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Fruit yield and root system distribution of 'Tommy Atkins' mango under different irrigation regimes[1]

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Key words:
regulated deficit irrigation
effective rooting depth
irrigation management

ABSTRACT

This study aimed to evaluate the fruit yield and the distribution of 'Tommy Atkins' mango root system under different irrigation regimes in the semiarid region of Bahia. The experimental design was completely randomized with five treatments and three replicates: 1 - Irrigation supplying 100% of ETc in phases I, II and III; 2 - Regulated deficit irrigation (RDI) supplying 50% of ETc in phase I (beginning of flowering to early fruit growth); 3 - RDI supplying 50% ETc in phase II (start of expansion until the beginning of physiological maturity); 4 - RDI supplying 50% ETc in phase III (physiological mature fruits); 5 – No irrigation during all three phases. The regulated deficit irrigation supplying 50% of the ETc during phase I and II provided larger root length density of 'Tommy Atkins' mango. Regardless of management strategy, the roots were developed in all evaluated soil volume and the highest density is concentrated from 0.50 to 1.50 m distance from the trunk and in 0.20 to 0.90 m depth in the soil, that suggests this region to be the best place for fertilizer application as well for soil water sensor placement. The application of RDI during fruit set does not influence either root distribution or production. Root system and crop production is significantly reduced under no irrigation conditions.

Palavras-chave:
irrigação com déficit regulado
profundidade efetiva das raízes
manejo de irrigação

Produtividade e distribuição do sistema radicular da mangueira 'Tommy Atkins' sob diferentes regimes de irrigação

RESUMO

Objetivou-se, com este trabalho, avaliar o rendimento de frutos e a distribuição do sistema radicular da mangueira 'Tommy Atkins' em diferentes regimes de irrigação no semiárido baiano. O delineamento experimental foi inteiramente casualizado com cinco tratamentos e três repetições: 1 - Irrigação suprindo 100% da ETc; 2 - Irrigação com déficit regulado (RDI) com 50% da ETc na fase I; 3 – RDI com 50% ETc na fase II; 4 - RDI com 50% ETc na fase III; 5 - Sem irrigação, nas fases: I (início da floração ao início da expansão dos frutos), II (início da expansão até início da maturação fisiológica) e na fase III (maturação fisiológica dos frutos). A irrigação com déficit hídrico controlado a 50% da ETc nas fases de pegamento e expansão dos frutos proporciona maior densidade de comprimento de raízes da mangueira 'Tommy Atkins'. Maior densidade de raízes independente da irrigação concentra de 0.50-1.50 m de distância a partir do tronco e 0.20-0.90 m de profundidade no solo, o que sugere ser o local mais adequado para aplicação de fertilizantes e posicionamento de sensor de umidade do solo. A aplicação da RDI durante a fase de maturação dos frutos não influencia na distribuição do sistema radicular ou produção. O sistema radicular e a produtividade são significativamente reduzidos quando em condição não irrigada.

Introduction

The knowledge of distribution of root system of agricultural crops enables accurate decision-making for a rational and sustainable use of cultural practices such as soil and water management and crop fertilization (Coelho et al., 2002; Santos et al., 2005; Sant'ana et al., 2012). Root length density (RLD) is a critical feature in determining crop potential to absorb water and nutrients (Azevedo et al., 2011).

The distribution patterns of mango root system and any other crop are consequences of the interaction among genetic factors, soil profile characteristics, soil water content that acts on the soil resistance to root penetration and component of water/air distribution.

The mango is cultivated in all northeastern states of Brazil, particularly in irrigated areas of the semiarid region, which have excellent conditions for crop development and achieving high yields and fruit quality. Water demand exceeds its availability in this region. In a vision of production and environmental sustainability, irrigation management strategies in relation to the rational water use should be adopted. In this context, the irrigation techniques called regulated deficit irrigation (RDI) and partial rootzone drying (PRD) can be highlighted.

Regulated deficit irrigation uses water stress to control vegetative and reproductive growth. It was initially applied in peach and pear orchards to control growth by imposing water stress at key stages of fruit development (McCarthy, 2000). RDI is an irrigation strategy used for fruit and other crops, that consists of water application with deficits during development stages of the plant whose growth and fruit quality have low sensitivity to water stress. This makes possible to reduce consumption of water and energy without large losses of fruit quality and production.

In mango the RDI was objective of research in Brazil by Silva et al. (2009), Cotrim et al. (2011) and Santos et al. (2013). These studies show that considerable amounts of water may be saved without affecting yield.

Mango root system is characterized by a taproot that may extend well into the soil, which provides good support of the plant and its survival during times of drought.

Studies in the scope of root system distribution of the mango (*Mangifera indica* L.) are little explored, especially regarding plants of different ages and submitted to different irrigation regimes.

In a study conducted by Choudhury & Soares (1992) with 'Tommy Atkins', irrigated by sprinkling under foliage in Latosol in Fruitfort Farm, Petrolina – Pernambuco, Brazil, the authors conclued that 68% of root absorption and 86% of support roots are located in the horizontal range from 0.90 to 2.60 m in relation to the trunk and in 0 to 1.00 m depth.

Coelho et al. (2001) evaluated the root distribution of 'Tommy Atkins' mangoes under localized irrigation (drip and micro-sprinklers) in sandy soil of coastal plains. In general, in a drip system, the plant roots were limited to 3.5 m from the trunk horizontally and 1.4 m in depth. Roots were limited to 3.0 m from the trunk and also to a depth of 1.4 m for micro-sprinkle.

