

## GAS EXCHANGES OF 'TOMMY ATKINS' MANGO TREES UNDER DIFFERENT IRRIGATION TREATMENTS

### TROCAS GASOSAS DA MANGUEIRA 'TOMMY ATKINS' SOB DIFERENTES REGIMES DE IRRIGAÇÃO

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**ABSTRACT:** Gas exchanges influence growth, development and production of crops and are associated with the plant water conditions, which can be dependent on the soil and climate conditions. The present study aimed at evaluating transpiration, photosynthesis, stomatal conductance, internal CO<sub>2</sub> concentration and foliar temperature of 'Tommy Atkins' mango trees under different irrigation treatments in the semiarid region of Bahia (BA, Brazil). The experimental design was a randomized block with five treatments and six replicates: 1, irrigation providing 100 % of crop evapotranspiration (ET<sub>c</sub>) in phases: I (early blooming to early fruit expansion), II (early expansion to early physiologic ripening) and in phase III (physiologic ripening of fruits); 2, regulated deficit irrigation (RDI) with 50 % of ET<sub>c</sub> in phase I; 3, RDI with 50 % ET<sub>c</sub> in phase II; 4, RDI with 50 % ET<sub>c</sub> in phase III; 5, no irrigation. Total or partial soil water deficit caused reduction in photosynthetic rate, transpiration and stomatal conductance of 'Tommy Atkins' leaves. Partial soil water deficit does not cause significant alterations in internal CO<sub>2</sub> concentration or in leaf temperature of 'Tommy Atkins' mango trees.

**KEYWORDS:** Regulated deficit irrigation. Plant physiological ecology. Irrigation management.

#### INTRODUCTION

Mango is cultivated in all northeast states of Brazil, mainly in irrigated areas of the semiarid region, which present excellent conditions for crop development and elevated yield and fruit quality. In this region the demand for water resources is greater than availability. In a productive and environmental sustainability approach, irrigation management strategies concerning rational water use must be adopted. In this extent, irrigation techniques such as regulated deficit irrigation (RDI) and partial root zone drying (PRD) can be mentioned.

Regulated deficit irrigation technique was initially applied in peach and pear orchards to control vegetative and reproductive growth through water stress at key stages of fruit development (McCARTHY, 2000). RDI is an irrigation management technique that consists of applying deficit irrigation in stages of plant development in which fruit growth and quality have low sensibility to water deficit (ROMERO; BOTÍA, 2006, SAVIĆ et al. 2008, GONZÁLEZ et al. 2009, INIESTA et al. 2009). In other words, it is possible to reduce water consumption and energy without great damages to fruit quality and orchard yield. In contrast, PRD irrigation management consists of rotating the side of the plant being irrigated, during 10 to 14 days, between the phenologic fruit-set phases and harvest. PRD uses biochemical responses of plants to water

stress to achieve a balance between vegetative and reproductive development; in consequence, there is significant improvement in production per unit of irrigation water applied (McCARTHY, 2000).

Regulated deficit irrigation was the study purpose in mango tree (Spreer et al., 2007, 2009; Luvaha et al., 2008; Silva et al., 2009 and Cotrim et al., 2011).

The proposal of the use of regulated deficit irrigation is of crucial importance mainly in regions with shortage and/or inadequate water distribution. The different management techniques allow the formation of different wetted soil profiles, producing total or partial soil water deficit, causing different characterizations of water availability for the crop. Shoot growth in plants under water deficit conditions can be limited as a result of decreased shoot water status (WAKRIM et al., 2005). The applicability of this approach is based on theory that soil water deficit induces the production of abscisic acid hormone (ABA) by the roots. This hormone diffuses to the vascular axis, concentrating in the air part, promoting partial stomata closure, control of vegetative growth and consequently reduction of water loss to the atmosphere.

The soil and climate water conditions can reflect in the plant water conditions, altering gas exchanges and foliar temperature, which directly influences growth, development and crop yield. Transpiration and CO<sub>2</sub> liquid assimilation can be

used as parameters for the study of water influence in the mango tree, given that transpiration is a good indicator of water availability in the plant (SCHAFFER et al., 1994). In a situation of good water availability, the cultivated plants generally present high transpiration rates (SALISBURY; ROSS, 1992).

Photosynthesis is an important biological process that converts energy from the sun into chemical energy of organic compounds. Water deficit is one of the factors that influence the photosynthetic process, which in turn, influence vegetable production. In the case of water as a limiting factor, cellular expansion is immediately delayed, reducing growth. If this stress persists, the stomata close, consequently inhibiting CO<sub>2</sub> capture (ROCHA; MORAES 1997). Jones (1985) emphasizes that water deficit can reduce photosynthesis by the decrease in the available foliar area to intercept solar radiation, by CO<sub>2</sub> diffusion decrease inside the leaf and by the decrease of the chloroplasts ability to fix CO<sub>2</sub>.

Temperature has been frequently pointed as a modulator of plants gas exchanges (CLARK, 2004). In general, temperature can affect the photosynthetic process direct and indirectly. Directly in enzymatic activity in the photosynthetic process and in the electron transporting chain; and indirectly when difference between leaf and air vapor pressure deficit occur. According to Berry and Björkman (1980), damages due to elevated temperatures result from the inactivation of

reactions in thylakoid membranes, due to greater fluidity of membrane lipids (TAIZ; ZEIGER, 2009) and enzymes involved in the photosynthetic metabolism.

Stomatal control is an important physiologic parameter by which plants limit water loss, generally reducing gas exchanges as response to several factors including water stress. In agreement with Gholz et al. (1990), little water availability affects plant growth, for promoting stomatal closure and, consequently, phytomass production. Stomatal closure is frequently used as a water deficiency indicator (McDERMITT, 1990).

The aim of this study was to evaluate transpiration, photosynthesis, stomatal conductance, internal CO<sub>2</sub> concentration and foliar temperature of 'Tommy Atkins' mango tree under different irrigation treatments in the semiarid of Bahia (BA, Brazil).

