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

DEFICIT IRRIGATION IN CONSECTUTIVE CYCLES ON YIELD AND WATER – USE EFFICIENCY IN 'TOMMY ATKINS' MANGO TREES

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SUMMARY: We aimed to understand two strategies of deficit irrigation and their effects on yield and water-use efficiency (WUE) in 'Tommy Atkins' mango trees, for three consecutive cycles. In the experiment with Regulated Deficit Irrigation (RDI), the treatments were: T1, full irrigation at every fruit development stage, 100% of ETc; T2, 100% of Etc at stages II and III and 50% of Etc at stage I; T3, 100% of ETc at stages I and III and 50% of ETc at stage II; T4, 100% ETc at stages I and II and 50% of ETc at stage III; T5, 100% of ETc at stages II and III and 75% of ETc at stage I; T6, 100% ETc at stages I and III and 75% of ETc at stage II and T7, 100% ETc at stages I and II and 75% of ETc at stage III. In the experiment with Partial Rootzone Drying (PRD) for the three crop stages: T1, 100% of ETc, conventional dripping irrigation; T2, 100%; T3, 80% of ETc; T4, 60% of ETc and T5, 40% of ETc. As for the treatments T2, T3, T4 and T5, the side to be irrigated was alternated every 15 days. At the end of 3 production cycles, we observed a reduction in productivity when RDI was applied at SI. The water-use efficiency was higher in the first cycle in relation to the third cycle under RDI. The PRD with 80% of ETc maintains the productivity and with 40% of ETc, increases WUE.

KEYWORDS: evapotranspiration, fruit production, *Mangifera indica*

IRRIGAÇÃO COM DÉFICIT EM CICLOS CONSECUTIVOS NA PRODUÇÃO E EFICIÊNCIA DE USO DA ÁGUA EM MANGUEIRA 'TOMMY ATKINS'

RESUMO: Objetivou-se compreender duas estratégias de irrigação com déficit e seus efeitos na produção e na eficiência de uso da água (EUA) em mangueira 'Tommy Atkins', por três ciclos consecutivos. No ensaio de Irrigação com Déficit Controlado (RDI) os tratamentos foram: T1, 100% evapotranspiração da cultura (ETc), nas três fases: FI, pegamento dos frutos;

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FII, expansão dos frutos e FIII, maturação fisiológica; T2, 100% da ETc nas FII e FIII e 50% da ETc na FI; T3, 100% da ETc nas FI e FIII e 50% da ETc na FII; T4, 100% ETc nas FI e FII e 50% da ETc na FIII; T5 100% da ETc nas FII e FIII e 75% da ETc na FI; T6 100% da ETc nas FI e FIII e 75% da ETc na FII; T7, 100% da ETc nas FI e FII e 75% da ETc na FIII. No ensaio com Irrigação Lateralmente Alternada (PRD) para as três fases da cultura: T1, 100% da ETc no sistema de gotejamento convencional; T2, T3, T4 e T5, com 100, 80, 60 e 40% da ETc, respectivamente, com alternância do lado a ser irrigado a cada 15 dias. Ao final dos 3 ciclos de produção, constatou-se que houve redução na produtividade quando se aplicou RDI na FI. A EUA foi maior no primeiro ciclo em relação ao terceiro na RDI. A PRD com 80% da ETc mantém a produtividade e com 40% da ETc aumenta a EUA.

PALAVRAS-CHAVE: evapotranspiração, fruticultura, *Mangifera indica*

INTRODUCTION

The region Northeast is characterized by having a great diversity of agricultural lands. These fields can achieve high yields of high-quality fruits when they are used in conjunction with a rational irrigation. In this region, the main hubs of irrigated crops are in semiarid areas, where predominates a high potential evapotranspiration, which creates water deficits throughout the whole crop cycle. This justifies the necessity of using modern techniques of irrigation management.

Fruit farming stands out in the agriculture sector of the semiarid region and the mango tree is, with considerable relevance, among the main cultivated fruit trees, especially for exporting of fresh fruits. From the national production of mangoes in 2014, the Northeast region accounted for 69.29%, in which the Bahia state is the largest producer with 54.87% of the national production (IBGE, 2014).