Root length segments have been determined from digital images obtained from field in video camera (Crestana et al., 1994) or from computer scanners (Coelho et al., 2001; 2005).

This study aimed to evaluate the fruit yield and the distribution of 'Tommy Atkins' mango root system under different irrigation strategies in the semiarid region of the Bahia State, Brazil.

Material And Methods

The study was conducted in an experimental area of the Development Company of the Valley of San Francisco and Parnaíba (CODEVASF) located at the Irrigated Perimeter of Ceraíma in the city of Guanambi, Southwest of Bahia (14° 17' 27" S, 42° 46' 53" W and 537 m of altitude). The mean annual rainfall is 680 mm and average annual temperature is 25.6 °C in an euthrophic Fluvic Neosol with high activity clay (Table 1).

Figure 1 depicts the daily values of precipitation and mean temperature values during the period of January 2010 to January 2012 in which the experiment was conducted.

Table 1. Physical characteristics of Fluvic Neosol

Physical characteristics	Depth (m)			
	0-0.25	0.25-0.50	0.50- 0.75	0.75-1.00
Coarse sand (g kg^{-1})[1]	80	50	10	0
Fine sand (g kg^{-1})[1]	410	430	760	160
Silt (g kg^{-1})[2]	270	280	120	520
Clay (g kg^{-1})[2]	240	240	110	320
Bulk density (kg dm^{-3})[3]	1.62	1.38	1.34	1.31
Water content at -10 kPa (m^3 m^{-3})[4]	0.43	0.37	0.19	0.54
Water content at-1.500 kPa (m^3 m^{-3})[4]	0.15	0.12	0.05	0.16

[1] By screening;
[2] Pipette method;
[3] Cylinder and the volumetric ring method;
[4] Porous plate equipment.

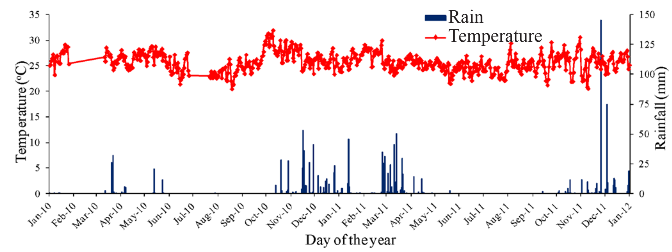

Figure 1. Average temperature (TEM) and rainfall (Rain) per day during years 2010 and 2011 in Ceraima, Guanambi, Bahia, Brazil

The experiment was conducted in an 11 and 12 year age orchard with plants at 8.0 x 8.0 m spacing, from flowering to fruit ripening. Plants were irrigated by micro-sprinklers with an emitter per plant, of 50 L h^{-1} flow rate at 200 kPa nominal pressure.

Common crop practices were used such as pruning followed by fertilization of 500 g of MAP (monoammonium phosphate), 200 g of ammonium sulfate, 150 g of potassium chloride and 20 kg of chicken manure per plant. Irrigation was performed daily during a period in which the plant emitted two vegetative shoots. After emitting the shoots, irrigation was ceased (Mouco & Albuquerque, 2005) and there was subsequent application of growth regulator, Paclobutrazol.

The study was based on the use of three irrigation strategies, being the regulated deficit irrigation (RDI), full irrigation and no irrigation.

The regulated deficit irrigation treatments were applied from flowering to fruit ripening in all three phases of fruit development as described by Cotrim et al. (2011). Phase I corresponds to the start of flowering (IF) and runs until fruit establishment, which happens around 65 days after the onset of flowering. Phase II comprises the expansion of the fruit occurring during 65 to 95 days after the IF. Phase III starts at the end of fruit growth and runs up to around 120 days after the IF (harvest).

The treatments were the following: 1 - Irrigation supplying 100% of crop evapotranspiration (ETc) in the phases I, II and III; 2 - RDI with 50% of ETc in phase I; 3 - RDI with 50% ETc in phase II; 4 - RDI with 50% ETc in phase III; 5 – No irrigation. Treatments were applied by varying irrigation time through control valves. Irrigation was performed based on reference evapotranspiration (ETo) determined daily by means of the

Penman-Monteith method (FAO standard method) (Allen et al., 1998), using data from an automatic weather station installed near the orchard. The crop coefficients (K_c) used in the calculation of evapotranspiration varied from 0.45 to 0.87 during the assessment phases, as used by Cotrim et al. (2011).

The irrigation water depths applied to various treatments are included in Figure 2. The irrigation started ten days after flowering and ended at 115 and 136 days after flowering when rainy season started, for cycles 1 and 2 of evaluation, respectively. From 115 and 136 days after flowering for cycles 1 and 2 of evaluation, precipitation supplied all evapotranspirometric crop demand. The water used for irrigation with electrical conductivity between 0.62 to 1.32 dS m^{-1} was pumped from wells in the experimental area.

