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FISIOLOGIA, PRODUÇÃO E QUALIDADE DE FRUTOS DA MANGUEIRA 'TOMMY ATKINS' SOB DIFERENTES SISTEMAS DE IRRIGAÇÃO

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1 RESUMO

Considerando a grande expressão econômica na produtividade da manga para a agricultura brasileira e a dependência da irrigação, que viabiliza o seu elevado cultivo no semiárido, objetivou-se avaliar a influência de arranjos de sistemas de irrigação na fisiologia, produtividade e qualidade dos frutos da mangueira cultivar 'Tommy Atkins' no Semiárido brasileiro. Foram testados quatro arranjos do sistema de irrigação (um microaspersor sob a copa – MPP; um microaspersor entre plantas – MEP; duas linhas laterais com gotejadores por fileira de planta - G2L e uma faixa de gotejo em formato de anel ou espiral - GRP ao redor da planta) sob um delineamento em parcelas subdivididas, com quatro arranjos como parcelas e dois ciclos produtivos como subparcelas, com cinco repetições. Foram avaliados os parâmetros fisiológicos (temperatura foliar, fotossíntese, transpiração e condutância estomática), de produção (número e produtividade e peso médio de frutos) e parâmetros da qualidade (densidade, volume, firmeza da polpa, teor de sólidos solúveis totais e acidez total titulável). As mangueiras submetidas aos tratamentos GRP e G2L apresentaram maior condutância estomática e melhores índices de qualidade e produção de frutos em relação aos arranjos MEP e MPP, exceto para os sólidos solúveis totais.

Palavras-chave: manga, irrigação localizada, fitotecnia.

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2 ABSTRACT

Considering the great economic expression in the productivity of mango for Brazilian agriculture and the dependence on irrigation, which enables its high cultivation in the semiarid region, the objective was to evaluate the influence of irrigation system arrangements on the physiology, productivity and quality of the mango fruit cultivate 'Tommy Atkins' in the Brazilian Semiarid. Four arrangements of the irrigation system were tested (a micro sprinkler under the canopy - MPP; a micro sprinkler between plants - MEP; two lateral lines with drippers per row of plant - G2L and a drip band in the shape of a ring or spiral - GRP around of the plant) under a split plot design, with four arrangements as plots and two production cycles as subplots, with five replications. Physiological parameters (leaf temperature, photosynthesis, transpiration and stomatal conductance), production (number and productivity and average fruit weight) and quality parameters (density, volume, pulp firmness, total soluble solids content and total acidity) were evaluated titratable). The hoses submitted to the GRP and G2L treatments showed higher stomatal conductance and better quality and fruit production indexes in relation to the MEP and MPP arrangements, except for the total soluble solids.

Keywords: mango, localized irrigation, plant breeding.

3 INTRODUCTION

The production of mango fruits (*Mangifera indica* L.) has represented a great economic expression for Brazilian agriculture. The country produced approximately 1.4 million tons of mangoes in the 2019 harvest, with an average productivity of 21 tons per hectare. The greatest production is concentrated in Northeast China, accounting for 77% of the national production, with the states of Pernambuco and Bahia being the largest producers, producing 518.2 and 442.2 tons, respectively (IBGE, 2020). The Tommy Atkins cultivar occupies approximately 30% of the total cultivated area in the São Francisco Valley (KIST et al., 2019) because of its attractive characteristics, which are mainly related to tolerance to mechanical injury and longer fruit shelf-life.

In the semiarid region, commercial mango cultivation is made possible through irrigation. Owing to the expansion of irrigated fruit-growing areas associated with prolonged droughts, water demand is growing, and the water supply is limited. Therefore, to enable profitable production and greater water resource security, water application strategies that ensure maximum water use efficiency are essential.

Importantly, although mango is considered a drought-tolerant plant, studies have shown that inadequate irrigation affects its physiology, growth rate and, consequently, quality and productivity (PRAKASH et al., 2015).

