 3.0 m × 2.7 m under micro-sprinkler irrigation, maintaining the soil covered by the straw of the plants. The experimental design was randomized blocks with four replicates, in a split-plot arrangement, with three soil surface wetted areas in the plots and five irrigation depths in subplots.

Irrigation water depths were determined by the ETc fractions of 0.70, 0.85, 1.00, 1.15 and 1.30 of ETc, considering the efficiency of the irrigation system of 0.85, with daily irrigations. Crop evapotranspiration (ETc) between two irrigations was obtained based on the potential evapotranspiration (ETo) determined by the Class-A pan method and on crop coefficients (Kc) established as a function of those suggested by Allen et al. (1998). The wetted area on the soil surface was determined by the radius of throw of the micro-sprinklers, according to their flow rates, through water collectors positioned in a grid (0.50 × 0.50 m) in an area with four plants (5 m × 4 m), and the emitter in the center. The soil surface wetted area 1, with 10.17 m^2, was obtained using emitter with flow rate of 20 L h^{-1} and radius of throw of 1.8 m; the soil surface wetted area 2, with 23.74 m^2, was obtained using emitter with flow rate of 63.6 L h^{-1} and radius of throw of 2.7 m, and the soil surface wetted area 3, with 28.26 m^2, was obtained using emitter with flow rate of 60 L h^{-1} and radius of throw of 3.0 m.

The process of soil surface wetted area determination was also used to obtain the mean precipitation intensity, based on the mean water depth of the collectors divided by the time (h) of the test, which was performed periodically. The mean precipitation intensity was used in the determination of irrigation time. Irrigation depths and soil surface wetted areas were differentiated in the controller through valves corresponding to each one of the factors, totaling 15 sub-main lines. Rainfall and class A pan evaporation were measured in a conventional weather station, installed close to the experiment.

Soil water status was evaluated through soil water tension, measured with a tensiometer using an analog tensimeter, before irrigations. Leaf area was evaluated based on the length and width of the third leaf during flowering period. Yield (t ha^{-1}) and the variables of fruit physical quality (mean length, weight and diameter of the central fruit from the second hand) were evaluated at harvest. Distance and effective depth of the root system were observed by opening soil pits in the plots, between the plant and the micro-

Figure 1. Experimental area located at Nova Porteirinha County in the Northern of Minas Gerais, Brazil.

Table 1. Soil physical-hydraulic characteristics: Texture, density and water contents corresponding to the potentials obtained in the soil water retention curve (Nova Porteirinha-Minas Gerais, Brazil).

Layer (m)	Sand	Silt	Clay	Soil density	Soil moisture (cm^3cm^{-3}) at tension (kPa)				
		(g kg^{-1})		(Mg m^{-3})	-10	-33	-100	-500	-1500
0-0.20	516	202	293	1.71	0.239	0.230	0.218	0.205	0.195
0.20-0.40	444	210	346	1.63	0.260	0.248	0.235	0.212	0.209
0.40-0.60	343	186	471	1.66	0.309	0.299	0.287	0.269	0.261

sprinkler, and by removing the roots from the soil in monoliths at the distances of 0.25, 0.50, 0.75 and 1.00 m from the plant and along the soil profile from the surface to 0.80 m, every 0.10 m. The images were processed according to Sant'ana et al. (2012), allowing the determination of root length at each distance and soil depth between the plant and the micro-sprinkler. Distance and effective depth of the roots corresponded to those with 80% of the cumulative total length from the plant and from soil surface (Sant'ana et al., 2012).

The data of mean length, weight and diameter of the central fruit of the second hand, leaf area and yield were submitted to analysis of variance in each cycle. The means of dependent variables were compared by Tukey test at 0.05 probability level for the independent variable soil surface wetted area. Regression analysis evaluated depended variables as a function of irrigation depths. Regression models were also fitted to the data of cumulative root length as a function of the distance from the plant and soil depth, referring to each soil surface wetted area.

