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Technical and economic indicators of papaya crops for the production factors water and organic compost

Indicadores técnicos e econômicos do mamoeiro aos fatores de produção água e composto orgânico

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ABSTRACT - The objective of this study was to analyze technical and economic indicators of responses of papaya (*Carica papaya* L.) to the production factors water and organic compost, in a rural property with characteristic of family farming in the Semiarid region of Brazil. The study was conducted from August 2019 to July 2020, in the first crop cycle, in the municipality of Pentecoste, Ceara, Brazil. A Formosa papaya crop (cultivar Tainung 1) was established with spacing of 2.5 × 2.5 m, and irrigated by a micro-sprinkler localized system. A randomized block design was used, with a split-plot arrangement and four replications. The primary treatments consisted of four irrigation water depths (60%, 80%, 100%, and 120% of the crop evapotranspiration), and the secondary treatments consisted of four organic compost rates (0%, 50%, 100%, and 150% of the required rate for the crop). The irrigation water productivity of 5.38 R$ (BRL) m^{-3}, related to the requirements of the production factors, on average, is five-fold the reference value for papaya crops under conventional production system. Rural credit allows the farmer to reach a social reproduction level with a papaya crop area that can be, on average, half of that needed under conditions without financing.

Keywords: Family farming. Agroecological transition. Water productivity. Socio-economic analysis. *Carica papaya* L.

RESUMO - A pesquisa teve como objetivo analisar indicadores técnicos e econômicos da resposta do mamoeiro (Carica papaya L.) aos fatores de produção água e composto orgânico em uma propriedade com característica de agricultura familiar no semiárido brasileiro. O estudo foi conduzido no período de agosto de 2019 a julho de 2020 no primeiro ciclo de produção no município de Pentecoste-CE. A cultura do mamoeiro Formosa tipo Tainung 1 foi estabelecida no espaçamento de 2,5 m x 2,5 m, sendo a irrigação realizada por sistema localizado do tipo microaspersão. O delineamento foi em blocos ao acaso com parcelas subdivididas em quatro repetições, com tratamentos primários constituídos por quatro lâminas de irrigação (60%, 80%, 100% e 120% da evapotranspiração da cultura) e tratamentos secundários por quatro níveis de composto orgânico (0%, 50%, 100% e 150% da dose requerida pela cultura). A produtividade da água de irrigação relativa aos requerimentos dos fatores de produção no valor 4,51 R$ m-3 representou em média cinco vezes o valor de referência para o cultivo do mamoeiro em sistema de produção convencional; O crédito rural permitiu alcançar o nível de reprodução social com o cultivo de uma área que em média representa a metade da área em condições que não ocorra o financiamento.

Palavras-chave: Agricultura familiar. Transição agroecológica. Produtividade da água. Análise econômico-social. *Carica papaya* L.

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INTRODUCTION

Brazil is one of the five largest papaya producing countries in the world, presenting favor climate and cultivars with high production potential over the years (LUZ et al., 2015; LUCENA, 2016). Papaya production in Brazil is concentrated in the Northeast and Southeast regions (SOUZA et al., 2016). In the Semiarid region within the Northeast region in Brazil, the use of irrigation for papaya crops has enabled improvements in the production of this crop (FEITOSA et al., 2018).

A sustainable agricultural production is based on a long-term production that improves environmental quality, associated resources, and quantity and economic viability of agricultural enterprises, resulting in improvements in quality of life for farmers (RAMÍREZ; GARCÍA; MEDINA, 2020).

The use of organic compost as soil fertilizers improves soil aggregation, mainly by affecting water infiltration, retention capacity, and drainage, improving soil aeration, contributing to the water balance of crops, and favoring root penetration (OLIVEIRA et al., 2009).

Irrigation is an alternative for supplying the water needed to crop productions; in some regions, it can be used for overcoming poor rainfall distributions (CARVALHO et al., 2014). In these regions, a correct and efficient irrigation water management is essential for crop productions. An efficient water management for crops requires a precise irrigation schedule based on measurements of local water consumption, where the irrigation should be applied to improve soil moisture and enable a better plant growth (KUMAR; JAT; SHANKAR, 2013).

The implementation of localized irrigation increases production costs, but it is important for obtaining higher fruit yield and quality, which somehow compensates the additional costs. The market value of organic products is usually higher; however, farmers focused on this advantage should be aware of production costs, which can nullify the advantage of better prices.

Cost management is one of the most important factors for any production system, as it is the basis for decision-making and ensures the profitability of enterprises. Unfamiliarity with production costs may result in marketing of products below their market value (SCHERWINSKI; LIMA, 2012).