## MATERIAL AND METHODS

The study was developed in an experimental area at the Company for Development of the Sao Francisco and Parnaíba Valleys (CODEVASF) located in the irrigated perimeter of Ceraíma, Guanambi, southwest of Bahia (14°17'27" S, 42°46'53" W and 537 m of altitude), Brazil. Data series analyses show that the annual average rainfall is 680 mm and annual average temperature is 25.6°C. The soil is a eutrophic fulvic neosol, which physical characteristics are in Table 1.

**Table 1.** Physical characteristics of Fulvic neosol

Physical characteristics	Depth (m)			
	0-0.25	0.25-0.50	0.50 – 0.75	0.75-1.00
Coarse sand (kg kg <sup>-1</sup> ) <sup>1</sup>	0.08	0.05	0.01	0.00
Fine sand (kg kg <sup>-1</sup> ) <sup>1</sup>	0.41	0.43	0.76	0.16
Silt (kg kg <sup>-1</sup> ) <sup>2</sup>	0.27	0.28	0.12	0.52
Clay (kg kg <sup>-1</sup> ) <sup>2</sup>	0.24	0.24	0.11	0.32
Bulk density (kg dm <sup>-3</sup> ) <sup>3</sup>	1.62	1.38	1.34	1.31
Water retention at-10 kPa (m <sup>3</sup> m <sup>-3</sup> ) <sup>5</sup>	0.43	0.37	0.19	0.54
Water retention at-1.500 kPa (m <sup>3</sup> m <sup>-3</sup> ) <sup>5</sup>	0.15	0.12	0.05	0.16

<sup>1</sup>By soil screening; <sup>2</sup>Pipette method; <sup>3</sup>Test tube and volumetrical ring method; <sup>4</sup>Volumetrical balloon method; <sup>5</sup>porous plate equipment.

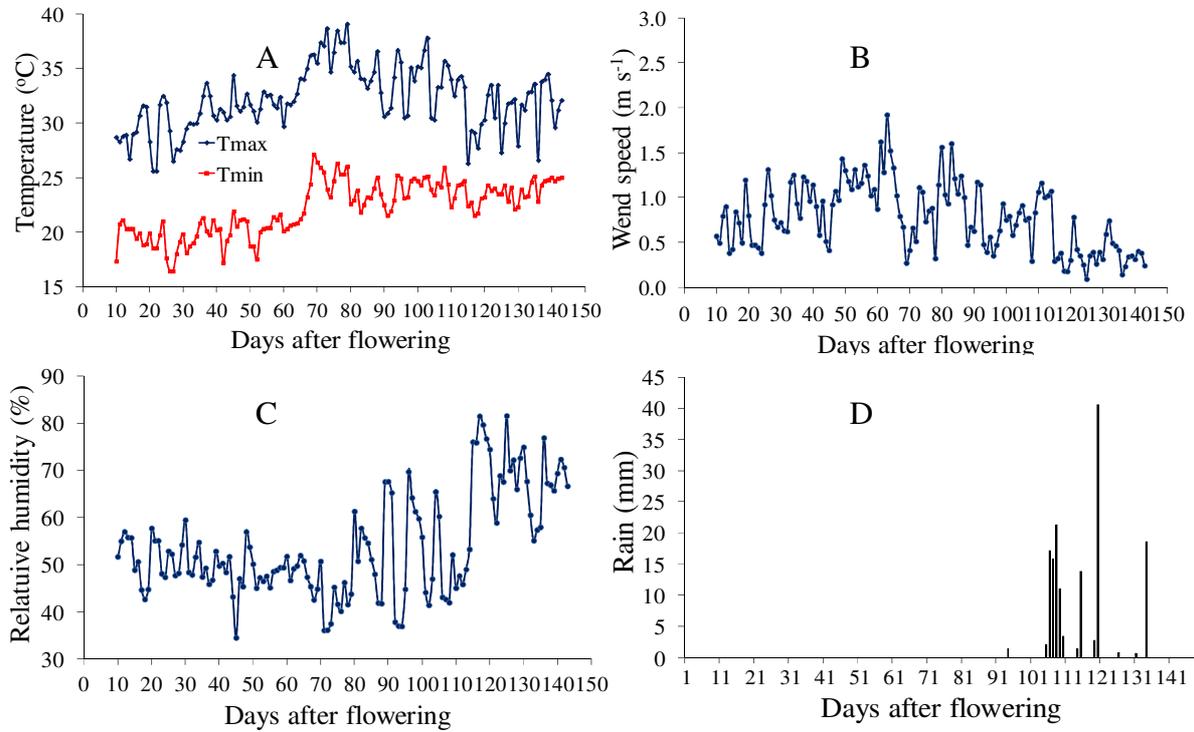
The behaviors of main climate elements are presented in Figures 1 and 2 for the first and the second evaluation cycles, respectively.

The experiment was conducted in an orchard with 8 m x 8 m spaced plants, 11 and 12 years of age, from blooming to fruit ripening. The plants were irrigated by microsprinkling with one emitter per plant, applying a 50 L h<sup>-1</sup> flow rate at 200 kPa pressure.