Coelho et al. (2015) emphasized that the productive and qualitative response of plants to irrigation depends mainly on the frequency, timing, irrigation system, crop stage, soil and climate conditions, and cultivar used. In localized irrigation, which maintains the same applied depth, the arrangement of emitters in crop areas can interfere with application efficiency and soil water redistribution (SIMÕES et al., 2018). Therefore, the arrangement of a localized irrigation system can interfere with a plant's response to irrigation, affecting production components and fruit quality.

In this context, determining the best irrigation system and installation layout that results in the most efficient water distribution in the soil is essential. Furthermore, the technologies available on the market and their cost–benefit ratios must be *considered*.

Given the above, the objective of this work was to evaluate the influence of irrigation system arrangements on the physiology, productivity and quality of the fruits of the 'Tommy Atkins' mango cultivar in two consecutive cultivation cycles in the Brazilian semiarid region.

4 MATERIALS AND METHODS

The research was carried out in an experimental area of Agranvil Farm, located at 09° 24' south latitude and 40° 20' west longitude, at an altitude of 370 m, in the municipality of Petrolina, Pernambuco, which is located in the Submédio region of the São Francisco Valley. According to the Brazilian Agricultural Research Corporation (2006), the soil was classified as Neossolo Quartzarenic, and its chemical characteristics are shown in Table 1.

Table 1. Chemical attributes of the soil of the orchard in the experimental area cultivated with 'Tommy Atkins' mango. Agranvil Farm, Petrolina, PE. 2013

Layers (m)	CE (dS m $^{-1}$)	pH	P (mg dm $^{-3}$)	K	In the	Her e	Mg	Al	H+Al	SB	CTC	V (%)
				(cmolc dm $^{-3}$)								
0-0.2	0.80	6.5	99.83	0.20	0.06	2.4	0.8	0.0	0.3	3.5	3.8	91.5
0.2-0.4	0.83	6.0	16.13	0.15	0.14	2.1	0.9	0.0	0.8	3.3	4.1	80.4

CE = electrical conductivity of the saturated extract; P = available phosphorus extracted by Mehlich; Ca = exchangeable calcium; Mg = exchangeable magnesium; Na = exchangeable sodium; K = exchangeable potassium; H+Al = exchangeable acidity; CEC = cation exchange capacity at pH 7.0; V = base saturation.

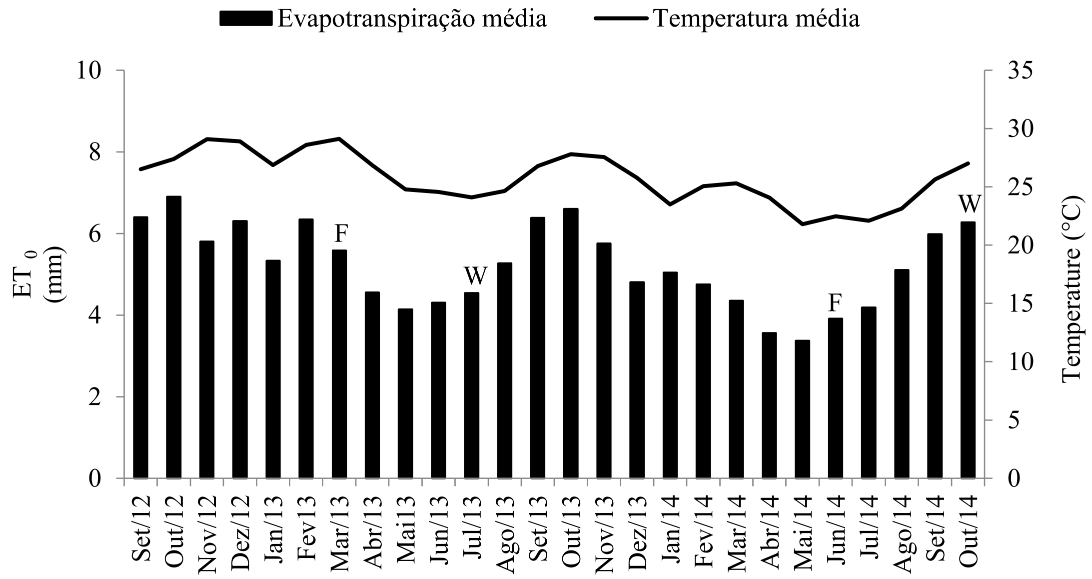
The experiment was carried out from September 2012 until the harvest of the second production cycle in October 2014 in an area of nine-year-old mango trees of the cv. 'Tommy Atkins' spaced 8 × 5 m apart. The management practices adopted for the plants included pruning after harvest, mineral fertilization, phytosanitary treatments and floral induction, as recommended by Mouco (2015). The harvests were carried out in the first cycle on July 15, 2013, and in the second cycle on October 23, 2014.