The adoption of techniques for irrigation management, that aim at sustainable productions with lower water demand, is of fundamental importance, particularly in semiarid regions, where the water demand is high and the availability of this resource is lower than in the remaining regions of the country (Santos et al., 2014a). Among these strategies, Regulated Deficit Irrigation (RDI) and Partial Rootzone Drying (PRD) can be highlighted (Sampaio et al., 2010; Santos et al., 2014a; Santos & Martinez, 2013).

RDI consists of water application with deficits at development and growth stages of the crop in which the plant has lower sensibility to the deficit, so as not to reduce the yield.

Conversely, PRD consists of alternating the side to be irrigated at a given frequency, as the most commons are 7, 14 and 21 days (Kang & Zang, 2004). PRD bases on biochemical responses of plants to reach a balance between the vegetative and reproductive development through water stress. As a consequence, there is a significant improvement in the production per unit of irrigation water applied (McCarthy et al., 2000).

The literature still lacks enough information regarding the use of RDI and PRD at the flowering and fruit setting stages in mango trees under semiarid conditions of Bahia state. Such information is needed to create concrete information grounded on scientific studies that can be taken to fruit producers and can be compatible with the current relation between society and environment. Therefore, the major objective of this study is understanding two irrigation strategies with water deficit (PRD and RDI) and how they affect yield and water-use efficiency (WUE) in 'Tommy Atkins' mango trees, over three consecutive cycles under the conditions of soil and climate of the semiarid in Bahia state.

MATERIAL AND METHODS

The experiment was conducted in a private field located in the irrigated perimeter of Ceraíma, in Guanambi, Southwest of Bahia (14º 17' 27" S, 42º 46' 53" W and 537 m altitude), Brazil. The average annual rainfall is 680 mm, in which the rain season is between November and March and, the average temperature of 25.6 ºC. The soil of the experimental area was classified as typical Eutrophic Flucic Neosol (EMBRAPA, 2013). The sand, clay and silt contents and the water retained at 10 and 1500 kPa, which are in Table 1. According to the Koppen, the climate classification of the region where the study was conducted is Aw: dry and hot semiarid.

Table 1. Characteristics of the soil at the experimental area. Guanambi, BA, 2013

Parameter	Depth (m)			
	0.00 – 0.25	0.25 – 0.50	0.50 – 0.75	0.75 – 1.00
Sand(g kg^{-1})	600	770	800	760
Silt (g kg^{-1})	240	150	120	160
Clay (g kg^{-1})	160	80	80	80
Water content at 10 kPa (kg kg^{-1})	0.23	0.16	0.14	0.16
Water content at 1500 kPa (kg kg^{-1})	0.12	0.07	0.06	0.07

The experiments were carried out using the RDI and PRD irrigation strategies over 3 production cycles, at an orchard of 'Tommy Atkins' mango, aging 16 years, which were spaced out at 10 x 8 m, from flowering to fruit ripening.

The irrigation water, with electric conductivity of 1.0 dS m^{-1}, came from a tube well. It was applied to the plots by means of a micro-sprinkler system for RDI and dripping irrigation for PRD. For RDI, two micro-sprinklers per plant with flow rate of 100L h^{-1} were used; and, for PRD, nine emitters with each having a flow rate of 8 L h^{-1}. Both systems were running at the pressure of 200 KPa.

The treatments with RDI and PRD were applied from flowering to fruit ripening, at the three development stages: from beginning of flowering to fruit setting (Stage I); during the fruit development (Stage II); and at the end of fruit growth and during the physiological maturation (Stage III). At the remaining stages, full irrigation was applied, as well as the suspension of irrigation at flower induction.