RESULTS

Climatic attributes were not similar during the three crop cycles. Irrigation water depths applied in each treatment (fraction of ETc) were different for each cycle (Table 2), because of the variation in the maximum evapo-transpiration (ETo) and crop evapotranspiration (ETc). The lowest irrigation water depth value recorded in cycle 1 was above 800 mm and, in cycles 2 and 3, above 990 mm and for the treatment 0.85 ETc, the irrigation water depths in all cycles were higher than 997 mm. These depths of water corresponded to values near to the ones observed by Bassoi et al. (2004) for maximum yields in the semi-arid of Petrolina, Pernambuco State whose aridity indexes were smaller than the ones of the Nova Porteirinha.

According to the analysis of variance (Table 3), there was no interaction between the factors soil surface wetted area x water depth during the three cycles for the evaluated dependent variables of 'Grand Naine' banana. There was effect of soil surface wetted area on central fruit length (CFL) in cycles 1 and 3, central fruit diameter (CFD) in cycle 2, central fruit weight (CFW) in cycle 3, total leaf area (TLA) in cycles 1 and 3 and yield (Y) in the three cycles. The irrigation depths influenced, independently, only central fruit length (CFL) in cycle 3.

The mean length of the central fruit of the second hand was the highest for the soil surface wetted area of 23.74 m^2 in cycle 1 (Table 4), and the lowest for the soil surface wetted area of 10.17 m^2 in cycle 3. The irrigation water depths did not influence mean diameter and weight of the

Table 2. Rainfall, crop evapotranspiration and total water depths required by the plants, according to the applied treatments (Nova Porteirinha-MG, Brazil).

Cycle	Rainfall (mm)	ETc (mm)	0.70ETc (mm)	0.85ETc (mm)	1.00ETc (mm)	1.15ETc (mm)	1.30ETc (mm)
1	819	1,108	821	997	1,173	1,349	1,525
2	1,163	2,097	1,543	1,813	2,083	2,353	2,624
3	344	1,466	991	1,204	1,416	1,629	1,841

central fruit in any of the cycles. The mean diameter of the central fruit remained constant as irrigation depth increased, with mean values of 35.0, 36.0 and 35.2 mm in the cycles 1, 2 and 3, respectively (Table 4), which are above 32 mm, thus classified within the extra category for Cavendish bananas. The mean fruit weight in cycle 3 for the soil surface wetted area of 23.74 m^2 was similar to that of the soil surface wetted area of 28.2 m^2 and higher than that of the soil surface wetted area of 10.17 m^2 (Table 4). Irrigation water depth has affected central fruit length (F test) but any regression model did not relate these variables. Based on fruit length classification (PBMH; PIF, 2006) the largest soil surface wetted area resulted fruits of length within the class of length greater than 22 cm and smaller than 26 cm, with mean of 24.30 cm. The smallest soil surface wetted area led to fruits within the class of length greater than 18 cm and smaller than 22 cm in the third cycle.

'Grand Naine' banana showed lower leaf area for the smallest soil surface wetted area (10.17 m^2) in cycles 1 and 3 (Table 5), as well as lower yield for this wetted area in all production cycles. Means of leaf area from larger soil surface wetted areas, 23.74 and 27.18 m^2, were not different between themselves for all cycles. The mean yields for these same conditions differed only in the first cycle (Table 5). Irrigation water depths did not influence both leaf area and yield in the range of 990 mm (0.7 ETc) to equivalent to 1840 mm (1.30 ETc).

The increase of soil surface wetted area was equal to 133% from 10.17 to 23.74 m^2 and to 18% from 23.74 to 28.26 m^2. These wetted volumes allowed greater effective lateral distance from plant and depth of roots (Figure 3). Effective distance from plant and effective depth were 0.84 and 0.53 m, respectively for soil surface wetted area of 10.17 m^2. The effective distances were 1.11 and 1.36 m and the effective depths were 0.53 and 0.58 m for the areas of 23.7 and 28.2 m^2, respectively (Figure 3), demonstrating that the wetted areas on the soil surface promote larger volume of soil for the distribution of roots.