A completely randomized design was used with five treatments and 3 replicates being one plant the experimental plot. The collection of roots was made after the harvest of the second cycle of evaluations. For each experimental plot, a trench was dug with the following dimensions (2.50 x 0.50 x 1.00 m in length, width and depth, respectively) in the longitudinal direction to the plant row. The volume of each sample was 500 cm^3 (10.00 x 10.00 x 5.00 cm in length, width and height, respectively). Samples were collected in four (4) depths and five (5) distances from the trunk. The mean sampled depths were 0.10, 0.35, 0.60 and 0.85 m beginning at 0.50 m from the trunk and driving away by increments of 0.50 m horizontally until reaching 2.5 m distance. After removal of roots with soil, samples were placed in plastic bags and taken to the laboratory where roots were separated from soil by washing with water. Once separated, the roots of each position of the soil profile were classified according to the diameters of the segments on transparency sheets and were digitized by using a scanner (Kaspar & Ewing, 1997; Coelho & Or, 1999) in TIFF files ("Tagged Image File Format").

Tagged Image File Format files were analysed using Adobe Photoshop to clean dark edges caused in the scanning process and submitted to the application Rootedge (Kaspar & Ewing, 1997) for determining the geometric characteristics: length and diameter of the roots. The root length, Lr (cm) was used to determine the root density length, RDL (cm cm^{-3}) in a sample volume Vr (cm^3), being the RDL = Lr Vr^{-1}.

Root density length was analysed considering all roots per treatment, very fine roots (diameter below 0.55 mm), fine roots (with diameter between 0.55 and 2.05 mm), small roots (diameter between 2.05 and 5.05 mm) and medium to very large roots (diameter above 5.05 mm) as Coelho et al. (2001).

Data analysis used a factorial scheme with variation sources: five treatments (water application regimes), five distances from the trunk and four depths. The means were compared by using Tukey test ($p < 0,05$).

Results and Discussion

It is seen in Figure 3A, B, C and D the density of root length (cm cm^{-3}) for full irrigation treatments in the three stages of fruit development, RDI with 50% of ETc in the phase of beginning of flowering to early fruit growth, RDI 50% of ETc in the phase of fruit expansion, and RDI 50% of ETc in the physiological maturation of the fruit, respectively.

The distribution of RDL is influenced by the water content in the soil as a result of management of irrigation adopted. Treatments 2 and 3 with the highest average of RDL in the

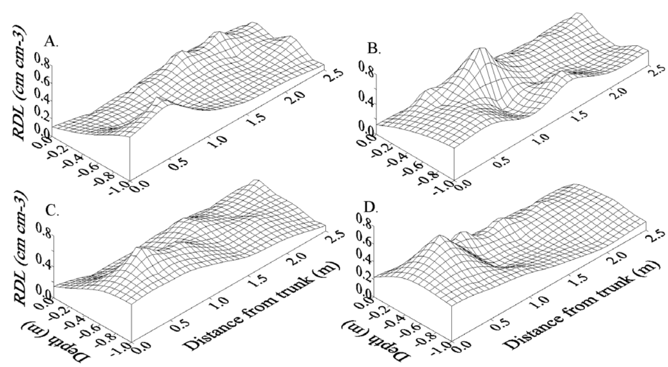

Figure 3. Root density length for irrigation treatments, 1 - 100% ETc in phases I, II and III (A); 2 - 50% ETc phase 1 (B); 3 - 50% ETc in phase II (C) and 4 - 50% ETc in phase III (D)

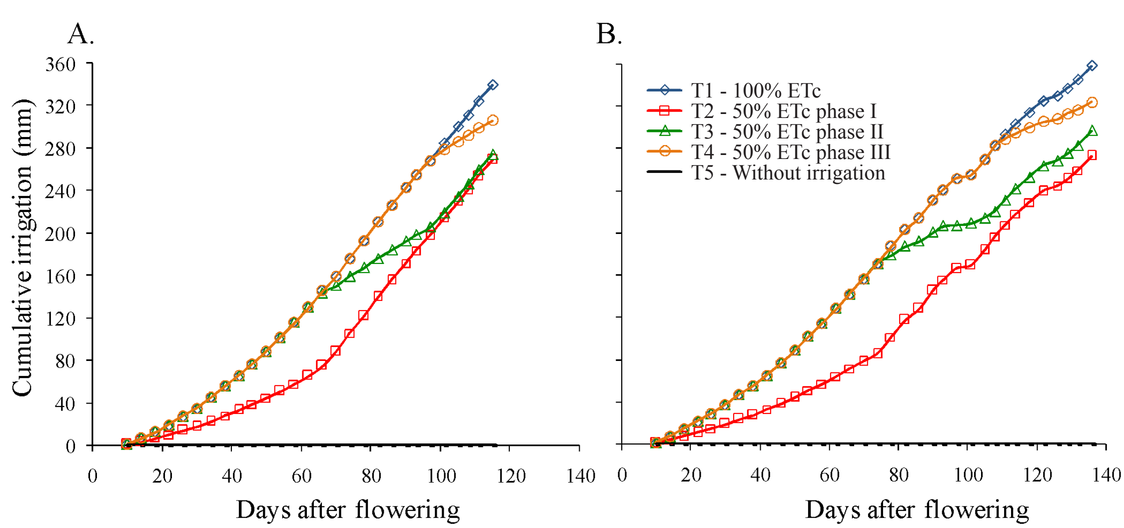

Figure 2. Cumulative irrigation applied in different treatments of RDI in 'Tommy Atkins' mangoes during the evaluation period, (A) first cycle and (B) second cycle

evaluated profile differed from treatment 5 (no irrigation), with lower RDL. There were no differences in RDL between treatments 1, 2, 3 and 4, as well as between treatments 1, 4 and 5. With these results, it is inferred that there is a tendency in RDL to increase when the plant surpasses the deficit in the stages of flowering and fruit expansion where the crop requires more water content in the soil. This can be attributed to the fact that under conditions of water deficit there is greater investment in roots (Taiz & Zeiger, 2009). These results corroborate to those showed by Boni et al. (2008), who verified larger vertical and horizontal root distribution for cashew cultivated in non irrigated conditions compared to irrigation conditions. The search for water is more intense by roots under smaller soil water availability. Since the mean annual precipitation at Paraipaba, Ceará, is about 985.7 mm, the precipitation levels, even under non irrigated conditions caused water deficit in the soil contributing to keep root alive and to promote larger development.