According to Silva Neto (2005), the generation of wealth for society, measured through addition value to production, and the economic viability at the production unit level, measured by the income of each production system, are indicators that can be used in studies of local agricultural development.

In this context, the objective of this study was to analyze technical and economic indicators of responses of papaya (*Carica papaya* L.) to the production factors water and organic compost, in the Semiarid region of Brazil.

MATERIAL AND METHODS

The experiment was conducted from August 2019 to July 2020 in the municipality of Pentecoste, Ceará, Brazil. The region presents a BSw'h', hot and semiarid climate, according to the Köppen classification, with an irregular rainfall distribution from February to May, and a mean annual rainfall depth of 860 mm. The soil physical and chemical attributes are shown in Tables 1 and 2. The soil of the area presented a light texture and, therefore, high water drainage capacity. The electrical conductivity of the soil saturation extract was 0.34 ds m^{-1}, which is well beyond the salinity threshold for papaya crops that present tolerance to salt water (2.0 dS m^{-1}) (AYERS; WESTCOT, 1999).

Table 1. Physical attributes of the 0 to 0.20 m soil layer of the experiment area.

Coarse sand	Fine sand	Silt	Clay	Soil density	Particle Density	Texture class
	g kg^{-1}			kg m^{-3}	kg m^{-3}	Sandy-loam
484	233	162	121	1270	2640	

Table 2. Chemical attributes of the 0 to 0.20 m soil layer of the experiment area.

P	OM	pH	K	Ca	Mg	H+Al	Al	SB	CEC	EC
mg kg^{-1}	g kg^{-1}					cmolc kg^{-1}				dS m^{-1}
39	9.41	6.3	0.38	7.4	2.2	1.49	0	10.1	11.6	0.34

P = available phosphorus; OM = organic matter; SB = sum of bases; CEC = cation exchange capacity; EC - electrical conductivity.

The experiment was carried out in a randomized block design, with a split-plot arrangement, consisted of four blocks with four primary treatments in the plots and four secondary treatments in the subplots. The area of the plots was 60 m^2 (1.0 × 60.0 m) and the area of the subplot was 15.0 m² (1.0 × 15.0 m) with six plants; the three central plants were used for the evaluations. Formosa papaya seedlings of the cultivar Tainung 1 (*Carica papaya* L.) were grown in polyethylene bags.

The plots consisted of irrigation water depths (60%, 80%, 100%, and 120% of the crop evapotranspiration (ETc), and the subplots consisted of four organic compost rates (0%, 50%, 100%, and 150% of the required rate for the crop), according to the recommendation proposed by Cunha and Haag (1980) and split according to the absorption rate established by these authors. The papaya plants were established in the field with a spacing of 2.5 × 2.5 m, totaling 64 experimental subplots.

The chemical attributes of the organic compost used in the experiment are shown in Table 3. The organic compost consisted mainly of bovine manure, which was wet daily for 30 days to reach the conditions required for use. The compost had good Ca and K availability, which are essential for the crop development and fruit formation, in addition to not causing toxicity by aluminum. The organic compost application was split into three applications with 60-day intervals, according to each treatment (without application, and application of 50%, 100%, and 150% of the required organic compost fertilizer rate), as shown in Table 4.

Table 3. Chemical attributes of the organic compost used.

P	K	Ca	Mg	Na	Al	pH
ppm	cmolc dm^{-3}					
1.53	16.67	19	28	1.88	0	8.8

Table 4. Distribution of split applications of organic compost (OC) rates (kg plant^{-1}), according to the treatments (percentages of the required organic compost fertilizer).

OC application	Without OC	50% of OC	100% of OC	150% of OC
	kg plant^{-1}			
First	0	1.2	2.4	3.6
Second	0	1.8	3.6	5.4
Third	0	3.5	7	10.5

The organic compost fertilizer was applied by distributing it over the planting ridge at 30 days before establishment of the crop in the field; 30 kg of organic compost per linear meter were used, a rate that was equal to all treatments. After the distribution of the organic compost, a soil turning was carried out to the incorporate it into the soil.

The irrigation water productivity was obtained by the ratio between total fruit yield (kg ha^{-1}) and the volume of water applied per unit of area (m^3 ha^{-1}) in each treatment during the crop cycle, according to Equation 1:

$$IWP = \frac{Y}{W} \quad (1)$$

where: *IWP* is the irrigation water productivity (kg m^{-3}); *Y* is the fruit yield (kg ha^{-1}); and *W* is the total volume of water applied per unit of area over the crop cycle (m^3 ha^{-1}). The selling price of the product, 2.00 R$ (BRL) kg^{-1}, was used to calculate the irrigation water productivity, which was expressed as R$ (BRL) m^{-3}.