The experimental design was completely randomized with seven treatments (T) for the trial with RDI: T1, full irrigation at every fruit development stage, 100% of ETc; T2, 100% of Etc at stages II and III and 50% of Etc at stage I; T3, 100% of ETc at stages I and III and 50% of ETc at stage II; T4, 100% ETc at stages I and II and 50% of ETc at stage III; T5, 100% of ETc at stages II and III and 75% of ETc at stage I; T6, 100% ETc at stages I and III and 75% of ETc at stage II and T7, 100% ETc at stages I and II and 75% of ETc at stage III. The trial with PRD consisted of the following treatments: T1, 100% of ETc without alternating the side; T2, 100%; T3, 80% of ETc; T4, 60% of ETc and T5, 40% of ETc. As for the treatments T2, T3, T4 and T5, the side to be irrigated was alternated every 15 days. In both experiments, there were six replicates and one plant as an experimental unit.

The irrigation was based on on the crop evapotranspiration (ETc), which is a product of the reference evapotranspiration (ETo), crop coefficient (Kc) and localized coefficient (Kl).

The ETo was indirectly determined by the Penman-Monteith standard method (Allen et al., 1998), using data from a local weather station, installed near the experimental area. The values of Kc used when calculating the crop evapotranspiration during the assessment phases ranged from 0.45 to 0.87, as used by Cotrim et al. (2011) and Santos et al. (2014a) for 'Tommy Atkins'. The Kl was calculated as a function of the ratio between the area shaded by the plant and the area wetted by the emitter, considering the higher of the two.

In order to manage the irrigation at the orchard during the experiment, the daily irrigation run time was determined as Cotrim et al. (2011), Santos et al. (2013, 2014a, 2014b) and Santos

& Martinez (2013). If it happened to rain, the amount of rain was subtracted from the ETc so as to find the irrigation run time.

After harvesting, the fruits were selected at each treatment, weighed and counted. Then, the water-use efficiency was determined (WUE). The WUE was obtained according to Silva et al. (2009), and adopted by Santos (2012) and Santos et al. (2014a), for all treatments, which is a relation between the yield and gross irrigation depth.

The data for productivity and water-use efficiency were subject to analysis of variance, considering 3 x 7 and 3 x 5 factorial experiments for RDI and PRD, respectively, as 3 is for the cycles and 7 and 5 are the irrigation levels. The means were compared to one another using the Tukey test at 5% of probability.

RESULTS AND DISCUSSION

The values of productivity of 'Tommy Atkins' for the experiment with PRD, when subjected to analysis of variance, exhibited a significant interaction at 5%, using the Tukey test.

Table 2. Productivity (t ha^{-1}) of 'Tommy Atkins' mango trees under partial rootzone drying in 3 consecutive production cycles

TREATMENTS	CYCLE		
	01	02	03
FI	8.54 Ab	16.68 Aa	16.44 Aa
PRD 100	6.99 Ab	14.31ABa	15.53 Aa
PRD 80	11.52 Aa	9.21 BCa	9.11 Ba
PRD 60	7.41Aa	8.16 BCa	9.29 Ba
PRD 40	7.67 Aa	7.60 Ca	9.35 Ba

Similar lowercase letters in the columns do not differ from one another at 5% of probability by Tukey test for the irrigation treatments and, similar uppercase letters in the rows do not differ from one another at 5% of probability by Tukey test for the cycles.

The partial rootzone drying irrigation, PRD, and the conventional irrigation (no alternation) applied to 'Tommy Atkins' mango trees by dripping did not significantly differ at 5% level for productivity in the first production cycle. In the second and third cycles, the application of PRD with 80, 60 and 40% of ETc reduced the yield of 'Tommy Atkins' mango trees in comparison with full irrigation (FI), without alternation. The best productivities were obtained in the second and third cycles when the plants were under full irrigation (FI) and PRD 100% of ETc (Table 2). Prior to setting up of the experiment, the plants went through a long period without adequate care which contributed to the depletion of reserves. This can explain the lower productivities in the first cycle and, the ongoing water deficit, perhaps, had also an impact on the plants, which could not express their productive potential in following cycles under the PRD deficit.

The water-use efficiency in ‘Tommy Atkins’ mango trees under PRD exhibited significant differences only for treatments ($p<0.01$).