It is widely accepted in the literature that roots of plants under moderate water deficit grows more than those that receive adequately water (Kramer & Boyer, 1995). This is explained by: (a) greater allocation of photoassmilates for root system, that enables water uptake at deeper soil layers and (b) availability of soil water content enough to keep root turgor and to provide root growth. On the other hand, irrigated plants show smaller root growth and larger aerial part. However, plants cultivated under irrigation and submitted to total soil water deficit as in the present work, as they are submitted to initial soil drying, they still show root growth larger than irrigated plants. When soil dries completely there is loss of turgor and root death and this may justify the same amount of roots in both treatments: irrigated and non-irrigated.

Considering the average RDL of 'Tommy Atkins' mango, regardless of management strategy under micro-sprinklers (Figure 4A), the RDL is included in the 2.5 m away from the trunk and the highest density is concentrated from 0.50 to 1.50 distance from the plant and from 0.20 to 0.90 m depth in the soil, that indicates suitable locations for sensor placement for water content evaluation for irrigation scheduling and locations for solid fertilizer application. The highest values of RDL near the plant may be related to increased volume in wet soil due to more emission of water by micro-sprinklers up to a mean radius of 1.50 m, and the fact that fertilizations have been carried out on a track in a circle distant 1.0 m the from the trunk. A similar result was found by Coelho et al. (2001), who, working with distribution of root system of 'Tommy Atkins' mango under micro-sprinkling observed greater root length density in the regions limited by the horizontal distances from the trunk from 0 to 3.0 m and depths ranging from 1.2 m (up to the horizontal distance of 0.5 from the trunk) and between 0 and 0.6 m for horizontal distances above 0.5 m.

Santos (1997) found that 86.5% of the total mango root length is located at a distance of 1.75 m from the plant. They also found that 70% of the total length is at 0.75 m soil depth. Concerning the distribution of roots from the trunk, the results obtained in this study corroborated to the ones of Santos (1997), and therefore, in the vertical reference the results showed greater root length density from 0.40 to 0.80 m depths. It is noteworthy that Santos (1997) used a five year old Haden cultivar and this study was carried out with a 12 year old 'Tommy Atkins'.

Under no irrigation (Figure 4B) the RDL is reduced throughout the profile. Roots become less turgid due to the continuous soil water stress; as a consequence many die contributing to RLD reduction. On the other hand, RLD of the crop under irrigation tends to be larger in the profile with higher wet volume and, under micro-sprinkler, the highest contribution of the wet area is included within the first few meters away from the emitter. When evaluating cashew root system irrigated by micro-sprinkler Boni et al. (2008) found relevant root concentration at depth of 0.25 m at a distance of 0.50 m from trunk. This concentration of roots near the trunk is due to the micro-sprinkler location and water distribution in the soil profile where roots tend to grow at zones of larger water availability for uptake. Coelho et al. (2002) found larger root distribution uniformity around the trunk.

The reduction of root system under non irrigated conditions compared to RDI application during fruit set and growth justify the smaller fruit production in that treatment (Table 2). The smaller number of fruits per plant for no irrigation (treatment 5) differed from the number of fruits of fully irrigated plants (treatment 1) and from the number of fruits of plants under 50% ETc RDI at fruit growth and maturation phases (treatments 3 and 4). Therefore, the application of RDI during fruit set does not influence either root distribution or production. On the other hand, root system and crop production is significantly reduced under no irrigation conditions. These results emphasize

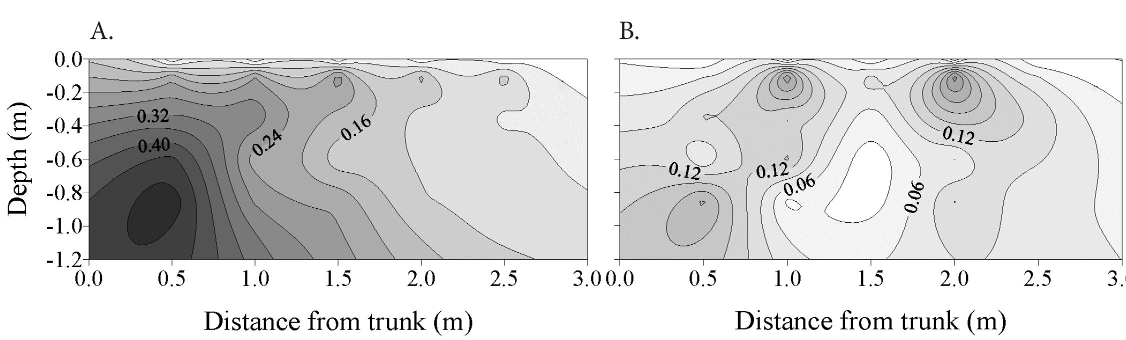

Figure 4. Distribution of root density length (cm cm^{-3}) in the longitudinal direction to the plant row with irrigation (A) and no irrigation (B)

Table 2. Number of fruit per plant for different treatments

Treatment				
1	2	3	4	5
273.3AB	183.0BC	231.5AB	331.2A	80.5C

Means followed by the same letter in the row do not differ by Tukey test ($p > 0.05$)
Treatments 1, 2, 3, 4 and 5 refer to supply of 100% ETc in phases I, II and III, 50% ETc in phase I, phase II and phase III, and without irrigation, respectively

the feasibility of indication of RDI after fruit set phase for 'Tommy Atkins' mango.