The organic compost use efficiency was calculated through the ratio between the production increase and the quantity of organic compost applied in each treatment, according to Equation 2:

$$CUE = \frac{\text{Yt -Y0}}{\text{C}_\text{t}} \quad (2)$$

where: *CUE* is the organic compost use efficiency, corresponding to kilogram of organic papaya produced per kilogram of organic compost applied (kg kg^{-1}); *Yt* is the papaya fruit yield in the treatment *t* (kg ha^{-1}), *Y0* is the papaya fruit yield in the control treatment (kg ha^{-1}); and *Ct* is the quantity of organic compost applied in the treatment *t* (kg ha^{-1}).

The soil penetration resistance was determined using an impact penetrometer (IAA, Planalsucar, Stolf), which was inserted into the soil from the soil surface to the depth of 0.30 m in each subplot of the experiment, totaling 64 points of evaluation. The data was compiled using spreadsheets in the program Excel.

The economic evaluation of the production unit was carried out by calculating the added value and income of the production unit, according to the methodology proposed by Silva Neto (2016). The added value of the production unit was obtained by Equation 3:

$$AV = GVP - IC - D \quad (3)$$

where: *AV* is the added value; *GVP* is the gross value of production; *CI* is the intermediate consumption (monetary value of goods and services consumed during the crop cycle); and *D* is the depreciation of equipment and installations facilities (monetary value consumed over several production cycles).

Depreciation was calculated using the linear method, based on the perspective of social reproduction, and based not on its value in a year, but on its mean value, which is constant, considering the useful life, without residual value, of the financed items, according to Equation 4:

$$Dm = (Va \text{ - } VR)/VU \quad (4)$$

where: *Dm* is the depreciation mean; *Va* is the value at the time of acquisition (year zero); *VR* is the residual value; and *VU* is the useful life.

The added value was calculated for a hectare of production, and a linear correlation ($AV = a \times UAA + b$; *UAA* = useful agricultural area) was used for the other hectares, in which the ordinate axis represents the added value and the abscissa axis represents the agricultural area, considering that the added value and the agricultural area have a dependency relation. The angular coefficient of the line (*a*) represents the marginal contribution in relation to the area, and the linear coefficient (*b*) represents the fixed capital required to implement the production system.

Considering the distribution of the added value, the income of the different agents that participate directly or indirectly in the production, including the farmer income, was calculated for each production unit, according to Equation 5:

$$FI = AV - I - W - T \quad (5)$$

where: *FI* is the farmer income; *AV* is the added value; *J* is the interest paid to banks (or other financial agent); *S* is the wages paid to workers (occasional or permanent), and *T* is the taxes paid to the State.

The added value and farmer income calculated for the production systems were used to develop linear models to describe the economic results, in this case, the added value or income of the production systems in relation to the useful agricultural area per unit of work, according to the linear model shown in Equation 6:

$$Y = ax + b \quad (6)$$

where: *Y* is the economic result (added value or income); *a* is the increase in economic result per unit of area; *x* is the area occupied by the production system; and *b* is the fixed cost.

The economic-social analysis was carried out using the added value and the farmer income as indicators, considering 1.0 ha of papaya crops in the first crop cycle, three fruit yield levels (maximum, mean, and minimum) obtained in the experiment, and the situations with and without financing.

The results found were subjected to statistical analysis, using the program ASSISTAT. The data of the treatments with organic compost and irrigation water depths were subjected to analysis of variance at 5% significance level.

RESULTS AND DISCUSSION

The analysis of variance for papaya fruit yield (Table 5) showed that the production factors (water and organic compost) alone had no significant effects at 5% significance level. However, the interaction between the factors showed significance at 5% level for papaya fruit yield.

Table 5. Analysis of variance (mean square) for papaya fruit yield (kg ha^{-1}) as a function of the production factors water and organic compost.

Sources of Variation	Degrees of freedom	Mean square
Block	3	6.15^{ns}
Irrigation water depths (IW)	3	4.18^{ns}
Residue (IW)	9	14.43
Organic compost (OC)	3	4.62^{ns}
IW × OC	9	29.92*
Residue (OC)	36	11.68
Coefficient of variation (%) (IW)	45.64	
Coefficient of variation (%) (OC)	41.06	

ns = not significant at 5% level; * = significant at 5% level.