The experiment was conducted in the field via four soil water distribution arrangements via localized irrigation, resulting in the following treatments: a) a 56 L h $^{-1 \text{ microsprinkler}}$ under the canopy, 0.3 m from the plant trunk – MPP; b) a microsprinkler between plants – MEP; c) two lateral drip lines per plant row – G2L; and d) a ring-shaped or spiral drip strip (pigtail) – GRP around the plant. The experimental design was a split-plot design, with the irrigation arrangements as plots and the two production cycles as subplots, with five replicates. For the two dripper-irrigated treatments, the spacing used was 0.5 m. The number of drippers per plant was 14, with a flow rate of 4 L h $^{-1}$.

Irrigation management was carried out with reference to crop evapotranspiration (ETc), which was based on reference evapotranspiration (ETo), which was calculated via the Penman–Monteith method (ALLEN, 1998) from daily climate data from a meteorological station installed near the experimental site. The irrigation shift was daily, and the crop coefficients for determining ETc were those proposed by Teixeira et al. (2008).

According to the Köppen climate classification, the region has a BSh climate type and dry and very hot steppes (ALVARES et al., 2013). The average ETo and average temperature values during the research were recorded daily during the two cultivation cycles (2012/2013 and 2013/2014) (Figure 1).

Figure 1. Reference evapotranspiration (ETo) and average monthly temperatures at the meteorological station near the experimental area. Petrolina, PE. 2012/2013 and 2013/2014 harvests. (F): Beginning of flowering. (C): Harvest.



To determine the number of fruits, average weight, and productivity of the mango cv. 'Tommy Atkins', the fruits of the useful plants per plot of the different treatments were harvested at the E2 maturity stage (BRECHT; YAHIA, 2017), counted, and weighed individually. The E2 maturity stage is adopted as the standard for export and is characterized by a light green skin color and, in the pulp, limited yellowing around the seed. To assess production quality, the fruits per plot were harvested separately in the quadrants of the plants (North, South, East, and West), constituting a split-plot arrangement. Three fruits per quadrant were harvested from the middle part of the canopy, placed in plastic boxes, and transported to the Postharvest Physiology Laboratory of Embrapa Semiárido.

The firmness of the fruits was read via a manual penetrometer (Effegi, model FT 327) at two opposite points in the equatorial region. The fruit pulps were homogenized in a domestic processor to determine the total soluble solids (SS) and total titratable acidity (TA). The SS content was determined via a manual refractometer (Pocket PAL$^{-1 \text{ model}}$), and the TA content was determined via the titration of 1 g of homogenized pulp diluted in 50 mL of distilled water, the addition of three drops of 1% phenolphthalein indicator, and titration with 0.1 N NaOH solution, with the results expressed in g of citric acid 100 g $^{-1}$ of pulp (INSTITUTO ADOLFO LUTZ 2008).

In the second crop cycle, the physiological parameters, i.e., leaf temperature, transpiration, stomatal conductance and photosynthesis, were determined via the IRGA meter Model Li 6400 LICOR®, whose analyses were carried out in the fruiting phase of the crop, between 10:00 am and 12:00 pm, without cloudiness, using leaves in the mature physiological stage and exposed to the sun.

The results obtained were subjected to analysis of variance, with the means compared via the Tukey test at 5%

probability with the aid of Sisvar software (FERREIRA, 2017).