Figure 5 shows the root density length (RDL) for different classes of diameters for treatments 1, 2, 3, 4 and 5, respectively. It is observed that for all treatments there is a distribution of roots for all classes of diameters around the profile, mainly for very fine roots (diameter less than 0.55 mm) and fine roots (diameter 0.55 and 2.05 mm) that are those with the highest contribution in the absorption of water and nutrients. This distribution in the soil profile may be related to continuous emergence of new roots from roots of larger diameter class. Under micro-sprinkling, Coelho et al. (2001) observed that very fine roots (0-0.5 mm) occurred between the depths of 0.4 to 0.8 m for horizontal distances less than 1.0 m. The fine roots (0.5- 2.0 mm) occurred up to the depth of 1.5 m for horizontal distances of up to 3.0 m; however, the highest percentages of incidence were registered for depths of 0 to 0.8 m for horizontal distances between 1.0 and 2.0 m. The small roots (2.0-5.0 mm) were also distributed throughout the profile with highest values for horizontal distances between 0 and 2.0 m. The roots above 5.0 mm in diameter concentrated themselves in depths of up to 1.5 m for horizontal distances below 2.0 m**,** such that the increase in the diameter corresponded to shorter horizontal distances from the trunk. In the present study it was found that under full and non-irrigation, the roots with diameters greater than 5.05 mm presented trends in higher RDL with increasing distance from the plant, it is noteworthy that in this work the samples were taken from 0.50 m from the trunk, whereas in the study of Coelho et al. (2001) samples were taken from the trunk, which presents the taproot and secondary roots.

Under irrigated conditions, even with RDI, in general, the results obtained here agree with those of Coelho et al. (2001); however, in non-irrigated conditions, the very fine and small roots (Figure 5A and C, respectively) show a tendency to concentrate on the surface layer at a distance greater than 1.0 m. The small roots are distributed throughout the evaluated profile (Figure 5B) and the roots with diameters greater than 5.05 mm presented higher concentration between the distances of 1.5 to 2.5 m from the trunk, as under non irrigated conditions roots