The results denote that the maximum papaya fruit yield (42,178 kg ha^{-1}) was obtained with the water depth and soil fertilizer application rate required for the crop production: totaling 13 kg plant^{-1}. The mean national papaya fruit yield in Brazil is approximately 42,000 kg ha^{-1} (IBGE, 2020) for conventional production systems. Garcia, Bezerra, and Freitas (2007) evaluated the dynamics of Formosa papaya production in the Chapada do Apodi region, Brazil, under different irrigation water depths and found a maximum fruit yield of 38,980 kg ha^{-1} under a conventional crop system, with application of the water depth required for the crop, denoting the importance of the factor water for fruit yield. The mean papaya fruit yield in the first crop cycle as a function of water and organic soil fertilizer are shown in Table 6.

Table 6. Means for papaya fruit yield (kg ha^{-1}) in the first crop cycle as a function of the production factors water and organic compost.

Irrigation water depths (mm)	Organic compost rates (kg plant^{-1})				Means
	0	6.5	13.0	19.5	
1122.8	24.761	20.772	30.216	25.015	25.191
1497.1	28.084	26.911	11.033	32.910	24.734
1871.4	19.531	22.820	42.178	24.654	27.296
2245.6	25.092	33.545	22.274	31.423	28.084
Means	24.367	26.012	26.425	28.501	

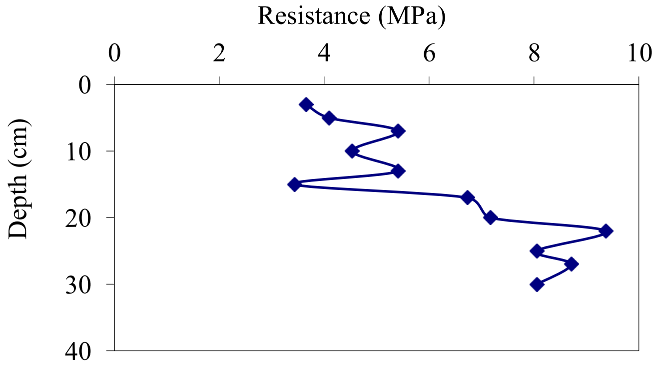
The production factor organic fertilizer application showed that the lowest mean fruit yield was obtained in the treatment with no application of organic fertilizer, denoting the importance and the effect of organic fertilizer on papaya fruit yield. In some subplots of the study area, the fruit yield data of some replications were well below those expected, compared to the other replications with the same primary and secondary treatments.

Thus, the possible causes for these occurrences in the experiment area is the existence of physical barriers in the soil profile, mainly in plots that had a low fruit yield. Soil penetration resistance is an important physical property for management and study of soil physical quality, as it is connected to several soil attributes that are indicators of the compaction level (FERNANDES et al, 2016).

Bartzen et al. (2019) reported that soil penetration resistance is a factor that directly affects root development and other phytotechnical aspects, which can compromise the crop production. Therefore, the soil resistance to penetration was evaluated using a Stolf penetrometer to evaluate the soil compaction level. The soil penetration resistance increases as soil compaction increases, limiting the root growth when higher than 1.5 to 3.0 MPa, according to Grant and Lanfond (1993) or than 2.0 to 4.0 MPa, according to Arshad, Lowery, and Grossman (1996); higher values were reported for no-tillage system, reaching 5.0 MPa, as shown by Ehlers et al. (1983).

Considering that the largest part of the radicular distribution of papaya is concentrated up to 0.30 m of depth, a soil penetration resistance close to 10 MPa at a depth of 0.20 m (Figure 1A) caused a high effect on the root development of the plants, resulting in low fruit yield, which was only 4169 kg ha^{-1} in the subplot. Contrastingly, in the other subplots, the resistance to penetration presented adequate values for root development, not limiting the crop development, resulting in a fruit yield of 47667 kg ha^{-1} (Figure 1B).

A)



B)

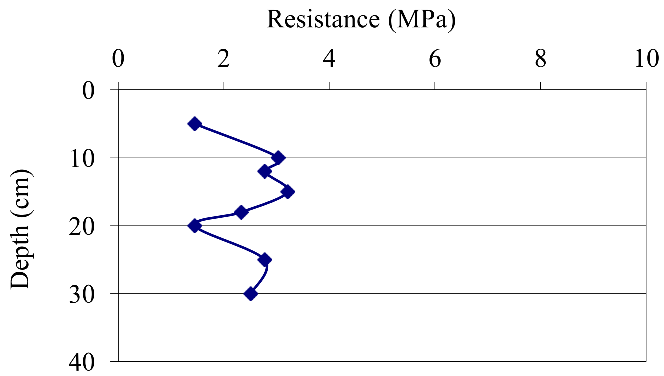


Figure 1. (A) Soil penetration resistance in the treatment with 60% of the irrigation water depth required and 150% of the organic compost rate required for the crop, which presented low fruit yield in the experiment area; (B) Soil penetration resistance in the treatment with the irrigation water depth and soil fertilizer rate required for the crop, which presented high fruit yield in the experiment area.