DISCUSSON

The results indicate that the soil surface area wetted influences the physical quality of fruits (F test), with evidence for mean fruit length, whose influence repeated for two of the three cycles evaluated, while the mean fruit weight was only influenced in cycle 3. Fruit dimensions such as length, diameter as well as fruit weight, are important attributes for genetic improvement and especially for market, because they interfere with the preference of the consumer and affect the yield of the fruit (Oliveira et al., 2013).

Fruits produced under the three soil surface wetted areas showed diameter values above 32 mm that is considered as the extra category for Cavendish bananas. These results do not agree with those reported by Figueiredo et al. (2006), who did not observe influence of soil surface wetted area, using one and two lateral lines of drippers, on the length of the central fruit of the second hand of 'Prata-Anã' banana. The influence of soil surface wetted area upon fruit length 'should be related to water and nutrient uptake, since water depth influenced it only on the third cycle in which means were close each other (Table 5). Therefore, the lateral root expansion due to the soil surface wetted area explains better the result.

Results of the range of mean diameter above 32 mm and weight of the central fruit above 180.36 g in all cycles, regardless the irrigation depths agree and disagree with others authors (Figueiredo et al., 2006; Coelho et al., 2006) due to factors not considered as sources of variation in the statistical model. Despite the statistical influence of soil surface wetted area on some physical attributes for one or two crop cycles, the results are not enough to conclude that soil surface wetted area and irrigation water depth affects all attributes of physical quality of banana fruits for general purposes.

Irrigation water depth did not influence leaf area and yield because the range of irrigation water depths from 0.70 to 1.30 ETc corresponded to the one in which the yield rate begins to decrease as irrigation depth increases. Larger yield rate reduction occurred for irrigation water depths in between 1.0 and 1.25 ETc, as observed in studies that evaluated banana yield as a function of irrigation depths (Costa et al., 2014; Coelho et al., 2006; Figueiredo et al., 2006). In addition, the non-effect of the irrigation water depth on leaf area and yield may be due to the range of irrigation water depths close to or higher than 0.85 ETc, considering cycles 2 and 3. Mean water contents varied in this range from 80% (-27 kPa) to 88% (-18 kPa) with minimum from 67% (-70 kPa) to 75% (-37 kPa) of available water in the layer of 0.00 to 0.20 m during part of the cycles 2 and 3 (Figure 2). A

Table 3. Analysis of variance of the studied variables.

Source of variation	DF	CFL cycle 1			CFL cycle 2			CFL cycle 3		
		MS	F	Sig	MS	F	Sig	MS	F	Sig
Block	3	2.516	2.03	0.1271	2.374	1.98	0.1350	6.834	2.20	0.1047
Area	2	7.723	6.23	0.0048	0.0339	0.03	*****	19.959	6.43	0.0041
Error A	6	1.240			1.202			3.104		
WD	4	0.193	0.20	*****	1.118	1.04	0.3991	5.075	2.70	0.0456
WD*Area	8	1.094	1.12	0.3763	0.7639	0.71	*****	2.477	1.32	0.2652
Residual	36	0.981			1.0731			1.877		
CV			3.9245			4.127			5.799	

Source of variation	DF	CFD cycle 1			CFD cycle 2			CFD cycle 3		
		MS	F	Sig	MS	F	Sig	MS	F	Sig
Block	3	0.0178	1.82	0.1603	0.00361	0.20	*****	0.05044	1.85	0.1558
Area	2	0.00889	0.91	*****	0.06358	3.55	0.0391	0.00334	0.12	*****
Error A	6	0.00976			0.01789			0.02728		
WD	4	0.00516	0.51	*****	0.01534	0.72	*****	0.00658	0.26	*****
WD*Area	8	0.00537	0.53	*****	0.01160	0.55	*****	0.00945	0.37	*****
Residual	36	0.01015			0.02116			0.02543		
CV			2.9124			4.1135			4.6517	