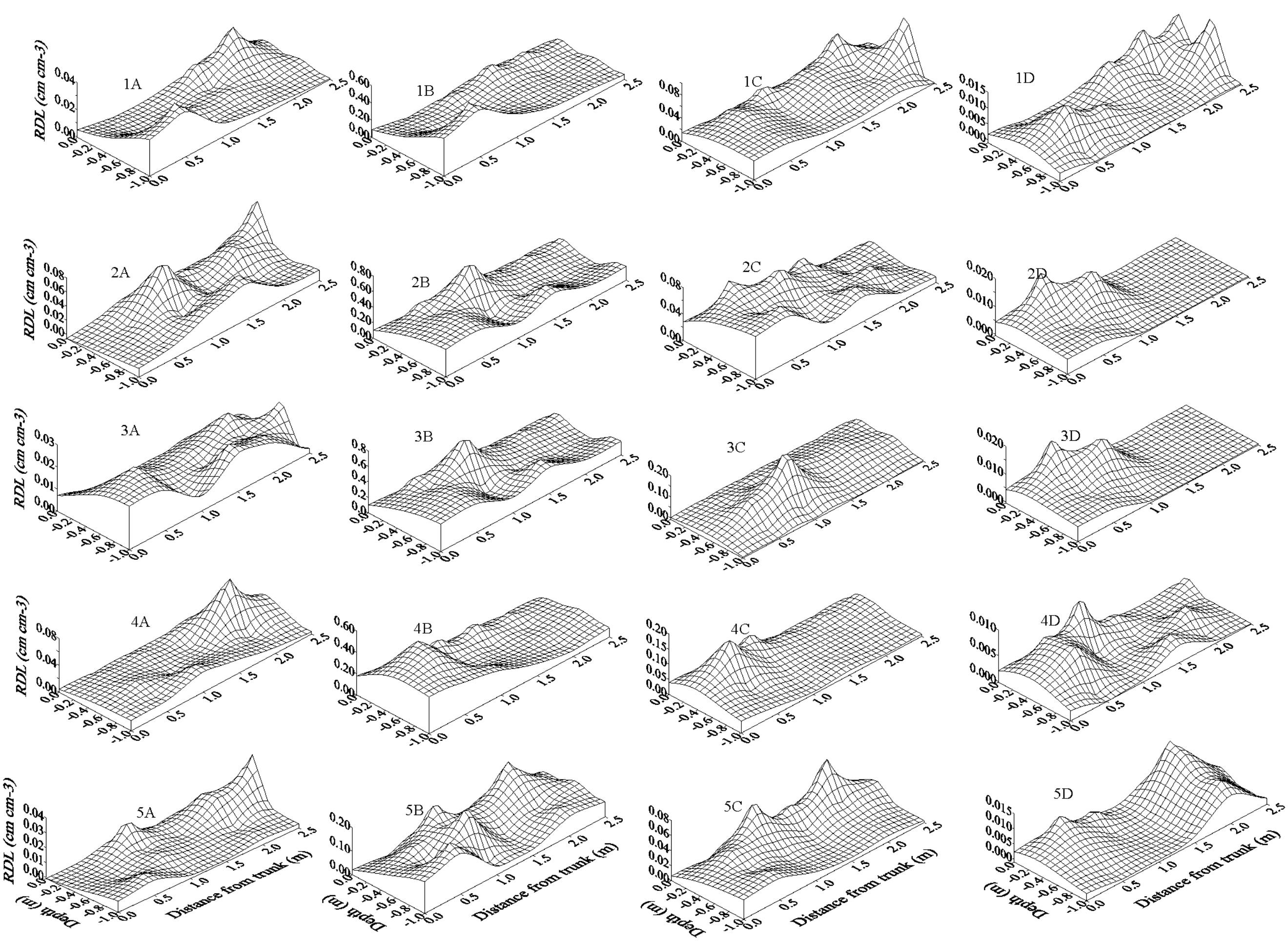

Figure 5. Root density length for treatment 1, 100% of ETc in phases I, II and III (1A-D), treatment 2, RDI with 50% of ETc in phase I (2A-D), treatment 3, RDI with 50% of ETc in phase II (3A-D), treatment 4, RDI with 50% of ETc in phase III (4A-D) and treatment 5, without irrigation (5A-D), Roots with diameter less than 0.55 mm (A); roots with diameter of 0.55 to 2.05 mm (B); roots with diameter of 2.05 mm to 5.05 mm (C) and roots with diameter greater than 5.05 mm (D)

tend to develop more and to concentrate at larger distances from the trunk, that is explained by the search of water by roots which is more intense for plants cultivated under non irrigated conditions (Boni et al., 2008).

Whereas the percentages of total root length, the fine roots with diameter between 0.55 and 2.05 mm represent 73.37% for treatment 5 and 78.63% for treatment 2 of all roots (Table 3). Since this diameter class is related to soil solution uptake and considering the distance from the trunk of 1.50 m as the one with larger concentration of RDL, this emphasizes the indication of place for soil water sensor and for fertilizer application at this distance from the trunk. In case of fertilizing 'Haden' mango in orchards with similar conditions like Selvíra - MS, Almeida et al. (2009) recommend that the soil location for fertilizer application should be in the range between zero and 1.66 m from trunk, where studies showed larger active root system for uptake. For roots with diameters greater than 5.00 mm, the percentages are less than 3.41%, this percentage is low compared to those found by Coelho et al. (2001). Coelho et al. (2001) evaluated root system distribution of 'Tommy Atkins' mango irrigated by micro-sprinkler and found 72,1% of roots with diameter between 0.50 and 2.00 mm and 13.2% of roots with diameter larger than 5.00 mm. These authors have quantified roots from the trunk whereas in the present work roots were quantified up to 0.50 m from the trunk. This proves that roots with larger diameter are located closer to pivotant root.

Regardless of the water imposition, there is reduction in total RDL, RDL of fine roots and RDL of small roots as it moves away from the plant. In Figure 6A-C there are the regression models to estimate the RDL as a function of horizontal distance from the plant. Note that for the average total RDL of fine roots and small roots, the linear model presented good fit with the significant regressive model at 0.01, indicating that for all total RDL, regardless of treatment, at each 1.0 m away from the plant between 0.50 and 2.50 m, there is a reduction of 0.11 cm in length of roots per each 1 cm^3. For fine roots, there is a reduction of 0.10 cm cm^{-3} of RDL per each meter of distance away from the trunk. And for small roots (diameters between 2.05 to 5.05 mm), there is a reduction of 0.02 cm cm^{-3} of RDL per each meter of distance away from the trunk. The decrease of RLD with the distance from trunk is related probably to the smaller soil water availability in the locations at larger distances from the trunk due to the smaller water application intensity