5 RESULTS AND DISCUSSION

Compared with those under the other treatments, the plants irrigated with the irrigation system arrangements with two lateral lines per plant row (G2L) and the spiral drip strip (GRP) presented greater net photosynthesis, stomatal conductance, and transpiration (Table 2). Considering that the applied water depth was the same for all the treatments, these two arrangements provided greater efficiency in terms of the photosynthesis rate and stomatal conductance for Tommy Atkins mango trees.

Table 2. Average values of photosynthesis, stomatal conductance, leaf temperature and transpiration of the leaves of 'Tommy Atkins' mango trees subjected to different arrangements in the irrigation system. Petrolina, PE, 2014.

Irrigation system arrangements	Photosynthesis (μ mol CO_2 m^{-2} s^{-1})	Stomatal conductance (mol H_2O m^{-2} s^{-1})	Leaf Temperature (°C)	Perspiration (mmol H_2O m^{-2} s^{-1})
MEP	8.71 bc	0.0335 b	38.06 a	1.60 b
MPP	6.83 c	0.0194 b	38.28 a	0.98 b
GRP	11.51 ab	0.0716 a	37.66 a	3.33 a
G2L	12.67 a	0.0783 a	37.09 a	3.50 to

Means followed by the same letter do not differ from each other at 5% probability according to Tukey's test. MEP: one microsprinkler between plants; MPP: one microsprinkler on the plant trunk; GRP: one ring drip strip around the plant; G2L: two lateral lines of drippers per plant row.

Allen et al. (1998) reported that vegetation cover interferes with water evaporation from the soil surface, increasing the shaded area, which can cause crop water deficits. On the basis of this finding, it can be inferred that in the present study, the MEP system, which recorded part of the wet bulb in an area not shaded by the plant, likely experienced relatively high daily evaporation rates, thus reducing the soil water potential and plant water availability. Similarly, Simões et al. (2017) reported a lower productivity of 'Tahiti' acid lime plants when water application was redistributed by a microsprinkler placed between plants.

In this scenario, low soil water availability likely caused a reduction in stomatal conductance in mango trees under the MEP arrangement, as plants tend to reduce water loss by reducing stomatal opening, thus avoiding a reduction in plant water potential. This is an essential mechanism for survival under water stress (SILVA et al., 2015). Low water availability can increase water use efficiency, but it can also negatively affect several physiological processes important for vegetative growth and development, such as transpiration, photosynthesis, and sugar synthesis, which are the main causes of reduced productivity (TAIZ & ZEIGER, 2017).

With respect to the number and average weight of fruits and productivity, there was a significant interaction ($p<0.05$) between the irrigation system arrangement factors and the mango tree culture cycles (Table 3).

Table 3. Number and average weight of fruits and productivity of mango trees (cv. Tommy Atkins) subjected to different irrigation system arrangements in two production cycles. Petrolina (PE), 2013/2014.

Irrigation system arrangements	Number of fruits		Average fruit weight (kg)		Productivity (t ha $^{-1}$)	
	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle
MEP	123.6 bB	210.3 aB	0.54 aA	0.46 bB	13.44 bB	20.72 aB
MPP	173.6 bA	215.2 aB	0.46 aB	0.43 aB	18.35 bA	22.22 aB
GRP	145.3 bB	272.7 aA	0.45 bB	0.51 aA	14.23 bB	27.55 aA
G2L	176.3 bA	272.2 aA	0.41 bB	0.52 aA	16.02 bA	29.02 aA

Lowercase letters compare production cycles for the same irrigation system arrangement. The uppercase letters compare irrigation system arrangements for the same production cycle. Identical letters do not differ from each other compared to a 5% probability using Tukey's test.
MEP: one microsprinkler between plants; MPP: one microsprinkler on the plant trunk; GRP: one ring drip strip around the plant; G2L: two lateral lines of drippers per plant row.

The increase in stomatal conductance, photosynthesis, and transpiration of plants irrigated with the GRP and G2L systems may have contributed to the increase in fruit number, average fruit weight, productivity, and fruit volume (Tables 3 and 4). These results were also reported by Almeida et al. (2015), who reported that reduced gas exchange decreases growth and fruit production in different agricultural crops. However, in the first cycle, the treatment with a microsprinkler close to the plant trunk (MPP), which was the emitter used in the orchard prior to this experiment, also resulted in greater productivity.