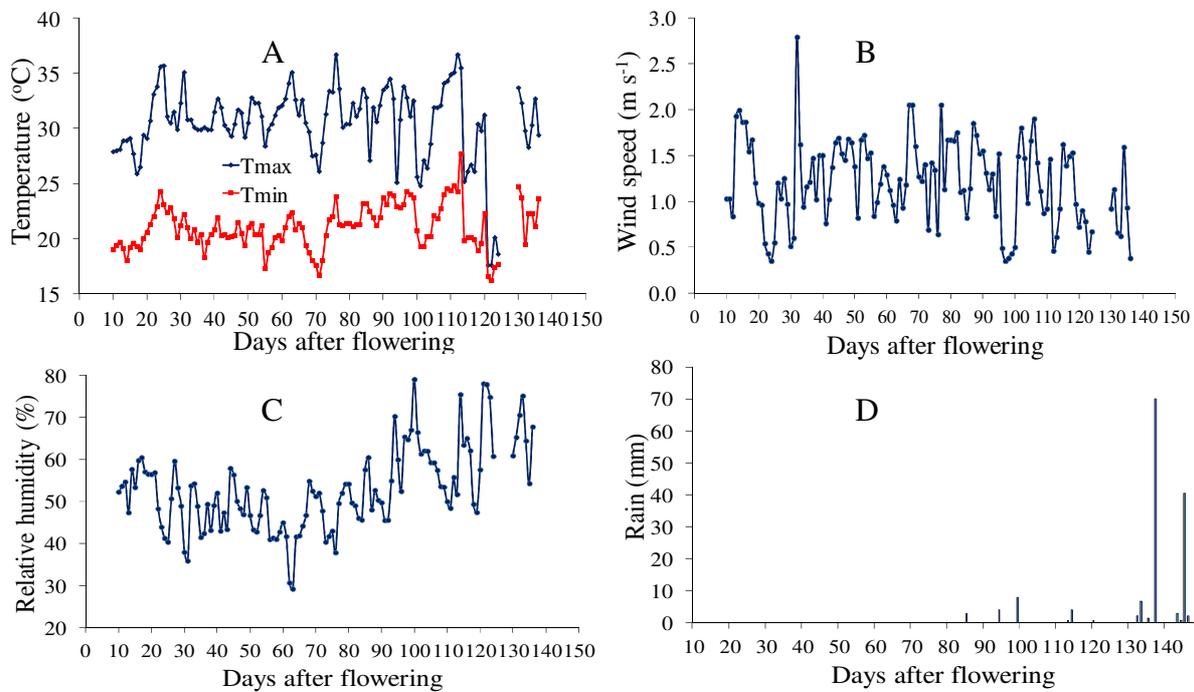
During the experiment mango production techniques used in the region were considered. In the two evaluated production cycles, after harvest, pruning and fertilizing, with 500g of MAP (monoammonium phosphate), 200g of ammonium sulfate, 150g of potassium chloride and 20kg of chicken dung, was carried out per plant. Irrigation was carried out daily during the period in which the plant was emitting up to two vegetative shoots. After emission of shoots, growth regulator

Paclobutrazol was applied. Subsequently irrigation was ceased and when plants presented symptoms of epinasty of terminal buds (MOUCO; ALBUQUERQUE, 2005), calcium nitrate was

applied in the leaves to break bud dormancy and to induce a uniform blooming.



**Figure 1.** A, Maximum (Tmax) and minimum (Tmin) temperatures. B, average wind speed. C, average relative air moisture. D, rainfall during first evaluation cycle.



**Figure 2.** A, Maximum (Tmax) and minimum (Tmin) temperatures. B, average wind speed. C, average relative humidity. D, rainfall during second evaluation cycle.

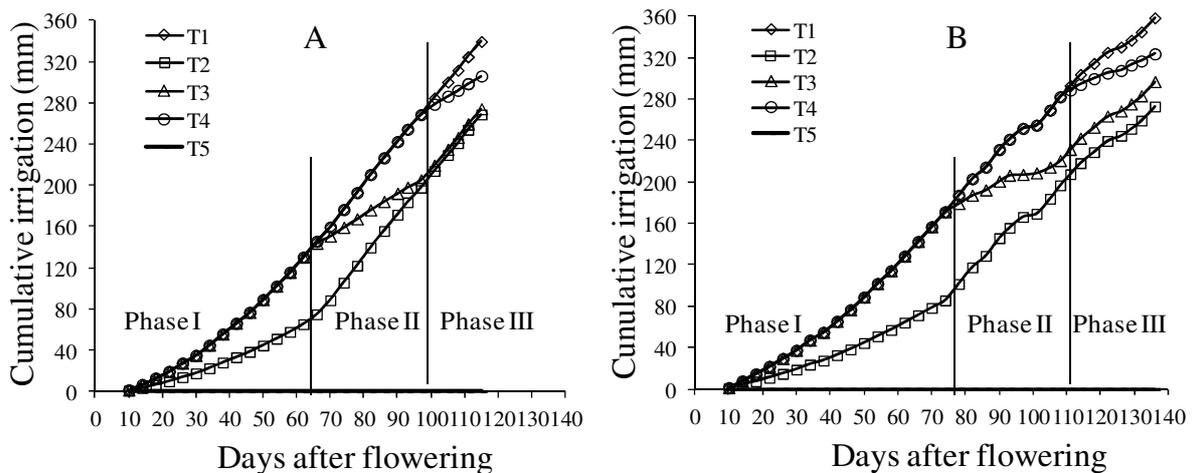
Regulated deficit irrigation treatments were applied from blooming to fruit ripening in three development phases according Cotrim et al. (2011). Phase I corresponds to early blooming (EB) up to fruit set, which happens around 65 days after beginning of blooming. Phase II corresponds to fruit expansion up to approximately 95 days after EB. Phase III corresponds to late fruit growth and physiologic ripening which occurs up to 120 days after EB.

A randomized complete block design was used with five treatments and six blocks, considering one plant per experimental unit. Treatments were applied in phases I, II and III of mango fruit development after the flower induction period. The treatments were the following: 1, irrigation providing 100% of crop evapotranspiration (ETc) from blooming to fruit harvest; 2, 50% Etc from early blooming to early fruit expansion and 100% Etc up to fruit physiologic ripening; 3, 100% of Etc from early blooming to early fruit expansion, 50% from early expansion up to early fruit physiologic ripening and 100% in fruit

physiologic ripening; 4, 100% of Etc from early blooming to late fruit expansion and 50% in physiologic ripening; 5, no irrigation.

The water used in irrigation originated from tubular wells with electric conductivity between 0.62 to 1.32 dS m<sup>-1</sup>. Irrigations were carried out based on the reference evapotranspiration (ET<sub>0</sub>) determined daily by 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<sub>c</sub>) used in the calculation of evapotranspiration, during the evaluation phases, were from 0.45 to 0.87, as used by Cotrim et al. (2011).

The total water depths applied in each treatment are shown in Figure 3. Water application began at day ten after blooming and finished at 115 and 136 days after blooming for evaluation cycles 1 and 2, respectively. From 115 and 136 days after blooming no irrigation was applied for evaluation cycles 1 and 2, since the rainfall supplied all crop evapotranspirometric demand.