Source of variation	DF	CFW cycle 1			CFW cycle 2			CFW cycle 3		
		MS	F	Sig	MS	F	Sig	MS	F	Sig
Block	3	631.854	1.25	0.3077	290.490	0.95	*****	1271.503	1.68	0.1885
Area	2	876.209	1.73	0.1922	81.5557	0.27	*****	2638.897	3.49	0.0413
Error A	6	507.376			305.388			756.7063		
WD	4	59.0762	0.19	*****	129.034	0.34	*****	943.2189	2.12	0.0981
WD*Area	8	316.565	1.02	0.4373	148.229	0.39	*****	386.6066	0.87	*****
Residual	36	309.618			383.917			444.3803		
CV			9.5067			10.356			12.750	

Source of variation	DF	TLA cycle 1			TLA cycle 2			TLA cycle 3		
		MS	F	Sig	MS	F	Sig	MS	F	Sig
Block	3	14.2674	3.83	0.0178	44.260	5.07	0.0050	12.538	6.43	0.0013
Area	2	63.9263	17.14	0.0000	16.4275	1.88	0.1670	28.661	14.70	0.0000
Error A	6	3.72986			8.72839			1.9502		
WD	4	1.24283	0.42	*****	7.33638	1.39	0.2562	3.3582	1.31	0.2833
WD*Area	8	2.75924	0.93	*****	4.56882	0.87	*****	2.6019	1.02	0.4402
Residual	36	2.98092			5.26966			2.555		
CV			13.522			17.534			19.972	

Source of variation	DF	Y cycle 1			Y cycle 2			Y cycle 3		
		MS	F	Sig	MS	F	Sig	MS	F	Sig
Block	3	167.74	2.17	0.1088	147.854	2.79	0.0546	1279.404	9.11	0.0001
Area	2	718.87	9.29	0.0006	246.06	4.64	0.0161	1030.749	7.34	0.0021
Error A	6	77.39			53.051			140.455		
WD	4	6.89	0.24	*****	41.806	1.21	0.3233	227.674	1.95	0.1227
WD*Area	8	11.697	0.41	*****	12.666	0.37	*****	44.497	0.38	*****
Residual	36	28.274			34.539			116.548		
CV			12.60			15.014			22.170	

WD, Water depth; DF, degrees of freedom; CV, coefficient of variation; MS, mean square; Sig, significance; CFL, central fruit length; CFD, central fruit diameter; CFW, central fruit weight; TLA, total leaf area; Y, yield.

Table 4. Mean central fruit length (CFL), diameter (CFD) and weight (CFW) of fruits for the different soil surface wetted areas and under different irrigation water depths for the three evaluation cycles.

Wetted areas	Central fruit length (mm)			Central fruit diameter (mm)			Central fruit weight (g)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
A1	24.62 B	24.98	22.25 B	34.56	36.00 A	34.19	176.49	189.62	149.35 B
A2	26.10 A	25.22	24.47 A	34.84	35.15 B	34.26	193.00	191.80	174.56 A
A3	25.00 B	25.11	24.14 A	34.38	34.94 B	34.40	185.78	186.18	172.11 A
% ETc	Cycle 1	Cycle 2	Cycle 3*	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
0.70	25.17	25.36	22.20	34.28	35.09	33.15	183.76	191.22	144.27
0.85	25.07	24.79	23.99	35.04	34.91	35.18	186.11	181.69	175.31
1.00	25.07	24.92	23.90	34.43	35.64	34.04	180.36	189.56	171.81
1.15	25.41	25.27	24.12	34.80	36.05	34.78	190.00	196.08	169.60
1.30	25.47	25.17	23.90	34.41	35.15	34.27	185.21	187.46	165.71

Means followed by equal uppercase letters in the column do not differ by Tukey test at 0.05 probability level.

Table 5. Leaf area and yield for the different wetted areas and under different irrigation water depths for the three evaluation cycles.