Table 4. Average values, in two cultivation cycles, of the density, volume and firmness of the fruit pulp for mango trees cv. 'Tommy Atkins' subjected to different irrigation system arrangements. Petrolina, PE. 2013/2014.

Irrigation arrangements	Density (g cm $^{-3}$)		Volume (cm $^{-3}$)		Firmness (N)	
	1st cycle	2nd cycle	1st cycle	2nd cycle	1st cycle	2nd cycle
MEP	1.06 aA	1.01 bA	517.0 aA	455.7 bB	108.5 aA	90.2 bB
MPP	1.06 aA	1.02 bA	435.8 BC	427.5 BC	107.4 aA	103.7 aA
GRP	1.08 aA	1.03 bA	420.4 bB	500.5 aA	102.3 aA	104.1 aA
G2L	1.07 aA	1.02 bA	390.3 bB	513.3 aA	100.8 aA	95.7 bAB

Lowercase letters compare production cycles for the same irrigation system arrangement. The uppercase letters compare irrigation system arrangements for the same production cycle. Identical letters do not differ from each other compared to a 5% probability using Tukey's test.
MEP: one microsprinkler between plants; MPP: one microsprinkler on the plant trunk; GRP: one ring drip strip around the plant; G2L: two lateral lines of drippers per plant row.

This result may be associated with lower atmospheric water demand in the first cycle, especially during the fruiting phase (Figure 1), in which evaporation losses for this microsprinkler treatment, which provides a larger wetted area than drippers do, may not have been as significant as those in the other cycles. Another characteristic that can be considered is that the plant's root system may have expanded more in the wet bulb region under this irrigation system than under the other treatments in the first cycle, which may have facilitated water and nutrient absorption.

The number of fruits and productivity were greater in the second crop cycle, which may be associated with the climatic differences between the growing years (Table 3). According to Sandip et al. (2015), mild temperatures are among the main factors that stimulate mango flowering. A difference of more than 6 degrees Celsius was observed between the average maximum temperatures during the flowering phase of the two cycles (2013--2014). Thus, the high temperatures in the first cycle, during the induction period and during flowering, may have been decisive for the lower panicle and fruiting rates, compromising productivity.

Flowering management for off-season production is performed by synchronizing branch initiation through pruning, the use of regulators and plant ripeners, and spraying with sprouting inducers (nitrates). It is also influenced by climatic conditions, such as the temperature for adequate flowering, fruiting, ripening, and fruit quality characteristics (DAVEMPORT et al., 2007). Another factor that may have contributed to the difference in productivity between the two cycles is the alternation of production present in mango cultivation (OLIVEIRA et al., 2015).

The lowest average fruit masses and volumes were observed in the second cycle of the MEP treatment (Tables 3 and 4). The larger area wetted by the microsprinklers, compared with the drippers, may have caused greater evaporation losses in the system, especially in the second cycle, which had a higher environmental water demand, in which evapotranspiration rates were higher during the fruiting phase. Levin et al. (2015) reported that water deficit during the fruiting phase of mango causes a significant decrease in average fruit weight.

Under water stress conditions, the amount of cytokinin produced in the roots is reduced to the aerial part of the mango tree, compromising fruit growth (SANDIP et al., 2015). Together, the lower average weight, length and diameter of the fruits are associated with water availability conditions lower than those required by the crop, thus causing a reduction in fruit volume (KUSLU et al., 2014).

The variables related to fruit quality were not influenced by position in relation to the canopy quadrant. However, for the variables density, volume and fruit firmness, there was a significant interaction ($p < 0.05$) between the irrigation system arrangements and the number of cycles (Table 4). The density of the fruits harvested in the second cycle is in agreement with that reported by Lacerda and Lacerda (2004), who reported that, in the harvest standard for export, mango should have a density between 1.01 and 1.02 g cm^{-3}.