**Figure 3.** Cumulative irrigation applied in different treatments of RDI to 'Tommy Atkins' mangoes during the evaluation period. (A) first cycle and (B) second cycle.

During phases I, II and III and for all treatments, the transpiration rate, photosynthesis rate, stomatal conductance, internal CO<sub>2</sub> concentration and foliar temperature were determined monthly in the first cycle and every fifteen days in the second evaluation cycle by an infrared CO<sub>2</sub> gas analyzer (IRGA, model LCpro, ADC, Bioscientific Ltd, Great Amwell, England). In the first cycle the measurements were carried out between 10:00 and 11:00am. In contrast, in the second evaluation cycle measurements were carried out between 1:00 to 2:00pm. Due to technical problems with the IRGA, measurements were

limited to 81 days after blooming in the second evaluation cycle.

The obtained gas exchanges, foliar temperature and yield data were submitted to analysis of variance. Averages were compared by Duncan's test, at 5% significance level.

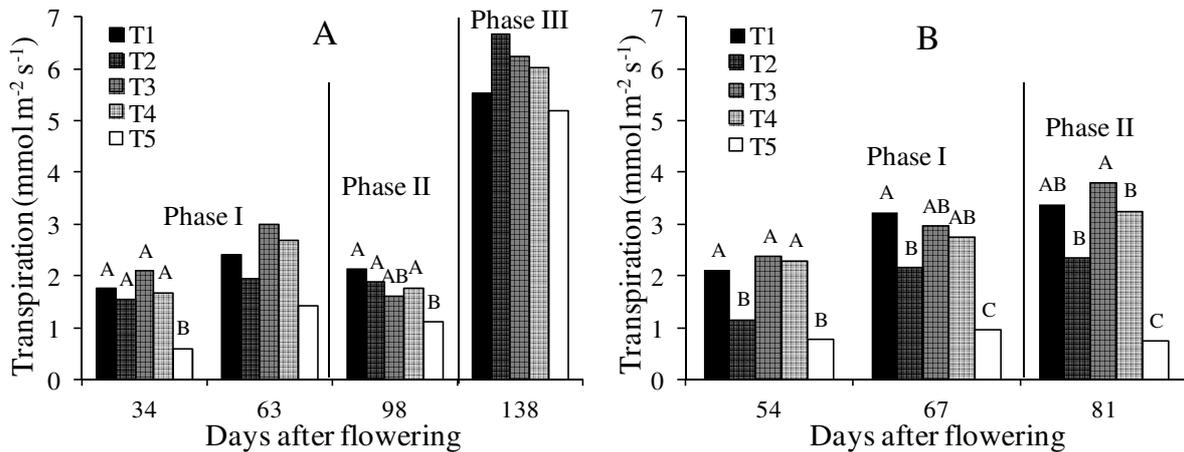
## RESULTS AND DISCUSSION

### Transpiration

The transpiration rate variations, in the three fruit development phases, for the different treatments, in the first and second evaluation cycles

are presented in Figure 4. It is observed that, in absence of irrigation, the mango tree transpiration presented lower values than the other treatments, exhibiting statistical difference at 5% significance level by Duncan's test. There were no significant differences in the first evaluation cycle for treatment 1 and RDI treatments. When RDI was applied in the first phase (T2), even when no significant differences were observed, transpiration in this

treatment represented 26% at day 34 after blooming and 34% at 63 day after plant transpiration blooming in T3. In the second phase of the first evaluation cycle, plant transpiration in T3 did not differ from T5 by Duncan's test. Although the transpiration in T3 do not differ from T1, it showed reduction of 24.2%, which can be caused by application of RDI at 50% of  $ET_c$  in phase II.



**Figure 4.** Transpiration of 'Tommy Atkins' mango tree in different treatments for three evaluation phases in first (A) and second (B) evaluation cycles. Averages followed by same capital letter or no letter in group, do not differ significantly by Duncan's test at 5% significance level. Variation coefficients (VC) at 34, 63, 98, 54, 67 and 81 days after blooming according to figure above are 44.37, 41.69, 26.24, 20.34, 43.80, 30.85 and 34.15, respectively.

From 110 days after blooming (phase III), in the first evaluation cycle, the rainfall was sufficient to increase soil water content and keep it at high levels. This probably contributed to the increase of the plant transpiration rates. Duncan's test showed no differences in transpiration values in the phase between treatments.

In the second evaluation cycle, at day 54 after blooming, transpiration in T2 and T5 were the lowest between treatments and did not differ by Duncan's test ( $P < 0.05$ ). In contrast, T1, T3 and T4, without deficit in phase I, which presented higher transpiration, differed statistically from T2 and T5, but did not differ between themselves.

At day 67 after blooming, T5, with less transpiration, differed from the other by Duncan's test ( $P < 0.05$ ) and T2 differed from T1. At 81 days after blooming, the treatment without irrigation, with less transpiration, differed from the rest by Duncan's test ( $P < 0.05$ ) and T2 differed from T3.

Overall, transpiration in plants with total (T5, no irrigation) and partial water deficit (T2, RDI in phase I and T3, RDI in phase II) presents lower values compared with treatments without water deficit and with partial water deficit in phase III,

considered the least sensitive phase to water deficit. Lovaha et al. (2008) found reduction in the rate of transpiration with increasing water deficit, corroborating the results of this work.