Wetted area (m^2)	Leaf area (m^2)			Yield ($t\ ha^{-1}$)		
	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
10.17	10.60^B	11.95	6.48^B	35.60C	35.13^B	39.55^B
23.74	14.37^A	14.07	8.80^A	48.69^A	42.96^A	53.27^A
24.18	13.33^A	13.25	8.73^A	42.28^B	39.34^{AB}	53.27^A
% ETc	Cycle 1	Cycle 2	Cycle 3	Cycle 1	Cycle 2	Cycle 3
0.70	12.86	14.19	7.67	41.36	41.05	44.55
0.85	12.56	12.07	7.81	37.33	42.28	50.19
1.00	12.75	13.01	8.60	38.43	42.07	52.87
1.15	12.13	13.05	8.30	38.96	42.33	49.20
1.30	13.54	13.14	7.64	39.64	43.24	46.68

Means followed by equal uppercase letters in the column do not differ for each cycle by Tukey test at 0.05 probability level.

20% depletion of soil water availability is the limit for beginning stress for banana crop (Robson and Bower, 1987).

The yields obtained in cycle 3 for the soil surface wetted area of 23.74 m^2 were similar to the 'Grand Naine' yields reported by Goenaga and Irizarry (1986), who observed maximum estimated value of 47.9 $t\ ha^{-1}$ for the water depth correspondent to 1.0 of class A pan evaporation. On the other hand, even with lower leaf area in cycle 3, the yield was higher than in the other cycles, suggesting the existence of other factors that may have influenced the increase in yield. The values of leaf area in cycles 1 and 2 are similar to those found by Coelho et al. (2006) for 'Grand Naine' banana. An exception occurred for leaf area in cycle 3, which showed the lowest value (8.00 m^2). However, this value is similar to that obtained by Oliveira et al. (2013), who reported maximum leaf area of 9.35 m² for 'Grand Naine' banana, 10 months after planting, with an estimated irrigation depth of 1,276 mm $cycle^{-1}$, in the Coastal Plains of Cruz das Almas, Bahia.

The higher values of leaf area and yield of 'Grand Naine' banana, cultivated under irrigation configurations with the greater soil surface wetted areas, 23.74 and 28.26 m^2, are associated with the larger wetted volume of soil to which these superficial soil surface wetted areas corresponded. Fifteen percent of roots were at distance of 0.15 m and 100% of roots at 1.36 m from plant for surface wetted area of 10.17 m^2 while less than 20% of roots were at 0.15 m from plant and 100% of roots was also at 1.36 m for 28.2 m^2 (Figure 3). A hundred percent of roots were found at depth of 0.75 m for surface wetted area of 10.17 m^2 while for 28.2 m^2 they were found at 0.90 m depth (Figure 3). Larger expansion of the root system as in distance or in depth represents more nutrients and water uptake per unit of soil volume. Therefore, it increases nutrient in plants (Donato et al., 2010), promotes higher vigor to the plants (Donato et al., 2013) contributing to the increment of fruit physical

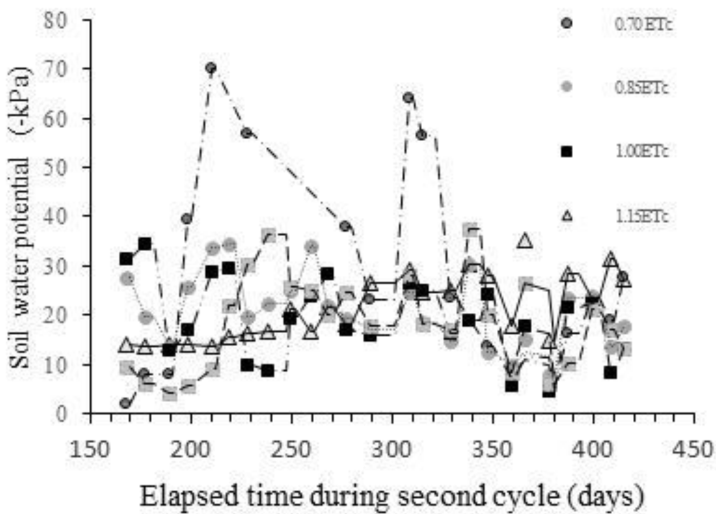

Figure 2. Soil water tension referring to the different water depths applied through irrigation during the second cycle.