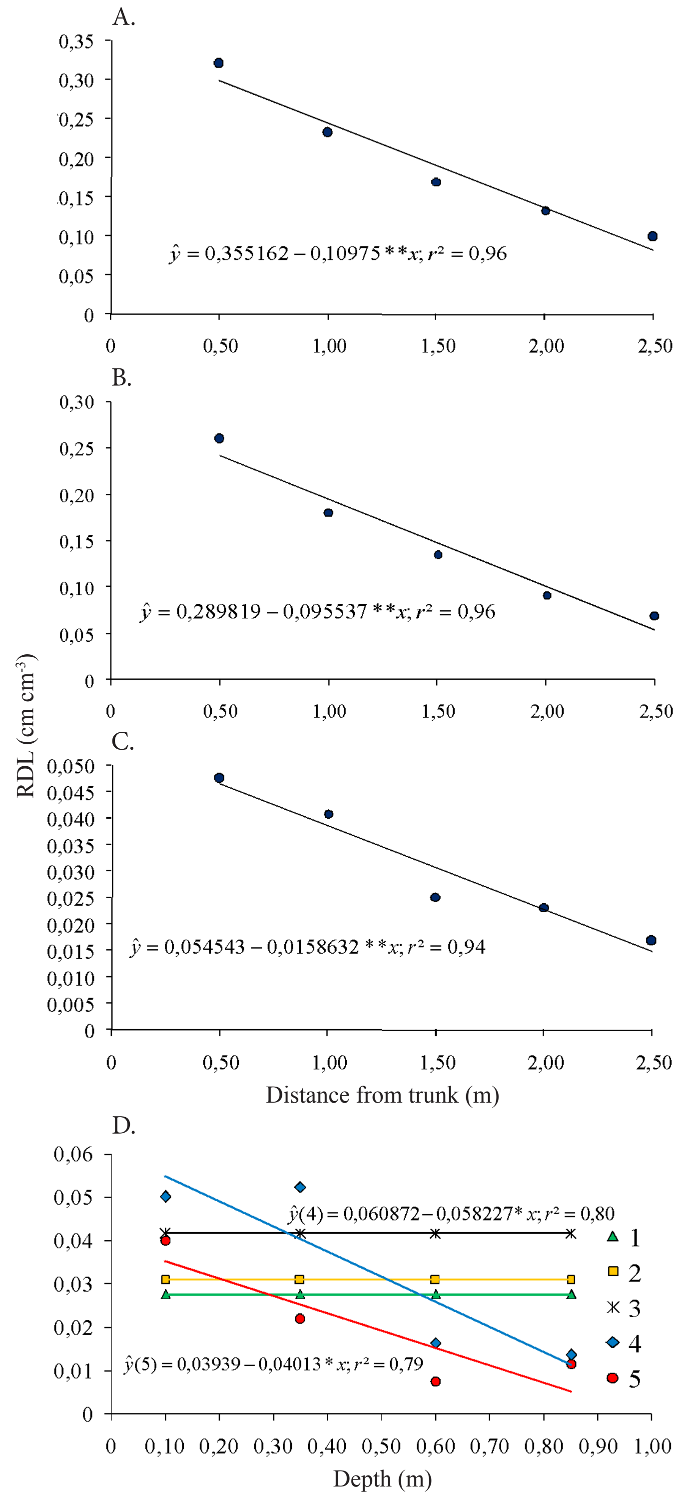

Figure 6. Root density length (cm cm^{-3}) - average total (A), total fine (B), total small (C) and Root density length (cm cm^{-3}) of small roots (D) for treatments 1, 100% of ETc in phases I, II and III; 2, RDI with 50% of ETc in phase I; 3, RDI with 50% of ETc in phase II; 4, RDI with 50% of ETc in phase III and 5, without irrigation

at these locations. Plants respond to spatial and temporal changes of the soil water tension by means of physiological and morphological modifications changing the architecture (spatial configuration) of their root systems; for instance, showing larger

Table 3. Percentage of total root length for the different treatments and for the different classes of diameters (T1. 100% of ETc in phases I, II and III; T2, RDI with 50% of ETc in fhase I; T3, RDI with 50% of ETc in phase II; T4, RDI with 50% of ETc in phase III and T5, No irrigation)

Treatment	Classes of diameter (mm)			
	< 0.55	0.55-2.05	2.05-5.05	>5.05
	% of total length			
T1	4.544	75.059	17.685	2.712
T2	7.674	78.631	12.452	1.242
T3	3.518	76.857	17.293	2.331
T4	7.222	74.949	16.676	1.151
T5	5.680	73.375	17.534	3.415

root growth in the direction of soil zones with larger water and nutrient availability.

Analyzing the vertical distribution of RDL, there were significant differences only for small roots at different depths for treatments 4 and 5. For both cases, a linear regression model was adjusted estimating the small RDL as a result of the depth in the limits between 0.10 and 0.85 m (Figure 6D). There was a reduction in the small RDL of 0.06 cm cm^{-3} for treatment 4 and a reduction of 0.04 cm cm^{-3} for treatment 5 per each 10 cm of depth of soil up to 0.85 m deep.

The results of root distribution under different irrigation regimes allow recommending the application of fertilizer at distances in between 0.5 to 1.5 m from the trunk, since the larger root length density and fine and short length roots are in the soil volume closer to the trunk. The acquisition of water and nutrient is strongly dependent upon fine roots, which fill most of any root system as found in this study for 'Tommy Atkins'. 70.80, 78.61 e 74.16% of total, fine and small roots, respectively, were found in between 0.50 a 1.50 m from the trunk, considering the total evaluated RLD, no matter the irrigation regime. In the same way, the insertion of soil water content sensors for irrigation schedule should take in account the same distances and the depths in between 0.30 and 0.90 m. 76% of total roots are in between 0.35 to 0.85 m depth, no matter the irrigation regime.

Conclusions

1. Regulated deficit irrigation (RDI) of 50% ETc at fruit set and growth provides larger root density length (RDL) of mango 'Tommy Atkins'.

2. Regardless of treatment, total RDL, fine RDL and small RDL of mango 'Tommy Atkins' decrease with increasing from the horizontal distance of the plant. The small RDL under no irrigated conditions and with RDI at physiological maturity presents a reduction with the depth in the soil profile.

3. Regardless of management strategy, the roots were developed in all evaluated soil volume and the highest density is concentrated from 0.50 to 1.50 m distance from the trunk and at 0.20 to 0.90 m depth in the soil that suggests this region to be the best place for fertilizer application as well for soil water sensor placement.