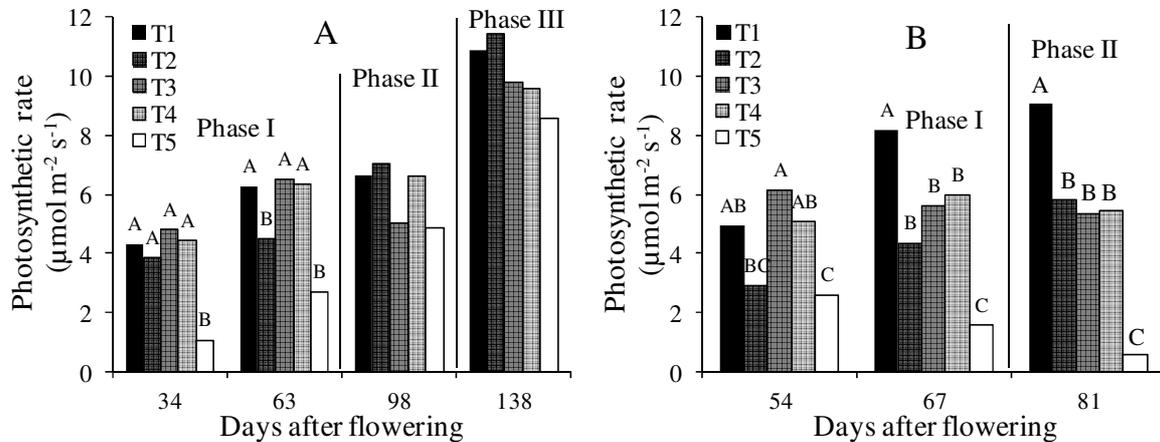
Under good water availability, the cultivated plants, generally, present high transpiration rates (SALISBURY; ROSS, 1992). The reduction in the transpiration rate in the plants leaves, under water deficit, can be explained by the crop adaptation in avoiding water loss. Castro Neto (2003) emphasizes that as soil water becomes scarce, the plant reduces its transpiration rate to reduce water loss and save soil water availability. That probably happens through stomatal closure caused by a signal emitted by the roots, vegetable abscisic acid hormone (ABA) synthesis and transport to the air part via xylem in response to soil water deficit. This mechanism preserves water in the plant, but interferes in  $CO_2$  assimilation and, consequently, in yield (TAIZ; ZEIGER, 2009).

### Photosynthesis

The photosynthetic rate for the different treatments, during the three evaluation phases, is shown in Figure 5. At day 34 after blooming, in the

first evaluation cycle, significant differences were observed only between T5 (no irrigation) and the rest. Conversely, at the end of phase I, at day 64 after blooming, T2 presented photosynthetic rate equal to that of T5. In the same measurement, there

were no photosynthetic rate differences between T3, T4, T1 and T2.



**Figure 5.** Photosynthetic rate of 'Tommy Atkins' leaves in different treatments for three evaluation phases in first (A) and second (B) evaluation cycles. Averages followed by same capital letter or without letters in group; do not differ significantly by Duncan's test at 5% significance level. Variation coefficients (VC) at 34, 63, 98, 54, 67 and 81 days after blooming according to figure above are 43.02, 37.11, 35.17, 26.25, 41.14, 27.23 and 34.33, respectively.

In the second phase of fruit expansion and growth, T3 presented a decline in the photosynthetic rate (Figure 5A), probably, due to RDI application in this phase, while, T2 showed increase in photosynthetic rate values. Significant differences were not observed between T2 and T3, by Duncan's test, at 5% significance level; however, there was 28.4% variation in the photosynthetic rate between T2 and T3.

In measurements carried out in phase III, at 138 days after blooming, there were no significant differences between treatments for photosynthetic rate. Probably, the rainfall in the area influenced the photosynthetic rate of plants submitted to water deficit, since the photosynthesis rates measured by IRGA are punctual. These vary with environmental, atmospheric conditions and soil moisture at the moment of reading, which cannot reflect the conditions experienced by the plant.

In the second evaluation cycle, at 54 days after blooming, the photosynthetic rate was lower in T5. There were no differences in the photosynthetic rate between T5 and T2. The T3, with higher photosynthetic rate, did not differ by Duncan's test ( $P < 0.05$ ) from T4 and T1. At 67 and 81 days after blooming, the T1 with higher photosynthetic rate differed from the other treatments and T5; while, T1 with lower photosynthetic rate, differed from T1,

T4, T3 and T2. No differences were observed between T4, T3 and T2.

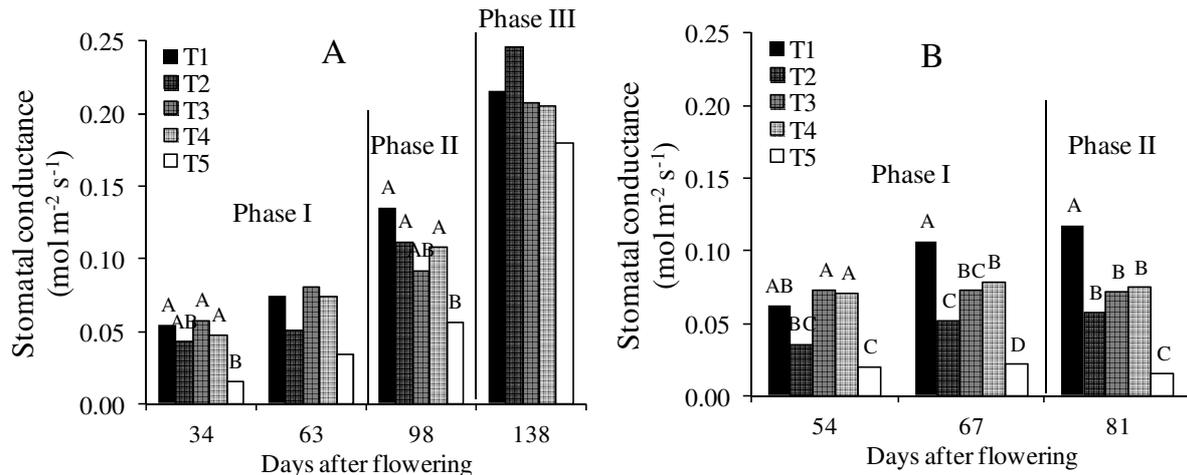
In general, the significant differences observed between the photosynthesis rates from the treatment without irrigation (T5) and the other treatments with lower values for T5, can be attributed to the stomatal closure caused by the water deficit, since this mechanism preserves water in the plant, to reduce transpiration, but it negatively interferes in  $\text{CO}_2$  assimilation (TAIZ; ZEIGER, 2009).

### Stomatal conductance

The stomatal conductance demonstrated important variations, mainly, between T5 and the others (Figure 6A) in the first evaluation cycle. There were no differences in stomatal conductance between T5 and T2 (RDI 50% of Etc in phase I) in the measurement at day 34 after blooming. However, at 63 days after blooming, there were no differences in stomatal conductance between treatments. It can be noticed that T5 (no irrigation) presented lower stomatal conductance value. This fact can be probably explained due to the plant water condition during the evaluated period, which caused stomatal closure, consequently, increasing stomatal resistance and decreasing stomatal conductance.

