

Full Length Research Paper

Profitability of yellow passion fruit as a function of irrigation depths under semiarid conditions

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In regions where rainfall is limited and irregular, irrigation technique is important for optimizing fruit plants production and profitability, such as yellow passion fruit. Therefore, this study investigates the economic viability of irrigations depth applied on passion fruit cultivation in the semiarid region of Paraíba State. The treatments were arranged on a factorial scheme that comprises four levels of ETo replacement (33, 66, 100 and 133%) and two yellow passion fruit hybrids (BRS Sol do Cerrado and BRS Gigante Amarelo), in a randomized block design, with five replications. Effective operational cost, administrative cost, total water cost, total production cost, gross income, net income, benefit/cost relation, balance of price and profitability index were evaluated. The best economic results were achieved with 'BRS Sol do Cerrado' hybrid under irrigation with 133% of ETo.

Key words: *Passiflora edulis*, hybrids, economic viability, drip irrigation.

INTRODUCTION

Yellow passion fruit (*Passiflora edulis* SIMS f. *Flavicarpa* DEG) is one of the most important fruit exploitation in Brazil, due to its use in nature as well as industrial beverages, besides excellent perspectives for exporting concentrated juice to Europe and USA (Ataíde et al., 2012).

Brazil is the biggest producer and consumer of this fruit

with 61,842 ha of growing area and estimated fruit production of 923,035 ton per year. The northeast of Brazil is the main producing area with 46,159 ha and 671,421 ton of fruit harvested, which correspond to 63% of national production (IBGE, 2014). According to Silva et al. (2015), the passion fruit has significant social and economic importance in Brazil and it is a versatile fruit

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that can be marketed in different forms, such as raw fruit, frozen pulps, juice, jams, yogurts, milk drinks and ice cream.

In Brazilian semiarid, specifically in the Paraíba State, the amount and quality of water are the factors that limit agricultural production. At this region the limited and irregular rainfall difficult the development of a non-irrigated fruit plant cultivation.

Nevertheless, in other Brazilian regions, where rainfall is regular year-round, passion fruit plants can be cultivated without irrigation techniques or with water supplementation when rainfall is below of the plant necessities (Arêdes et al., 2009). In this context, there is a history of research on the technical feasibility of irrigation methods according to Valipour (2012a) in determining optimal values for these systems. Thereafter, many attempts have been made to access appropriate design of sprinkle and trickle irrigation system (Valipour, 2012b).

By the benefits of localized irrigation system into the other techniques especially surface irrigation, more accurate design of this systems for saving in water resources, increasing irrigation efficiency, and finally encourage farmers to use of this system in order to save water resources (Valipour, 2012a).

Research with yellow passion fruit, in several regions of Brazil, have shown that this specie, in spite of having a high production cost and also a negative price fluctuations in the consumer market, has economic potential to increase employment and as well financial return; which has been matched and has often exceeded the rates achieved by the main crops in the country such as other species of fruit trees, cereals and vegetables crops (Kits et al., 1996; Araújo Neto et al., 2008; Arêdes et al., 2009; Hafle et al., 2011).

Economic analyses of the production chain is a significant index to show the implementation of a new technology and it has been studied for some researchers as Araújo Neto et al. (2008), Arêdes et al. (2009), Hafle et al. (2011) and Silva et al. (2015). The viability of a production chain depends directly on correct agricultural management, however, one should take into account all factors involved in this process (Hafle et al., 2012). Although there are researches with irrigated passion fruit cultivation (Araújo et al., 2012; Dias et al., 2012; Freire et al., 2014), there is still the lack of information about using this technology and the profitability of BRS Sol do Cerrado and BRS Gigante Amarelo hybrids under Paraíba State semi-arid conditions. These information are necessary to the farmers because they will help them to make the right decision of the resources used in its production, as also improving the performance of this fruit plant by enabling the expansion of areas under cultivation and guide the proper choice of the variety most adapted to the soil and climate of the semi-arid region.

Thus, this research was carried out to evaluate the economic viability of the application of different irrigation

depths in yellow passion fruit crop in the semi-arid region of Paraíba State.

MATERIALS AND METHODS

Plant material

The 'BRS Gigante Amarelo' and 'BRS Sol do Cerrado' are genotypes obtained by breeding program of Embrapa and has been indicated for all Brazilian regions, especially due its productivity and fruit quality when subjected to the adoption of technologies such as irrigation. The great interest according to the Embrapa researchers is due to the adaptation of these cultivars to all regions of the Brazil, which were proven after extensive evaluations in different regions, including in states in the Northeast.