Tables 7 and 8 present the mean values of irrigation water productivity for the papaya crops as a function of the production factors water and organic compost, expressed in kg m^{-3} and R$ (BRL) m^{-3}, respectively.

The mean irrigation water productivity increased as the organic compost rate was increased, reaching the best results in the treatment with 20,800 kg ha^{-1} for the irrigation water depths of 60% and 100% of the crop evapotranspiration; the lowest value was found in the treatment with no application of organic compost. These results denote a production efficiency, when considering the results presented by ADECE (2015), which reported a yield of R$ (BRL) 0.89 m^{-3} for papaya crops in the state of Ceará. In addition, Sousa et al. (2017) evaluated papaya crops subjected to application of different rates of plant ash and carnauba palm residues and found increases in irrigation water productivity as the combined rates applied were increased.

Table 7. Irrigation water productivity (kg m^{-3}) of papaya crops (cultivar Tainung 1) as a function of the production factors water and organic compost, in Pentecoste, CE, Brazil.

Irrigation water depths (mm)	Organic compost rates (kg ha^{-1})				Means
	0	10,400	20,800	31,200	
1122.8	2.21	1.85	2.69	2.23	2.24
1497.1	1.88	1.80	0.74	2.20	1.65
1871.4	1.04	1.22	2.25	1.32	1.46
2245.6	1.12	1.49	0.99	1.40	1.25
Means	1.56	1.59	1.67	1.79	1.65

Table 8. Irrigation water productivity (R$ (BRL) m^{-3}) of papaya crops (cultivar Tainung 1) as a function of the production factors water and organic compost, in Pentecoste, CE, Brazil.

Irrigation water depths (mm)	Organic compost rates (kg ha^{-1})				Means
	0	10,400	20,800	31,200	
1122.8	4.41	3.70	5.38	4.46	4.49
1497.1	3.75	3.60	1.47	4.40	3.30
1871.4	2.09	2.44	4.51	2.63	2.92
2245.6	2.23	2.99	1.98	2.80	2.50
Means	3.12	3.18	3.34	3.57	3.30

Improving water use efficiency is a key factor for continuously increasing fruit yield in crops growing in arid and semiarid regions (GUOJU et al., 2016). However, in the present work, the production factor water showed that the irrigation water productivity presents an inverse correlation with this factor, as shown by Melo et al. (2020), who found that the water use efficiency in papaya crops decreased as the irrigation water depth was increased due to water losses by percolation. According to Silva et al. (2017), the main yield losses connected to application of excess water to crops is due to the leaching of nutrients. In addition, Dinka (2016) reported that excess water from irrigation in crops causes soil waterlogging, resulting in a decreased production, or even in total loss of the crop season.

The organic compost use efficiency, considering the production factors water and organic compost rates required for the crop, was 1.09 kg of papaya fruits per kg of organic compost applied.

Tables 9, 10, and 11 show, respectively, fixed costs, variable costs, and depreciation costs. These values, combined with the gross value of production, constitute the variables required for calculating the added value referent to the annual production of organic Formosa papaya crops grown under irrigation; the maximum, mean, and minimum productivity levels obtained in the experiment; and the conditions with and without financing through rural credit from the Brazilian National Program for Strengthening Family Agriculture (Pronaf). The Tables show the difference in added value with and without financing for different production levels, denoting a significant impact on the farmer income.

Table 9. Annual added value corresponding to 1.0 ha (maximum fruit yield).

Description		Value
Fixed Cost (FC)	Cistern	R$ (BRL) 5,492.00
	Motor-pump	R$ (BRL) 1,240.83
	Pipes and implements	R$ (BRL) 5,868.30
	Irrigation System	R$ (BRL) 5,125.40
	Total	R$ (BRL) 17,726.53
	Financing installment	R$ (BRL) 1,772.65
Variable cost (VC)	Mechanization	R$ (BRL) 1,800.00
	Seeds and Seedlings	R$ (BRL) 1,115.00
	Organic fertilizer	R$ (BRL) 2,403.00
	Alternative control	R$ (BRL) 100.00
	Electricity	R$ (BRL) 378.52
	Harvest	R$ (BRL) 1,920.00
	Total	R$ (BRL) 7,716.52
	Financing installment	R$ (BRL) 771.65
Depreciation (D)	Annual	R$ (BRL) 1,303.52
Production	Gross value of production (GVP)	R$ (BRL) 84,355.84
Added value (AV) with financing	AV = GVP -(FC+VC+D)	R$ (BRL) 80,508.02
AV without financing	AV = GVP -(FC+VC+D)	R$ (BRL) 57,609.27

Table 10. Annual added value corresponding to 1.0 ha (mean fruit yield).