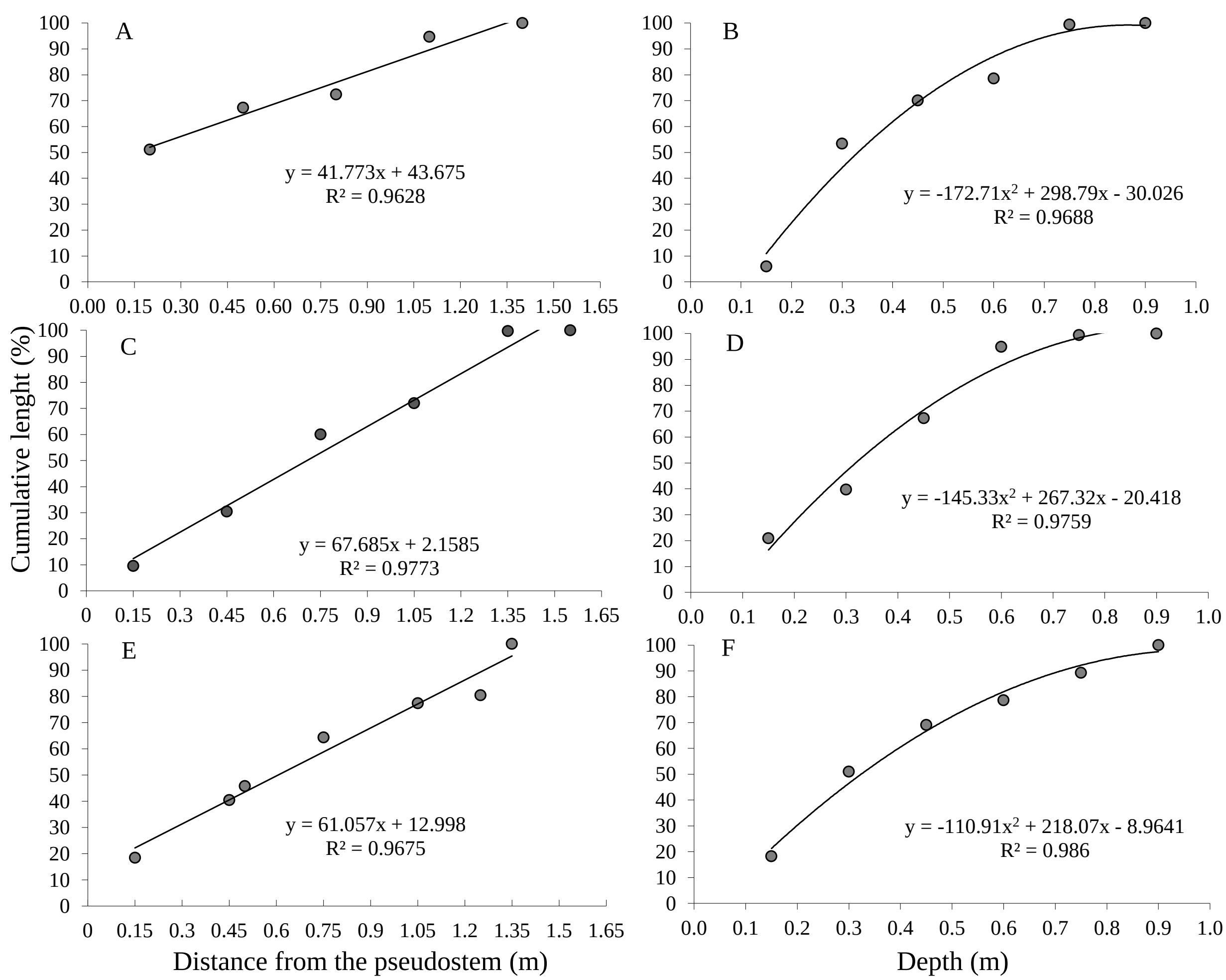

Figure 3. Cumulative root length (%) as a function of the distance from the plant (A) and soil depth (B) for the soil surface wetted area of 10.17 m^2, distance (C) and depth (D) for the soil surface wetted area of 23.7 m^2 and distance (E) and depth (F) for the soil surface wetted area of 28.2 m^2. Nova Porteirinha-MG, Brazil.

quality and yield of banana crop as observed in the present study.

Conclusions

1. Central fruit diameter and weight, leaf area and yield of 'Grand Naine' banana are not altered by irrigation depths from 821 to 1,525 mm for a total evapotranspiration in the cycle of 1,108 mm, as well as for irrigation depths equal to or higher than 991 mm and total crop evapotranspiration in the cycle equal to or higher than 1,466 mm;
2. Larger soil surface wetted area promotes greater expansion of the root system, higher leaf area, higher fruit length and higher yield in 'Grand Naine' banana;
3. The use of micro-sprinklers with greater radius of throw, equal to or higher than 2.70 m, promoted wetted volume with better moisture conditions for the production of 'Grand Naine' banana, considering fractions of the required water depths between 0.85 and 1.15 of ETc or water depths between 897 and 1,349 mm for 1,108 mm of ETc during the cycle, between 1,204 and 1,629 mm for 1,466 mm of ETc during the cycle and between 1,813 and 2,353 mm for 2,097 mm of ETc during the cycle.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Allen RG, Pereira LS, Raes D, Smith M (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome 300(9):D05109.