In agreement with Flexas et al. (2006), when stomatal conductance is below  $0.1 \text{ mmol m}^{-2} \text{ s}^{-1}$ , a condition of significant water stress is characterized. Even without irrigation, stomatal conductance presented values superior to  $0.1 \text{ mmol m}^{-2} \text{ s}^{-1}$ , which evidences that the decrease in soil water content was not sufficient to cause significant water stress; this can be an intrinsic characteristic in mango tree crop. This fact is in agreement with Castro Neto (1995 and 2003), concerning the use of water stress as a promoter of blooming induction in

mango tree. This author argues that the application of water stress has not been carried out correctly. The soil keeps enough available water for vegetative growth, which constitutes one of the main barriers to blooming. This discussion shows the mango tree tolerance to water deficit, compatible with its botanical origin, since it belongs to the Anacardiaceae family, with species predominantly known for the tolerance to drought, such as the umbu tree, aroeira tree and cashew tree.



**Figure 6.** Stomatal conductance in plants of 'Tommy Atkins' mango in different treatments in first (A) and second (B) evaluation cycles. Averages followed by same capital letter or without letters in group do not differ significantly by Duncan's test at 5% significance level. Variation coefficients (VC) at 34, 63, 98, 54, 67 and 81 days after blooming according to figure above are 53.92, 50.76, 34.66, 33.52, 45.61, 31.39 and 36.52, respectively.

In phase II, T5 once again presented significant differences comparing with T1, T2 and T4, not differing by Duncan's test from T3 (RDI in phase II). In phase III, however, no significant differences were observed between treatments, possibly due to the rainfall.

In general, differences were not verified in mean values of stomatal conductance between T1 and T2-T3-T4 during the crop cycle, even with existence of soil water layer variations. Possibly, the water limitations applied to plants were not sufficient to cause great stomatal conductance variations. Nevertheless, this response was not observed when water limitation was significant, as noticed in T5. This indicates that, when soil water deficit is not very significant, stomatal conductance variations follow the same tendency as plants with no water deficit. Bergonci et al. (2000) confirmed this observation while evaluating stomatal conductance in corn as an indicator of water deficit.

In the second evaluation cycle, treatment 3, with higher stomatal conductance, did not differ ( $P < 0.05$ ) by Duncan's test from treatments 4 and 1

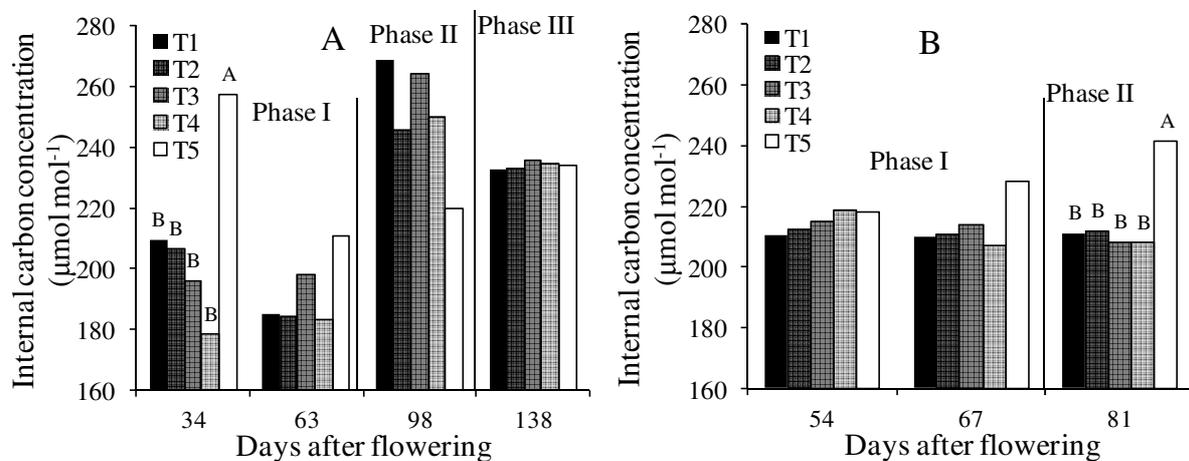
in phase I. Treatment 5, with lower stomatal conductance, did not differ from treatment 2. At 67 days after blooming, treatment 1, with higher stomatal conductance, differed from the rest. There were no differences between treatments 4 and 3, or between treatments 3 and 2. Treatment 5, with lower stomatal conductance, differed from the rest. At 81 days after blooming, treatment 1 differed from the rest; there were no differences between treatments 4, 3 and 2 and treatment 5, with lower stomatal conductance, differed from the rest.

In the second evaluation cycle, mainly in the end of phase I and beginning of phase II, there were differences in stomatal conductance between RDI treatments and treatment 1, differently from the first evaluation cycle, in which difference was observed only between T1 and T5. This variation can be explained by the climate conditions at the moment of measurements, given that in the first cycle, measurements were carried out after ten in the morning and, in the second cycle, after two in the afternoon.

### Internal CO<sub>2</sub> concentration

The internal CO<sub>2</sub> concentration, in the first evaluation of phase I (Figure 7A), was affected in T5, possibly, by damages in the photosynthetic apparatus, fact that may have contributed with CO<sub>2</sub> accumulation. The highest internal CO<sub>2</sub> concentration observed in T5 differed significantly from the other treatments, probably, through stomatal closure as showed in Figure 7A. In the second evaluation of phase I (Figure 7A), significant differences were not found between treatments. Normally, if there is no CO<sub>2</sub> fixation metabolic activity decrease, a reduction is observed in internal CO<sub>2</sub> concentration associated to a reduction in stomatal conductance (RASCHKE, 1979).