Description		Value
Fixed Cost (FC)	Cistern	R$ (BRL) 5,492.00
	Motor-pump	R$ (BRL) 1,240.83
	Pipes and implements	R$ (BRL) 5,868.30
	Irrigation System	R$ (BRL) 5,125.40
	Total	R$ (BRL) 17,726.53
	Financing installment	R$ (BRL) 1,772.65
Variable cost (VC)	Mechanization	R$ (BRL) 1,800.00
	Seeds and Seedlings	R$ (BRL) 1,115.00
	Organic fertilizer	R$ (BRL) 2,203.00
	Alternative control	R$ (BRL) 100.00
	Electricity	R$ (BRL) 302.81
	Harvest	R$ (BRL) 1,920.00
	Total	R$ (BRL) 7,440.81
	Financing installment	R$ (BRL) 744.08
Depreciation (D)	Annual	R$ (BRL) 1,303.52
Production	Gross value of production (GVP)	R$ (BRL) 52,652.58
Added value (AV) with financing	AV = GVP -(FC+VC+D)	R$ (BRL) 48,832.33
AV without financing	AV = GVP -(FC+VC+D)	R$ (BRL) 26,181.72

Table 11. Annual added value corresponding to 1.0 ha (minimum fruit yield).

Description		Value
Fixed Cost (FC)	Cistern	R$ (BRL) 5,492.00
	Motor-pump	R$ (BRL) 1,240.83
	Pipes and implements	R$ (BRL) 5,868.30
	Irrigation System	R$ (BRL) 5,125.40
	Total	R$ (BRL) 17,726.53
	Financing installment	R$ (BRL) 1,772.65
Variable cost (VC)	Mechanization	R$ (BRL) 1,800.00
	Seeds and Seedlings	R$ (BRL) 1,115.00
	Organic fertilizer	R$ (BRL) 2,003.00
	Alternative control	R$ (BRL) 100.00
	Electricity	R$ (BRL) 227.11
	Harvest	R$ (BRL) 1,920.00
	Total	R$ (BRL) 7,165.11
	Financing installment	R$ (BRL) 716.51
Depreciation (D)	Annual	R$ (BRL) 1,303.52
Production	Gross value of production (GVP)	R$ (BRL) 39,062.68
Added value (AV) with financing	AV = GVP -(FC+VC+D)	R$ (BRL) 35,270.00
AV without financing	AV = GVP -(FC+VC+D)	R$ (BRL) 12,867.52

Figure 2 shows the functional correlations between added value and useful agricultural area for the papaya production unit considering the maximum, mean, and minimum yields in the situations with and without financing.

Despite the difference in the added value relative to 1.0 ha did not change in absolute values for the conditions with and without financing, regardless of the fruit yield situation analyzed, it was not found in percentage values, as the situation with lower fruit yield showed difference of up to 65%.

Paiva (2019) reported that the higher fixed costs needed to implement enterprises without financing is a strong limitation for the activity, thus showing the importance of rural credit as a social tool for farmers that use irrigation to produce.

Thus, the use of Pronaf financing (rural credit) by the farmer for implementation of a production unit was considered in the present work, which has a 2.75% interest rate per year; this interest refers to fixed and variable costs (Table 12).

The wage paid to workers was composed considering that a family production unit eventually has the need for hiring external workers. Thus, the results of the variables required for calculating the farmer income for an area of 1.0 ha, under conditions with and without financing, are obtained by the difference between the added value of the production and the costs with interest paid to financing agents, taxes paid, and wages paid to workers for production units with or without financing.

The farmer income for 1.0 ha was used to project a linear increase up to 2.0 ha and show this correlation, in which the ordinate axis represents the farmer income and the abscissa axis represents the agricultural area, considering that the farmer income and the agricultural area have a dependency relation (Figure 3).

The social reproduction level is connected to the income needed for the social reproduction based on the minimum wage, which was R$ (BRL) 1,045.00 in 2020, and is an indicator responsible for assuring the maintenance and sustainability of the production unit. Thus, the higher the fixed capital per person required to implement the production unit (coefficient b) and the lower the marginal contribution related to the area (coefficient a), the higher the useful agricultural area per person and the possibility of the workers in the family receiving an enough income for their maintenance in the agricultural activity.