According to Embrapa researchers, 'BRS Gigante Amarelo' is a highly productive hybrid under irrigation, reaching around 60 tons/ha in the first production year. Its fruit is yellow, has an oblong shape, and weighs 120 to 350 g. Already 'BRS Sol do Cerrado' is a hybrid of passion fruit that can be grown throughout the year under irrigation in different soil types, except in areas subjected to frost. Flowers occur year-round, with the highest concentration in the dry season, which improves its cultivation in Alto Piranhas region in the Paraíba State, being more tolerant to leaves diseases such as bacterial blight, virus and anthracnose (Andrade Neto et al., 2015).

Study site and experimental conditions

The experiment was conducted at Alto Piranhas region located in Paraíba State. This region has 6° 21' S of latitude and 37° 48' W of longitude and height of 250 m from sea level.

The climate type in the region, according to Köppen classification, is BSw'h', belonging to the group of semiarid climate, with average annual rainfall of 870.0 mm, average annual temperature of 27°C, relative air humidity of 75% and monthly average evaporative demand of 120 mm, with average annual rainfall concentrated in the months from February to April.

The soil from experimental area was classified as Eutrophic fluvial neosol with sandy loam textural classification. The physical and chemical characterization of the soil layer from 0.00 m to 0.30 m were: pH (H₂O) = 7.1; P (Mehlich⁻¹) = 36 mg dm⁻³; K = 0.83 cmolc dm⁻³; Ca = 2.8 cmolc dm⁻³; Mg = 0.7 cmolc dm⁻³; Na = 0.16 cmolc dm⁻³; Al = 0.0 cmolc dm⁻³; H+Al = 0.49 cmolc dm⁻³; organic matter = 9.54 g kg⁻¹; bulk density = 1.51 g cm⁻³; total porosity = 0.47 m³ m⁻³.

Treatments and experimental design

The experimental design was a randomized block with 5 replications, on a factorial scheme 4 x 2 composed of four irrigation depths (33, 66, 100 and 133% from ETo, corresponding to 323, 646, 978 and 1300 mm cycle⁻¹, respectively) and two yellow passion fruit hybrids (BRS Sol do Cerrado e BRS Gigante Amarelo). The experimental unit was composed of 3 plants. Seedlings were grown in greenhouse and they were transplanted to the field in the spacing 4 m x 3 m and were conducted in vertical espalier with one wire (Figure 1A).

Irrigation management

For irrigation management, the reference evapotranspiration was calculated by Penman-Monteith (Equation 1). The data used to estimate the ETo were obtained daily from an automated weather station installed near the experimental area. According to Valipour



Figure 1. Yellow passion fruit plants cultivated in vertical espalier with one wire (A) and irrigation management (B).

(2014), the Penman-Monteith method is suitable for estimating the water requirement of crops, despite showing variation around 10% compared with the lysimetric measures. Although this method has been applied in various regions of the world, it needs too many parameters to estimate reference crop evapotranspiration (Valipour 2015), hence it is important to assess its use in this research.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \left(\frac{900U_2}{T + 273} \right) (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$

In which: ET_o = reference transpiration (mm day^{-1}); R_n = net radiation on culture surface ($\text{MJ m}^{-2} \text{day}^{-1}$); heat flow in the soil ($\text{MJ m}^{-2} \text{day}^{-1}$); Δ = slope of the vapor pressure curve versus air temperature ($\text{kPa } ^\circ\text{C}^{-1}$); U_2 = wind speed measured at two meters high (m s^{-1}); T = average air temperature ($^\circ\text{C}$); e_s = water vapor saturation pressure (kPa); e_a = actual pressure of water vapor (kPa); γ = psychrometric factor (MJ kg^{-1}).

The crude depth, water application rate and the time of irrigation were determined by Equations 2, 3 and 4, respectively (Mantovani et al., 2006).

$$LB = \frac{ET_o K_c KL - Pe}{Ef}; LB \leq 0; LB = 0 \quad (2)$$

In which: LB = crude depth (mm); ET_o = reference evapotranspiration according to Penman-Monteith (mm); K_c = crop coefficient, considered 1 for application of ET_o ; KL = percentage of wetted area by the water emitter; Pe = rainfall during the experimental period (mm); Ef = irrigation method efficiency (decimal).

$$Ia = \frac{n \times v}{ec} \quad (3)$$

In which: Ia = water application rate (mm h^{-1}); n = number of emmitter per plant; v = emitter flow (L h^{-1}); ec = area occupied by the plant (m^2).

$$Ti = \frac{LB}{Ia} \quad (4)$$

In which: Ti = irrigation time (h); LB = crude depth (mm day^{-1}); Ia = water application rate (mm h^{-1}).