Coelho EF, Ledo CAS, Silva SO (2006). Produtividade da bananeira 'Prata-Anã' e 'Grand Naine' no terceiro ciclo sob irrigação por microaspersão em tabuleiros costeiros da Bahia. Rev. Bras. Frutic. 28(3):435-438.

Coelho EF, Oliveira RC, Pamponet AJM (2013). Necessidades hídricas de bananeira tipo Terra em condições de tabuleiros costeiros. Pesqui. Agropecu. Bras. 48(9):1260-1268.

Coelho EF, Simões WL , Carvalho JEB (2008). Distribuição de raízes e extração de água do solo em fruteiras tropicais sob irrigação. Cruz das Almas, BA: Embrapa Mandioca Frutic. Trop. 80p.

Costa FS, Coelho EF, Borges AL, Pamponet AJM, Silva ASM, Azevedo NF (2014). Crescimento, produção e acúmulo de potássio em bananeira 'Galil 18' sob irrigação e fertilização potássica. Pesqui. Agropecu. Bras. 47(3):409-416.

Donato SLR, Coelho EF, Santos MR, Arantes A, Rodrigues MG V (2015). Eficiência de uso da água em bananeira. Informe Agropecu. 36(288):46-59.

Donato SLR, Lédo A, Pereira MCT, Coelho EF, Cotrim CE (2010). Estado nutricional de bananeiras tipo prata sob diferentes sistemas de irrigação. Pesqui. Agropecu. Bras. 45(9):980-988.

Donato SLR, Marques PR, Coelho EF (2013). Vegetative traits and yields of a 'Dwarf Pome' and its tetraploid hybrid under different irrigation systems. Acta Hortic. 986(17):131-138.

FAOSTAT (2015). Food and Agriculture Organization of the United Nations. Disponível em: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor. Access in july 22, 2015.

Figueiredo FP, Mantovani EC, Soares A, Costa LC, Ramos M, Oliveira FG (2006). Produtividade e qualidade da banana prata anã, influenciada por lâminas de água, cultivada no Norte de Minas Gerais. Rev. Bras. Eng. Agríc. Ambient. 10(4):798-803.