Subbarao et al. (1995) affirmed that stomatal control is one of the mechanisms used by the plant to minimize water loss. Nevertheless, in spite of allowing lower water loss, it causes reduction of CO<sub>2</sub> assimilation (photosynthesis), fact observed in this study. Stomatal closure reduces CO<sub>2</sub> entrance; therefore, it reduces liquid CO<sub>2</sub> assimilation, which cannot decrease internal CO<sub>2</sub> concentration. Thus, the reduction in stomatal conductance for values close to 0.1 mol m<sup>-2</sup> s<sup>-1</sup> caused reduction in photosynthesis rate. However it did not cause reduction in internal CO<sub>2</sub> concentration, which in turn, did not present values inferior to 150 μmol mol<sup>-1</sup> (Figure 7).



**Figure 7.** Internal carbon concentration in 'Tommy Atkins' mango trees in different treatments in first (A) and second (B) evaluation cycles. Averages followed by same capital letter or without letters in group, do not differ significantly by Duncan's test at 5% significance level. Variation coefficients (VC) at 34, 63, 98, 54, 67 and 81 days after blooming according to figure above are 17.40, 11.22, 12.34, 3.79, 5.03, 6.61 and 6.58, respectively.

During phase I, there were decreases in concentrations for T1, T2 and T5 and stabilization for T3 and T4. From the end of phase I and beginning of phase II, there was an increase for all the treatments. This characteristic can be explained by a condition that favored plants from T5, T2 and T1 and limited enzymes expression of the photosynthesis biochemical phase of other treatments.

In phase III, no significant differences were found between treatments, possibly, due to rainfall on days that preceded evaluations, despite the tendency in increasing carbon internal concentration in T5 and the opposite relation in the other treatments.

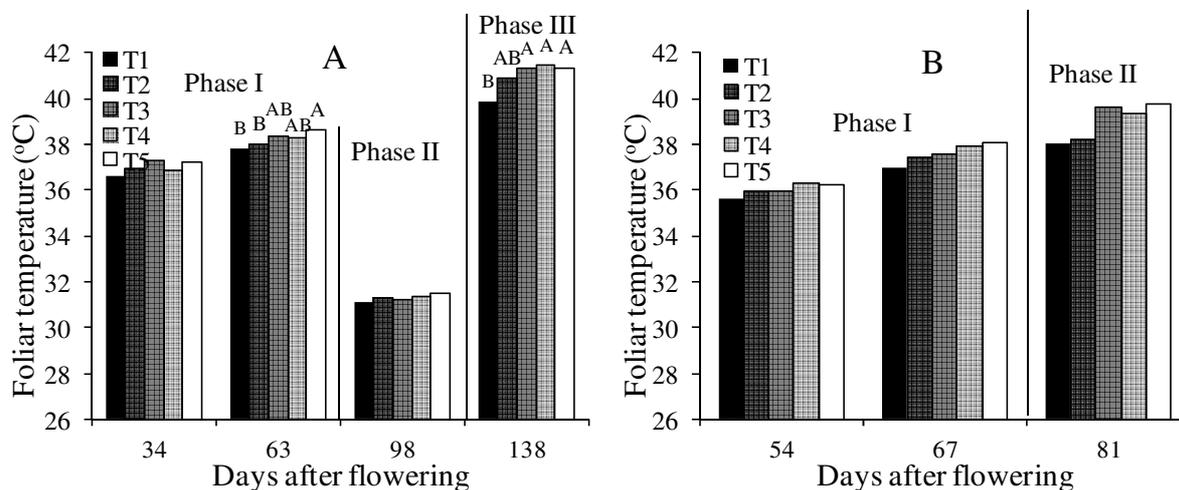
In the second evaluation cycle, there were no differences, among treatments, in the internal concentration of CO<sub>2</sub> at 54 and 67 days after blooming. However, at 81 days after blooming,

treatment 5 differed from the rest ( $P < 0.05$ ) by Duncan's test. This increase was probably caused by stomatal closure as showed in Figure 6A.

There were no significant differences in the foliar temperature between treatments in the first evaluation period of phase I. However, significant differences were observed in the second evaluation period of phase I; T1, T2, T3 and T4 did not differ among them by Duncan's test. T5, with higher foliar temperature, differed significantly from T1 and T2, but did not differ from T3 and T4. In phase II, no significant differences were noticed between treatments, possibly, due to the weather presenting many clouds, which limited capture of solar radiation by the leaves, contributing to the reduction in foliar temperature in all treatments. In the last evaluation phase (phase III), the lowest temperatures were observed in the leaves of T1

plants, comparing to the leaves of the other treatments (T3, T4 and T5).

From 110 days after blooming (phase III) in the first cycle, the rainfall in the area was sufficient to increase soil water levels, nevertheless, it was not sufficient to alter the foliar temperature of plants from RDI treatments.



**Figure 8.** Foliar temperature in 'Tommy Atkins' mango tree submitted to different treatments and evaluation phases. Averages followed by same capital letter or without letters in group do not differ significantly by Duncan's test at 5% significance level. Variation coefficients (VC) at 34, 63, 98, 54, 67 and 81 days after blooming according to figure above are 1.31, 1.12, 0.73, 2.25, 3.20, 2.15 and 3.10, respectively.

In the second evaluation cycle, there were no significant differences in the foliar temperature between treatments in the three performed measurements. However, it can be verified that without irrigation the plants present foliar temperature 4.37% higher than in the treatment with full irrigation.

When soil water deficit causes stomatal closure, the radiation captured by the leaf tends to promote foliar heating, through which foliar temperature can raise 4 to 5°C above room temperature (MAGGIOTTO, 1996). The high foliar temperature can reach damaging levels to the plant metabolism (TAIZ; ZEIGER, 2009) and cause photosynthetic rate and enzymatic activity reduction and even enzyme denaturation (HALE; ORCUTT, 1987). Even when significant differences are not noticed in foliar temperature between the partial water deficit treatments and the full irrigation treatment, it is observed that, in absolute values, plants submitted to water deficit present higher foliar temperatures. According to Hale and Orcutt (1987), this temperature increase contributed to the reduction in the photosynthetic rate, as previously observed.

### Foliar temperature

The foliar temperature variation observed in the three production phases for the different treatments is presented in Figure 8.