In the first cycle of the mango, there was no difference in pulp firmness (Table 4). In the second cycle, the MEP treatment resulted in lower pulp firmness, possibly due to a reduction in fruit turgor, since the wet bulb was established between the plants in a less shaded location than the other treatments were prone to greater evaporation. Notably, adequate irrigation management can increase the water content of mangos, influencing their firmness (WEI et al., 2017).

According to Schouten et al. (2007), tissue firmness is altered by biochemical reactions and variations in turgor. According to Sams (1999), less severe water stress that does not cause fruit wilting may increase pulp firmness. Zhou et al. (2017) explained that the increased firmness under these conditions is due to limited pulp cell division and expansion and increased cell density and palisade tissue thickness.

There was a cycle × irrigation system arrangement interaction for the total soluble solids (SS) and total titratable acidity (TA) values, with no significant difference across the different quadrants (Table 5). In general, the SS content was greater in the second cycle, whereas the TA content was lower, probably because of the higher average temperatures during fruit ripening and harvesting during the second cycle (Figure 1). This result may be associated with the fact that climatic conditions can interfere with the physiological and biochemical processes of the plant and that high temperatures contribute to ethylene production, resulting in higher rates of carbohydrate accumulation and the degradation of organic acids in the fruit pulp (TAIZ & ZEIGER, 2017).

Table 5. Average values, in two cultivation cycles, of the total soluble solids (SS) content and total titratable acidity (AT) of the pulp of 'Tommy Atkins' mango fruits subjected to different irrigation system arrangements. Petrolina, PE. 2013/2014.

Irrigation system arrangements	SS (°Brix)		AT (%)	
	1st cycle	2nd cycle	1st cycle	2nd cycle
MEP	7.14 bA	8.26 aA	1.22 aB	0.76 bA
MPP	7.04 bA	8.79 aA	1.20 aB	0.81 bA
GRP	7.00 bA	7.46 aB	1.33 aAB	0.70 bA
G2L	7.15 aA	7.38 aB	1.40 aA	0.75 bA

Lowercase letters compare production cycles for the same irrigation system arrangement. The uppercase letters compare irrigation system arrangements for the same production cycle. Identical letters do not differ from each other compared to a 5% probability using Tukey's test.
MEP: one microsprinkler between plants; MPP: one microsprinkler on the plant trunk; GRP: one ring drip strip around the plant; G2L: two lateral lines of drippers per plant row.

In the second cycle, the fruits from the MEP and MPP treatments presented a relatively high content of total soluble solids. The lower number of fruits produced under these conditions may have influenced this result, since the greater number of sinks for synthesized photoassimilates (such as sugars and organic acids) should compromise quality attributes, as was also observed for mango trees by Oliveira et al. (2019). Another parameter that may also have influenced this result was the occurrence of higher evaporation rates in the second cycle during the fruiting season, which, according to Levin et al. (2015), can lead to a significant reduction in average fruit weight, as observed under the conditions of this experiment (Table 3), increasing the concentrations of soluble solids.

Different water availability levels for plants can lead to changes in the soluble solids content of fruits, as described by Wei et al. (2017) and Zhou et al. (2017). The authors noted the advantage of fruits with higher soluble solids content when water availability for plants was relatively lower, as observed in this state for the MEP treatment. However, the influence of the production cycle on most of the quality variables analyzed, including soluble solids content, is noteworthy. As the cycles are characterized by flowering and harvest management under different climatic conditions, the climate determines some of the observed responses to characteristics such as pulp firmness and total soluble solids content. and fruit volume.

6 CONCLUSIONS

The cultivation of the 'Tommy Atkins' mango variety, which was subjected to a localized irrigation system with rows and two rows of drippers, presented greater stomatal conductance and better fruit production and quality than did the arrangements with microsprinklers, except for the total soluble solids content.

Variations in the quality of mango cv. Tommy Atkins, represented by the firmness of the pulp and total soluble solids content, indicate that determining the harvest point on the basis of the color of the skin may not ensure the same degree of fruit ripeness and, consequently, a similar chemical composition between fruits harvested in different seasons.

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