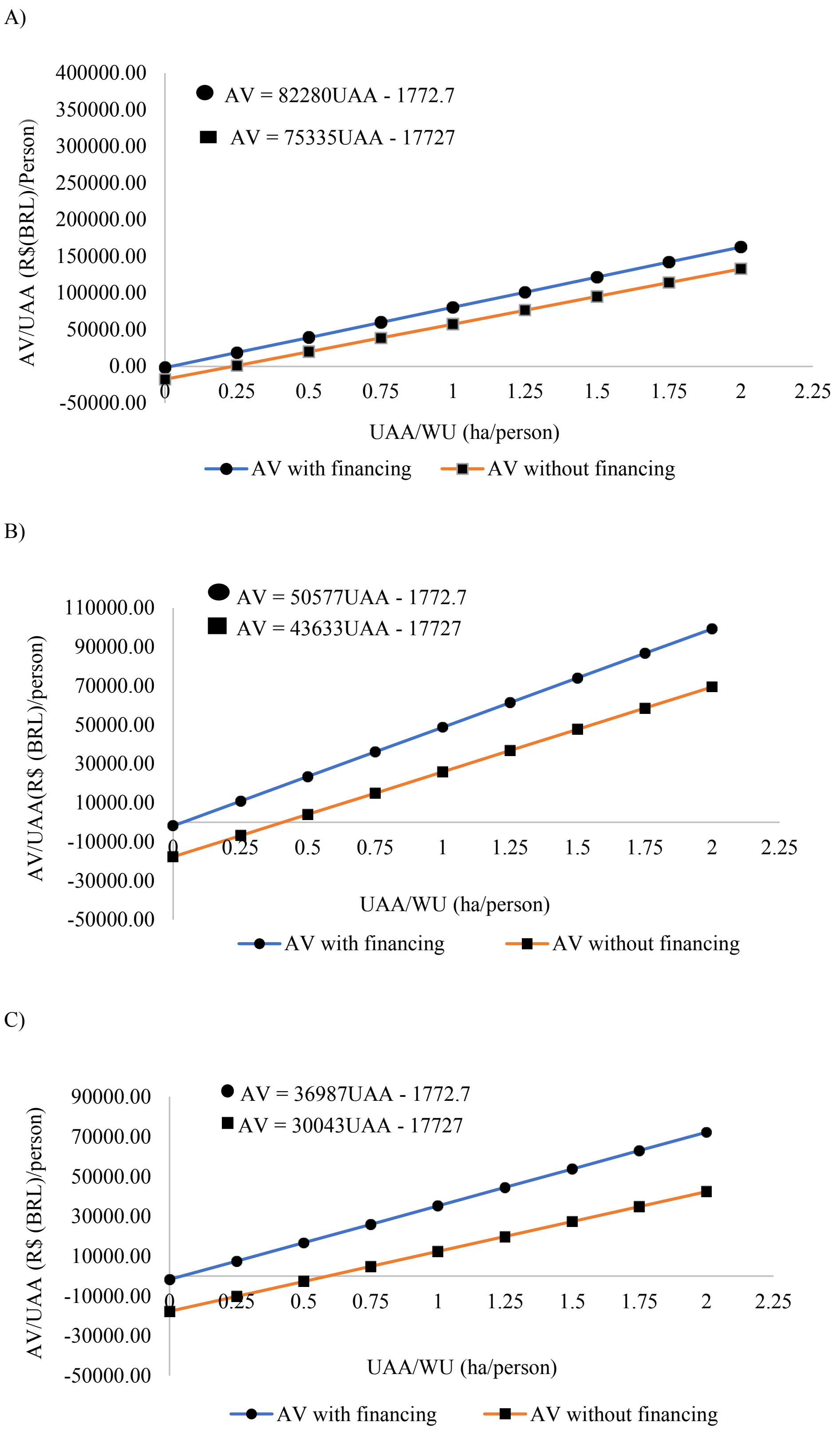


Figure 2. Added value (AV) as a function of the useful agricultural area (UAA) for the organic papaya production unit, considering maximum (A), mean (B), and minimum (C) fruit yields.

Table 12. Interest paid to the financing agent (Pronaf) related to rural credit for investment, with an interest rate of 2.75% in 2020 for 1.0 ha of annual production.