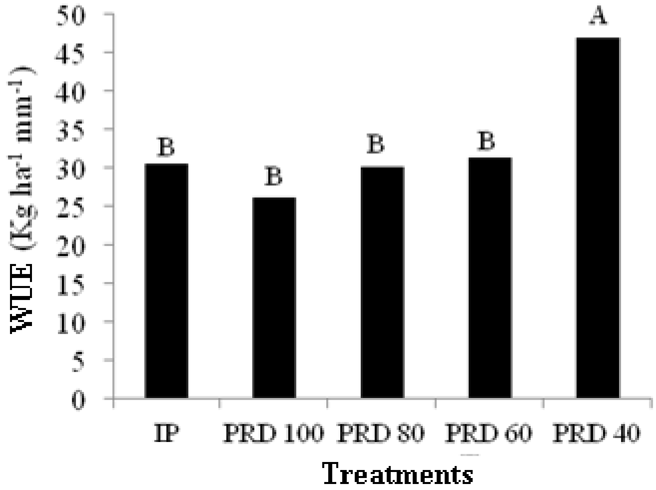

Figure 1. Water-use efficiency – WUE of ‘Tommy Atkins’ mango trees under partial rootzone drying, PRD. Guanambi, BA. Means followed by the same letter on bars do not differ from one another at 5% level of significance by Tukey test. The coefficient of variation – CV (%) was 38.79.

The WUE was higher under the condition of PRD at 40% of ETc, even with low productivity (Table 2). This result is interesting because it shows a positive effect on mango tree, since the larger relative reduction of the irrigation depth did not proportionally reduce the productivity. Similar results were found by Santos et al. (2015) in a study done with ‘Tommy Atkins’ mango trees as well. Evaluating only one cycle, they observed that applying PRD caused a significant reduction in productivity by comparison with full irrigation. However, they also demonstrated that, PRD 40 increased the water-use efficiency.

The values of productivity and water-use efficiency (Figure 2) in ‘Tommy Atkins’ mango trees for the experiment with RDI, when subjected to analysis of variance, exhibited a significance ($p<0.05$) for the treatments.

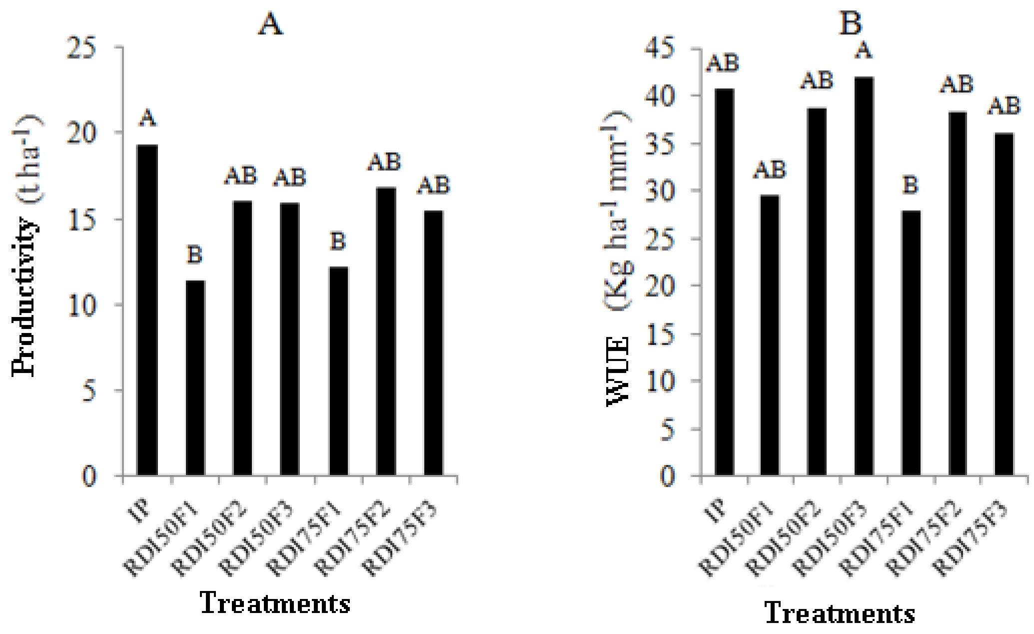

Figure 2. Productivity (A) and water-use efficiency – WUE (B) of 'Tommy Atkins' mango trees under regulated deficit irrigation, RDI. Guanambi, BA. Means followed by the same letter on bars do not differ from one another at 5% of significance by Tukey test. The coefficients of variance – CV (%) for total productivity and WUE were 35.96 and 37.01, respectively.