Management of the application of different water depths was carried out by varying the number of drippers per plant, using 1, 2, 3 and 4 pressure compensating drippers, with a nominal flow rate of 4 L h^{-1} , corresponding to depth of 33, 66, 100 and 133% of ET_o respectively (Figure 1B).

The fertilizers were applied through fertigation, every 15 days, in such a way to distribute nutrients throughout the crop cycle. Thus, a Ventury injector was used with a flow rate of 70 L h^{-1} .

Profitability and economic analysis

Fruit yield was estimated taking into account weight and number of fruits per plant (Mg ha^{-1}), and the estimated net income (RL) (Equation 5) was obtained through the response function ($Y(W) = \beta_0 + \beta_1 W_1 + \beta_2 W_2 + e$), cost of water ($CW = \frac{CEE}{LL} \times Pee$) (Andrade

Júnior et al., 2001) and the cost of production (CP) (Pimentel et al., 2009).

$$RL = \frac{(Y_w \times P - (CP + C_w \times W))}{10 \times W} \quad (5)$$

In which:

$Y(W)$ - Fruit yield as a function of applied water depth (Mg ha^{-1});

β_0, β_1 e β_2 - Regression parameters;

W_1 e W_2 - Irrigation depths;

e - Random error;

CW = Cost of irrigation water ($\text{US\$ mm}^{-1}$);

CEE = Electricity consumption during the crop cycle (kwh ha^{-1});

LL = Total water depth applied during the crop cycle (mm);

Pee = Price of kwh ($\text{US\$ kwh}^{-1}$), was obtained from Paraíba electrical power company;

P = Price of passion fruit on Catolé do Rocha county market (Paraíba State) was calculated on the basis on a weekly survey in street markets. The price paid to the farmer, that is, 50% of the

Table 1. Description of the absolute values and percentages of the cost of production on the first year of cultivation of passion fruit hybrids (*P. edulis* f. *Flavicarpa*) BRS Sol do Cerrado and BRS Amarelo Gigante irrigated with different replacement rates of ETo.

Description of costs	Irrigation depths							
	33% of ETo		66% of ETo		100% of ETo		133% of ET	
	Value	%	Value	%	Value	%	Value	%
COE (US\$ ha⁻¹)								
Inputs	2,281.09	39.00	2,281.09	38.40	2,281.09	37.50	2,281.09	36.90
Soil tillage and planting	400.00	6.80	400.00	6.70	400.00	6.50	400.00	6.40
Phytosanitary treatment	417.39	7.10	417.39	7.00	417.39	6.80	417.39	6.70
Harvest	434.78	7.40	434.78	7.30	434.78	7.10	434.78	7.00
Purchase of equipment	3,500.00	26.00	3,500.00	25.60	3,500.00	25.00	3,500.00	24.6
Subtotal (US\$ ha ⁻¹)	5,055.00	86.40	5,055.00	85.10	5,055.00	83.20	5,055.00	81.80
CEA (US\$ ha⁻¹)								
Financial charges	685.50	11.70	685.50	11.55	685.50	11.20	685.50	11.10
CTA (US\$ ha ⁻¹)	108.26	1.80	195.31	3.29	328.60	5.41	436.52	7.00
CTP (US\$ ha ⁻¹)	5,848.85	100	5,935.81	100	6,069.10	100	6,177.02	100.0

average price paid at these locations during the years 2011 and 2012 was also taken into account.

To analyze passion fruit production costs (CP), the expenditures and charges were grouped into the related categories:

(a) Effective operational cost (EOC): this comprises direct costs with financial disbursement to the activities from soil tillage and fruit harvest;

(b) Costs and administrative expending: it reflects fixed costs or indirect expenses for interest, social charges, administration fee and equipment depreciation:

(b.1) Remuneration of the farmer's capital calculated on the basis of 0.5% per month on the COE's half value: it aims to remunerate the alternative use of farmer's capital if he or she chooses for financial savings application;

(b.2) Land remuneration that correspond to the real value of 1.0 ha rentals in the region;

b.3) Depreciation of machinery and equipment: this includes financial resources to acquire spare parts which should correspond to 10% of the irrigation equipment;

b.4) Management fee calculated on the basis of 6% of the COE; and

(c) Total operating costs (COT), corresponding to the sum of the overall expenses of (a) + (b).