Description		Value
Costs	Fixed Cost	R$ (BRL) 17,726.53
	Variable cost	R$ (BRL) 7,716.52
	Wage paid to workers	R$ (BRL) 7,480.00
	Total	R$ (BRL) 32,923.05
Interest	2.75%	R$ (BRL) 905.38

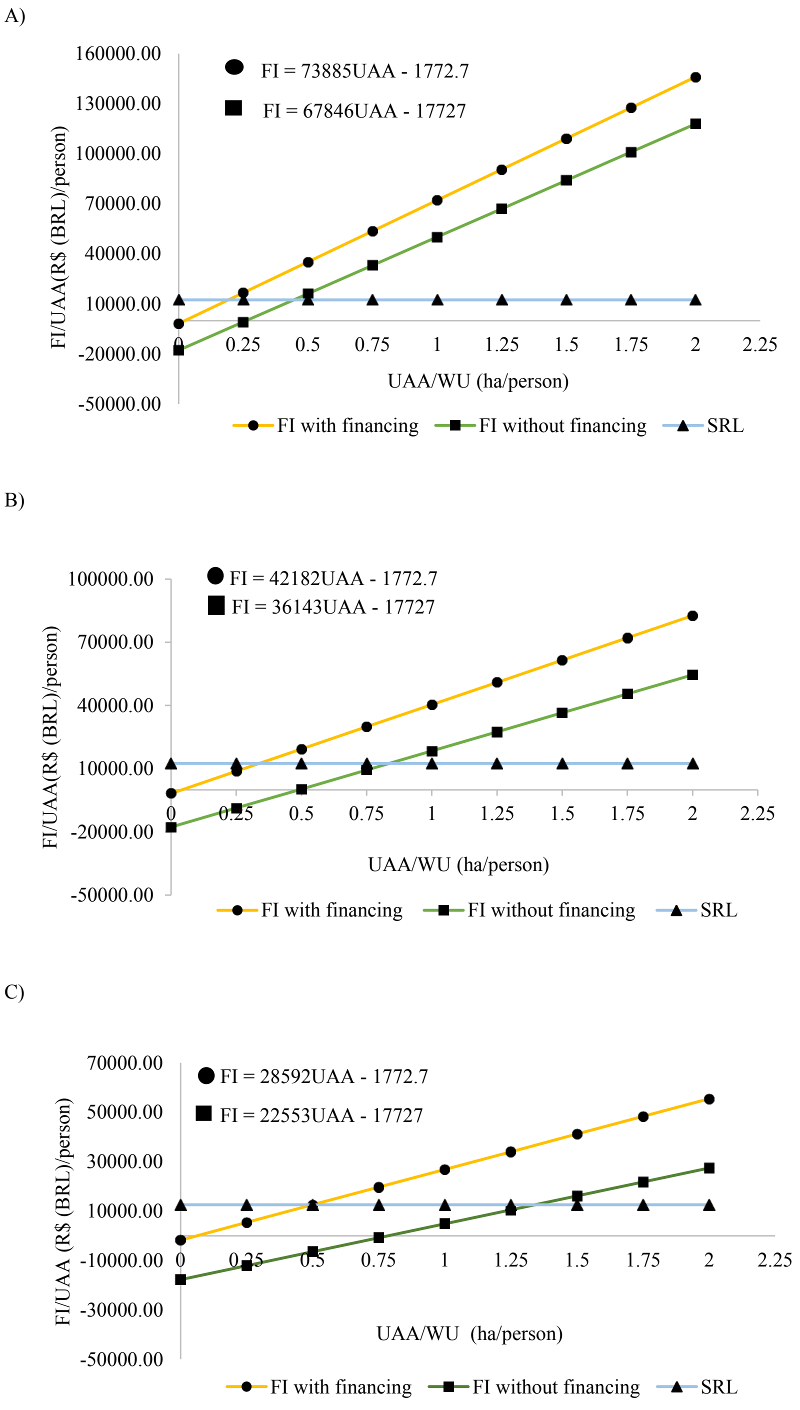


Figure 3. Farmer income as a function of useful agricultural area (maximum fruit yield) (A); Farmer income as a function of useful agricultural area (mean fruit yield) (B); and Farmer income as a function of useful agricultural area (minimum fruit yield) (C).

The functional correlation between the farmer income and useful agricultural area denotes that the condition with financing results in a higher marginal income when compared to the condition without financing for the three fruit yield levels analyzed. This result is shown by the more pronounced slope of the line that represents the condition with financing. Moreover, the area needed for reaching the social reproduction level was always smaller in the condition with financing, i.e., in which the production unit was established with resources from rural credit for the three fruit yield levels analyzed.

CONCLUSIONS

The irrigation water productivity of 5.38 R$ (BRL) m^{-3}, related to the requirements of the production factors, is on average five-fold the reference value for papaya crops under conventional production system.

The correlation between the farmer income and the useful agricultural area denotes that the financing results in a higher marginal income when compared to the condition without financing, for the three fruit yield levels analyzed.

Rural credit allows the farmer to reach a social reproduction level using a papaya crop area that can be, on average, half of that needed under conditions without financing.

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