In general, the temperatures registered in the treatment with full irrigation were lower. This lower heating, or better refrigeration, registered in the leaves of plants under full irrigation, is due to evaporative heat loss (latent heat) which occurs because water evaporation requires energy. In the environment, leaves under stress, either by supraoptimal temperature and by excessive radiation, need to dissipate great amounts of heat, which can be done by the radiation emission of long waves (infrared emission), by sensitive heat loss and latent heat loss (TAIZ; ZEIGER, 2009). The ratio between sensitive and evaporative heat losses is called Bowen ratio. In well-irrigated crops, plant transpiration is high (SALISBURY; ROSS, 1992), reducing Bowen ratio and, consequently, the leaves temperature.

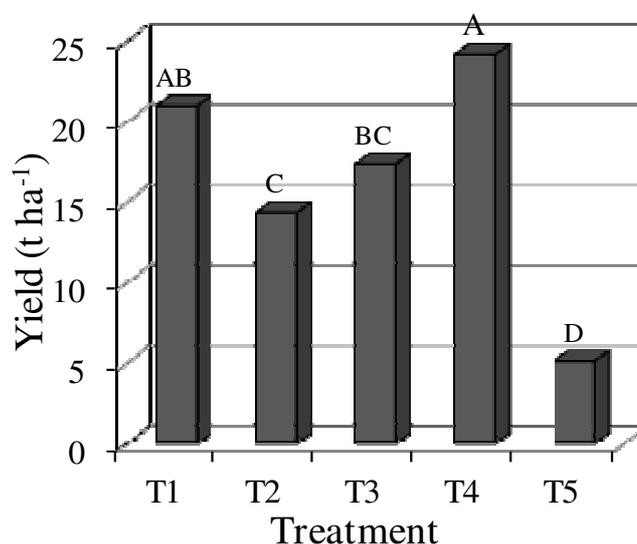
The physiological and ecology behavior is resultant from the balance of several environmental factors and not only one factor. The optimum temperature for CO<sub>2</sub> carboxylation by the rubisc enzyme, ribulose-1.5-bisphosphate carboxylase-oxygenase is 22°C. This enzyme predominates in plants with C<sub>3</sub> photosynthetic mechanism, as the mango tree. The balance between the rubisc carboxylase and oxygenase activities is governed by

the enzyme kinetic properties, temperature and concentration of CO<sub>2</sub> and O<sub>2</sub> substrates. Under concentration of environmental CO<sub>2</sub>, an increase in temperature modifies the rubisc kinetic constants and increases oxygenation rate, mainly, carboxylation (TAIZ; ZEIGER, 2009), that is, increases the photorespiration with decrease in the plant liquid photosynthesis rate. In general, below 30°C, the quantum production of photosynthesis, evaluated by CO<sub>2</sub> mol fixed by absorbed quantum, in C<sub>3</sub> plants is normally elevated and, above this limit, presents significant fall.

### Yield

The average yield of the two productive cycles is shown in Figure 9. Treatment 4 with yield

15.40% higher, did not differ significantly ( $P < 0.05$ ) by Duncan's test from the control treatment (T1). In contrast, when RDI at 50% of ET<sub>c</sub> is applied in the fruit-set phase (T2), there is significant reduction of 31.47% in total yield. Without irrigation the average yield in the two evaluation cycles was 5.10 t ha<sup>-1</sup>, differing significantly from the other treatments with irrigation. Taiz and Zeiger (2009) mentioned that plants under water deficit suffer disorders in water balance, nutrient absorption, growth inhibition, phenologic cycle, photosynthesis and, consequently in yield. This fact is confirmed in the present study, since plants without irrigation presented lower photosynthesis rates and yield.



**Figure 9.** Total yield for different treatments considering the two evaluation cycles.

DaMatta (2007) emphasized that the reduction in production is associated to a decline in photosynthetic rates. This decline, in great part, is induced by low soil water availability, either by a direct dehydration effect of the photosynthetic apparatus or by an indirect effect through stomatal closure, which restricts CO<sub>2</sub> absorption. It can be observed in Figure 5 that the photosynthetic rate in the leaves of plants from T5 and T2 present inferior values to other treatments, mainly in the fruit-set phase, and T3 with lower photosynthetic rate in the fruit expansion phase. Significant reductions are observed in yield in T5, T2 and T3, which can be explained by low photosynthetic rate, according to DaMatta (2007).

### CONCLUSIONS

Total or partial soil water deficit causes reduction in the photosynthetic rate, transpiration and stomatal conductance of 'Tommy Atkins' leaves.

Partial soil water deficit causes no significant alterations in internal CO<sub>2</sub> concentration or in foliar temperature of 'Tommy Atkins' mango trees.

Regulated deficit irrigation application with 50% ET<sub>c</sub> in the fruit set phase and no irrigation causes significant yield reduction. It is inferred, there are a relation in the reduction of the photosynthetic rate, transpiration and stomatal conductance with yield reduction of 'Tommy Atkins' mango.

**RESUMO:** As trocas gasosas influenciam o crescimento, o desenvolvimento e a produção das culturas e estão relacionados às condições hídricas da planta que podem ser uma resposta ao estado hídrico do solo e às condições de clima. Objetivou-se com este trabalho avaliar a transpiração, fotossíntese, condutância estomática, concentração interna de CO<sub>2</sub> e temperatura foliar da mangueira ‘Tommy Atkins’ sob diferentes regimes de irrigação no semiárido baiano. O delineamento experimental foi em blocos casualizados com cinco tratamentos e seis repetições: 1 – Irrigação suprindo 100% da ETc nas fases: I (início da floração a início da expansão dos frutos), II (início da expansão até início da maturação fisiológica) e na fase III (maturação fisiológica dos frutos); 2 – 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. O déficit hídrico total ou parcial no solo ocasionou redução na taxa fotossintética, na transpiração e na condutância estomática das folhas da mangueira ‘Tommy Atkins’. O déficit hídrico parcial no solo não ocasiona alterações significativas na concentração interna de CO<sub>2</sub> e na temperatura foliar da mangueira ‘Tommy Atkins’.

**PALAVRAS-CHAVE:** Irrigação com déficit controlado. Ecofisiologia vegetal. Manejo de irrigação.

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