Goenaga R, Irizarry H (1998) Yield of banana grown with with supplemental drip irrigation on na ultisol. Exp. Agric. 34(4):439-448.

IBGE-SIDRA (2016). Produção agrícola municipal. Disponível em: http://www.sidra.ibge.gov.br. Acesso em 05 jul. 2016.

Kissel E, Van Asten P, Swennen R, Lorenzen J, Carpentier SC (2015). Transpiration efficiency versus growth: Exploring the banana biodiversity for drought tolerance. Sci. Hortic. 185:175-182.

Montenegro AAT, Gomes ARM, Miranda FR, Crisóstomo LA (2008). Evapotranspiração e coeficiente de cultivo da bananeira para a região litorânea do Ceará. Rev. Ciênc. Agron. 39(2):203-208.

Muthusamy M, Uma S, Backiyarani S, Saraswathi MS (2014). Computational prediction, identification, and expression profiling of microRNAs in banana (*Musa* spp.) during soil moisture deficit stress. J. Hortic. Sci. Biotechnol. 89(2):208-214.

Oliveira CG, Donato SLR, Mizobutsi GP, Silva JM, Mizobutsi EH (2013). Características pós-colheita de bananas 'Prata-Anã' e 'BRS Platina' armazenadas sob refrigeração. Rev. Bras. Frutic. 35(3):891-897.

Oliveira JM, Coelho FMA, Coelho EF (2013). Crescimento da bananeira Grande Naine submetida a diferentes lâminas de irrigação em tabuleiro costeiro. Rev. Bras. Eng. Agríc. Ambient. 17:1038-1046.

PBMH PIF (2006). Programa Brasileiro para a Modernização da Horticultura e Produção Integrada de Frutas. Normas de classificação de banana. São Paulo: CEAGESP. (Documentos, 29).

Ravi I, Uma S, Vaganam MM, Mustaffa MM (2013). Phenotyping bananas for drought resistance. Frontiers Physiol. 4(1):1-15.

Robson JC, Bower JP (1987) Transpiration characteristics of banana leaves (Cultivar 'Williams') in response to progressive depletion of available soil moisture. Sci. Hortic. 30:289-300.

Rocha FJ (2009). Resposta da lima ácida 'Taithi' (*Citrus latiolia* Tan.) a diferentes percentagens de área molhada. Piracicaba: ESALQ-USP. 56 p.

Sant'ana JAV, Coelho EF, Faria MA, Silva EL, Donato SLR (2012). Distribuição de raízes de bananeira "Prata- Anã" no segundo ciclo de produção sob três sistemas de irrigação. Rev. Bras. Frutic. 34(1):124-132.

Silva EN, Bezerra FML (2009). Evapotranspiração e coeficientes de cultivo da bananeira no Vale do Curu, CE. Rev. Ciênc. Agron. 40(2):203-210.

Surendar KK, Devi DD, Jeyakumar P, Velayudham K, Ravi I (2015). Changes in Proline and Polyphenol oxidase enzyme activity in some Banana Cultivars and Hybrids under water stress. Genom. Appl. Biol. 6(4):1-6.

Surendar KK, Rajendran V, Devi DD, Jeyakumar P, Ravi I, Velayudra MK (2013). Impact of water deficit on growth attributes and yields of banana cultivars and hybrids. Afr. J. Agric. Res. 8(48):6116-6308.

Teixeira AHC, Bassoi LH, Costa WPLB, Silva JAM, Silva EG (2002). Consumo hídrico da bananeira no Vale do São Francisco estimado pelo método da razão de Bowen. Rev. Bras. Agrometeorol. 10(1):45-50.

Vanhove AC, Vermaelen W, Panis B, Swennen R, Carpentier SC (2012). Screening the banana biodiversity for drought tolerance: can an *in vitro* growth model and proteomics be used as a tool to discover tolerant varieties and understand homeostasis. Frontiers Plant Sci. 3(176):1-10.