Regulated deficit irrigation with 50 and 75% of ETc at fruit setting stage (Stage I) causes a significant reduction of 41.12% and 36.98%, respectively, in productivity of 'Tommy Atkins' mango trees, when compared to the treatment with full irrigation (100% of ETc).

Nevertheless, when RDI with 50 and 75% of crop evapotranspiration are applied at fruit growth (Stage II), as well as at physiological maturation stage (Stage III), we did not observe any reduction in yield. This behavior probably occurred because the stage that stretches from the end of growth the physiological maturation of fruits is less sensitive to water deficit that the other stages in which water deficit was applied. This result is in accordance with Teixeira et al (2012) for the period that is between flowering and fruit setting of 'Palmer' mango trees, which demonstrate a higher sensibility to water stress in the soil, as reducing 45% of irrigation depth caused low productivity.

The water-use efficiency, as well as the productivities we observed, was influenced by the treatments with RDI. By analyzing the Figure 2B, differences are observed between the treatments RDI with 50% of ETc applied at physiological maturation of fruits (RDI50S3) in comparison with the treatment with RDI with 75% of ETc applied from flowering to fruit setting (RDI75SI). This reinforces the idea of higher sensibility of mango trees at flowering stage to low levels of irrigation. Santos et al. (2014a) has also verified it, which emphasizes that the use of RDI with 50% of ETc at the stage of fruit maturation is more effective in increasing the WUE. Identical results, with different irrigation levels, were demonstrated by Spreer et al (2009) who found higher water-use efficiency in mango trees under water deficit of 30 to 50%.

The values of water-use efficiency (WUE) of 'Tommy Atkins' mango trees, when subjected to analysis of variance, also exhibited significance ($p<0.05$) for source of variation 'cycle', which had a significant decrease between the first and third cycles on the order of 20%. As the management becomes adequate, from the first cycle, it was possible to advance the flowering, which made the third cycle be in a period of higher demand for water and absence of raining. This allowed applying larger amounts of water, which contributed to a lower water-use efficiency.

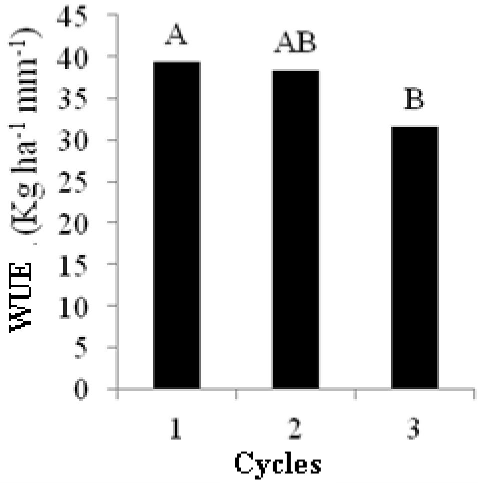

Figure 3. Water-use efficiency – WUE of 'Tommy Atkins' mango trees under regulated deficit irrigation, RDI, Guanambi, BA. Means followed by the same letter on bars do not differ from one another at 5% of significance by Tukey test. The coefficient of variance – CV (%) was 37.01.

CONCLUSIONS

Partial rootzone drying (PRD) with 40% of ETc maintains the productivity and increases the WUE in the first evaluation cycle; however, this can make the following cycles reduce their productivity when deficit is applied up to 40% of ETc.

Regulated deficit irrigations with 50 and 75% of ETc at fruit setting stage reduce the productivity. Though, they maintain the productivity when applied at development stage or at fruit maturation stage.

Regulated deficit irrigation with 50 and 75% of ETc applied at fruit setting stage reduce the water-use efficiency when compared to applications of RDI with 50% of ETc at the fruit maturation stage.

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