4. The application of RDI during fruit set does not influence in the production and the crop production is reduced under no irrigation condition and RDI during the beginning of flowering to early fruit growth.

Literature Cited

Allen, R. G.; Pereira, L. S.; Raes, D.; Smith, M. Crop evapotranspiration: guidelines for computing crop water requirements. FAO: Rome, 1998. 300p. Irrigation and Dranaige Paper, 56.

Almeida, E. V.; Fernandes, F. M.; Boliani, A. C. Distribuição do sistema radicular do porta-enxerto coquinho sob copa da mangueira cv. Haden. Revista Brasileira de Fruticultura, v.31, p.798-804, 2009.

Azevedo, M. C. B.; Chopart, J. L.; Medina, C. C. Sugarcane root length density and distribution from root intersection counting on a trench-profile. Scientia Agricola, v.68, p.94-101, 2011.

Boni, G.; Costa, C. A. G.; Gondim, R. S.; Montenegro, A. A. T.; Oliveira, V. H. Distribuição do sistema radicular do cajueiro-anão precoce (clone CCP-09) em cultivo irrigado e sequeiro, Ceará, Brasil. Revista Ciência Agronômica, v.39, p.1-6, 2008.

Choudhury, E. N.; Soares, J. M. Comportamento do sistema radicular de fruteiras irrigadas. I. Mangueira em solo arenoso sob irrigação por aspersão subcopa. Revista Brasileira de Fruticultura, v.14, p.169-176, 1992.

Coelho, E. F.; Oliveira, F. C.; Araújo, E. C. E.; Vasconcelos, L. F. L.; Lima, D. M. Distribuição do sistema radicular da mangueira sob irrigação localizada em solo arenoso de tabuleiros costeiros. Revista Brasileira de Fruticultura, v.23, p.250-256, 2001.

Coelho. E. F.; Oliveira, F. C.; Araújo, E. C. E.; Vasconcelos, L. F. L. Distribuição de raízes de laranja 'Pêra' sob sequeiro e irrigação por microaspersão em solo arenoso. Pesquisa Agropecuária Brasileira, v.37, p.603-611, 2002.

Coelho, E. F.; Or, D. Root distribution and water uptake patterns of corn under surface and subsurface drip irrigation. Plant and Soil, v.206, p.123-136, 1999.

Coelho, E. F.; Santos, M. R.; Coelho Filho, M. A. Distribuição de raízes de mamoeiro sob diferentes sistemas de irrigação localizada em Latossolo de Tabuleiros Costeiros. Revista Brasileira de Fruticultura, v.27, p.175-178, 2005.

Cotrim, C. E.; Coelho Filho, M. A.; Coelho, E. F.; Ramos, M. M.; Cecon, P. R. Regulated deficit irrigation and Tommy Atkins mango orchard productivity under microsprinkling in Brazilian semi arid. Engenharia Agrícola, v.31, p.1052-1063, 2011.

Crestana, S.; Guimarães, M. F.; Jorge, L. A. C.; Ralisch, R.; Tozzi, C. L.; Torre, A.; Vaz, C. M. P. Avaliação da distribuição de raízes no solo auxiliada por processamento de imagens digitais. Revista Brasileira de Ciência do Solo, v.18, p.365-371, 1994.

Kaspar, T. C.; Ewing, R. P. Rootedge: Software for measuring root length from desktop scanner images. Agronomy Journal, v.89, p.932-940, 1997.

Kramer, P. J.; Boyer, J. S. Water relations of plants and soil. 2.ed. New York: Academic Press, 1995. 495p.

McCarthy. Regulated deficit irrigation and partial rootzone drying as irrigation management techniques for grapevines. In. Deficit irrigation practices, water reports, Rome: FAO, n.22, 2000. p.79-87.

Mouco, M. A. C.; Albuquerque, J. A. S. Efeito do paclobutrazol em duas épocas de produção da mangueira. Bragantia, v.64, p.219-225, 2005.

Sant`Ana, J. A. V.; Coelho, E. F.; Faria, M. A.; Silva, E. L.; Donato, S. L. R. Distribuição de raízes de bananeira 'Prata-Anã' no segundo ciclo de produção sob três sistemas de irrigação. Revista Brasileira de Fruticultura, v.34, p.124-133, 2012.

Santos, C. A. S. Distribuição espacial e absorção de água pelo sistema radicular da cultura da manga (*Mangifera indica* L.) irrigada por microaspersão. Piracicaba: ESALQ, USP, 1997. 51p. Dissertação Mestrado

Santos, D. B. dos; Coelho, E. F.; Azevedo, C. A. V. de. Absorção de água pelas raízes do limoeiro sob distintas freqüências de irrigação. Revista Brasileirade Engenharia Agrícola e Ambiental, v.9, p.327-333, 2005.

Santos, M. R.; Martinez, M. A.; Donato, S. L. R. Gas exchanges of Tommy Atkins mango trees under different irrigation treatments. Bioscience Journal, v.29, p.1141-1153, 2013.

Silva, V. de P. R. da; Campos, J. H. B. C.; Azevedo, P. V. de. Water-use efficiency and evapotranspiration of mango orchard grown in northeastern region of Brazil. Scientia Horticulturae, v.120, p.467-472, 2009.

Taiz, L.; Zeiger, E. Fisiologia vegetal. 4.ed. Porto Alegre: Artmed, 2009. 848p.