In addition to net income, other profitability indicators such as benefit/cost relation, equilibrium price and index of profitability were calculated by the following equations:

$$B/C = RB/CTP \quad (6)$$

$$PE = CTP/Y \quad (7)$$

$$IL = RL/RB \times 100 \quad (8)$$

In which:

B/C = benefit/cost relation (non-dimensional);

RB = gross income (US\$ ha⁻¹ year⁻¹);

CTP = total production costs (US\$ ha⁻¹ year⁻¹);

PE = equilibrium price (US\$ Mg⁻¹);

Yw = estimated productivity (Mg ha⁻¹);

IL = profitability index (%).

RESULTS

Cost of production

On Table 1 are shown the production costs for both 'BRS Sol do Cerrado' and 'BRS Gigante Amarelo' passion fruits hybrids. The cost generated by this factor is related to the price of seed, being equal to both genotypes. It should be observed it was included at disbursement stage of seedlings production, as a component of costs to calculate the effective operational cost (COE); it had the absolute value of US\$ 5,055.00 ha⁻¹ year⁻¹, which corresponded to 86.43, 85.16, 83.19 and 81.84% of the total production cost (CTP), in relation to water replacement depths 33, 66, 100 and 133% of ETo, respectively (Table 1). When the COE was fractionated, it was observed that the inputs accounted for 39 and 36.93% of the total cost of production process for the irrigation depths of 33 and 133%, respectively. These values corresponded to 1.95, 3.29, 5.41 and 7.07% from total cost of fruit production, respectively.

Technical indexes used to calculate costs of the research were obtained by monitoring the current field experiment. Labor, tractor rental and inputs considered were those used in Catolé do Rocha County-PB from 2009 to 2012. COE (effective operational cost), CEA (costs of administrative burden), CTA (Water total cost) and CTP (total cost of production).

Regarding costs of administrative burden (CEA), this value was US\$ 685.50 ha⁻¹. To the costs of irrigation water, these values were US\$ 108.26 (33% of ETo), US\$ 195.31 (66% of ETo), US\$ 328.60 (100% of ETo) and US\$ 436.52 per hectare (133% of ETo), which corresponded to 1.95, 3.29, 5.41 and 7.07% of the total

Table 2. Economic indicators on the first year of cultivation of passion fruit hybrids (*P. edulis* f. *Flavicarpa*) BRS Sol do Cerrado and BRS Gigante Amarelo irrigated with different replacement rates of ETo.

Economic indicators	Irrigation depths							
	33% of ETo		66% of ETo		100% of ETo		133% of ETo	
	SC	GA	SC	GA	SC	GA	SC	GA
Productivity (Mg ha ⁻¹) ha ⁻¹)	10.80	16.30	19.10	20.60	25.00	22.80	28.00	22.60
Price (US\$ Mg ⁻¹)	569.56	569.56	569.56	569.56	569.56	569.56	569.56	569.56
Gross income (US\$ ha ⁻¹)	6,151.30	9,328.90	10,926.20	11,772.34	14,265.87	12,992.40	16,008.8	12,917.10
Net income (US\$) ha ⁻¹)	302.4	3,480.06	4,990.36	5,836.53	8,196.78	6,923.25	9,831.8	6,740.11
Benefit/Cost (B/C)	1.05	1.59	1.84	1.98	2.35	2.14	2.59	2.09
Equilibrium price (US\$ Mg ⁻¹)	541.55	358.82	310.77	288.143	242.76	266.18	220.61	273.32
Profitability index (%)	4.92	37.30	45.60	49.50	57.40	53.20	61.40	52.10

SC (BRS Sol do Cerrado) and GA (BRS Gigante Amarelo).

production cost for replacement depths 33, 66, 100 and 133% of ETo, respectively (Table 1).

Passion fruit hybrids cultivation had a total production cost of 5,848.85 US\$ ha⁻¹ (33% of ETo), 5,935.81 US\$ ha⁻¹ (66% of ETo), 6,069.10 US\$ ha⁻¹ (100% of ETo) and 6,177.02 US\$ ha⁻¹ (133% of ETo) (Table 1).

Yield and economic indicators

Regarding economic indicators (Table 2), there was no economic deficit for any of the hydric replacement depths studied. The lower net income (302.45 US\$ ha⁻¹ year⁻¹) was attained by 'BRS Sol do Cerrado' irrigated with 33% of ETo. The bigger net income (9,831.0 US\$) was also attained by this hybrid irrigated with 133% of ETo. It was observed that the best benefit/cost relation with 2.59 value for that same water replacement, which shows for each US\$ 1.00 invested generated a net income of US\$ 1.59.

The higher profitability index (61.41%) was attained by 'BRS Sol do Cerrado' under 133% ETo of water replacement, however, under 33% ETo, the highest profitability index (37.30) was obtained by 'BRS Gigante Amarelo', higher than 'BRS Sol do Cerrado' under lower water availability. For equilibrium price, it was observed that when 'BRS Sol do Cerrado' was irrigated with 133% of ETo, the price paid by the ton of fruit decreased the price from US\$ 541.56 to US\$ 220.60, even so, this cultivation system ensures the production costs.

When the productivity was reduced due to water stress by low water availability to plants (from 28.00 and 22.6 Mg ha⁻¹ at 133% of ETo to 10.80 and 16.30 Mg ha⁻¹ at 33% of ETo by 'BRS Sol do Cerrado' and 'BRS Gigante Amarelo', respectively), the price paid for the product was the determining factor for which there was no prejudice to the cultivation system (Table 2). However, under water scarcity the 'BRS Gigante Amarelo' shows higher profitability index per unit of water depth applied (Figure 2).

DISCUSSION

Differences regarding the total production cost occurred due to the amount of water applied to replace the hydric status of the plants, taking into account that its cost is based on the amount of electricity used during the water pumping process from water source to the plants.

Some researchers such as Kits et al. (1996) have evaluated agricultural and economic aspects of yellow passion fruit plants, whom, in a study on planting densities, observed that expenses on inputs and labor accounted for 98 and 97% of the total cost of production, when the fruit plants were grown at a spacing of 2 m x 1.25 m and 2 m x 3.75 m, respectively. Araújo Neto et al. (2008) reported that inputs along with labor were 57.83% compared to minimal cultivation and 60.46% compared to conventional tillage. Hafle et al. (2011) reported that passion fruit plants training pruning account for 73.9% from inputs along with labor.

In this context, labor costs studied in this research (around 80%) are less than those achieved by previous authors. This current result may be related to the growing technology in use, that is, one in which weeds are controlled by herbicide applied in the planting lines and mechanical mowing between planting lines which requires few labor. These agricultural practices comprise labor price and machinery working time. Moreover, the use of genetic material more resistant to pests and diseases decreased spraying during passion fruit growing and, therefore, the use of labor.

The economic profitability is dependent on the quantity produced and the price paid for the product. In relation to the passion fruit growing system in the semiarid region of Paraíba State, good productivity was observed considering mainly the potential of the hybrids evaluated in this study under irrigation.

By analyzing yellow passion fruit profitability, Kits et al. (1996) recorded net income corresponding to US\$ 3,560.68 ha⁻¹. Araújo Neto et al. (2008) cited a higher value of net income around US\$ 5,524.77 ha⁻¹. In another



Figure 2. Yield of yellow passion fruit 'BRS Gigante Amarelo' irrigated in the Brazilian Semiarid.

study, Arêdes et al. (2009) found a net income of US\$ 5,749.29 ha⁻¹ and the benefit/cost relation of 1.24. The results found in this study (US\$ 8,196.7 ha⁻¹ and US\$ 9,831.8 ha⁻¹) mainly with 'BRS Sol do Cerrado' were higher than those presented by Kits et al. (1996) Araújo Neto et al. (2008) and Arêdes et al. (2009).

This may be related to the high productivity of the genotypes in this research and the high price paid for the fruits in the local market. These results show that irrigated fruit activity enables good economic returns, generates currency from outside and jobs mainly in areas where irrigation technology can be used, promoting greater water savings and economic returns.

Moreover, the productivity of 'BRS Gigante Amarelo' was higher than the 'BRS Sol Cerrado' under lower water availability. In this case, 'BRS Sol Cerrado' is more productively irrigated with larger volume of water, but water use efficiency is reduced. On the other hand, increase in productivity may not compensate for increase in water availability for this genotype as well as reduce its efficient use (Sousa et al., 2005).

According to Sousa et al. (2005), the water use efficiency relates accumulation of biomass or commercial production to the amount of water applied or evapotranspired by the crop. Thereafter, proper irrigation management stands out in irrigated agriculture for improved efficiency in water use. Among the means and techniques used to increase the water use efficiency in irrigated agriculture, is the use of drip irrigation and water supply along with high frequency and low amount.

Conclusions

Irrigated passion fruit cultivation provides economic returns in the semiarid region of Paraíba State. The best economic results were obtained with 'BRS Sol do Cerrado' under irrigation depth of 133% of ETo. Under water scarcity the 'BRS Gigante Amarelo' shows higher profitability index per unit of water depth applied.

Conflict of Interests

The authors have not declared any conflict of interest.

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