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VIABILIDADE ECONÔMICA DO CULTIVO DE MAMÃO FERTIRRIGADO SOB DIFERENTES DOSES DE POTÁSSIO

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1 RESUMO

O Brasil possui uma atuação de destaque no mercado nacional e internacional de produção de mamão. Para otimizar esta produção, faz-se necessário o uso de tecnologias como a de fertirrigação. Todavia, compreender a viabilidade econômica de tal tecnologia é de suma importância para estimular seu uso. Nesse contexto, o objetivo do presente trabalho foi avaliar a viabilidade econômica do cultivo do mamão fertirrigado sob diferentes doses de potássio. A fertirrigação ocorreu por meio de sistema de irrigação por gotejamento, com gotejadores apresentando vazão de 1,4 L h^{-1}. O experimento foi instalado em Igarape-açú, no nordeste do Pará. A metodologia utilizada para aferir a viabilidade econômica do cultivo de mamão fertirrigado é uma adaptação de trabalhos anteriores. A partir da análise realizada, verificou-se que o uso da fertirrigação por meio de um sistema de irrigação por gotejamento, aplicando-se uma dose de 480 kg K_2O ha^{-1}, resultou em fluxo de caixa com valor presente líquido (VPL) de R $ 27.806,33, uma taxa interna de retorno (TIR) de 48,10% e uma relação benefício/custo (B/C) de 2,01. Portanto, para um hectare de mamão fertirrigado com doses de potássio, nas condições edafoclimáticas observadas, a produção com adoção da tecnologia fertirrigação por gotejamento, constitui-se numa opção viável.

Palavras-chave: fruticultura, lucratividade, quimigação, fertirrigação.

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2 ABSTRACT

Brazil has an outstanding performance in the national and international market of papaya production. To optimize this production, the use of technologies such as fertigation is necessary. However, understanding the economic viability of this technology is of paramount importance to stimulate its use. In this context, the objective of this study was to evaluate the economic viability of fertigated papaya under different doses of potassium. Fertigation was done by drip irrigation system, with drippers presenting a flow rate of 1.4 L h^{-1}. The experiment was installed in Igarape-açú, in the northeast of Pará. The methodology used to assess the economic viability of fertigated cultivation of papaya is an adaptation of previous works. From the analysis performed, it was found that the use of fertigation through a drip irrigation system, applying a dose of 480 kg K2O ha^{-1}, resulted in a cash flow with a net present value (NPV) of R$ 27,806.33, an internal rate of return (IRR) of 48.10%, and a benefit/cost ratio (B/C) of 2.01. Therefore, for one hectare of fertigated papaya with doses of potassium, under the observed edaphoclimatic conditions, the production with the adoption of the drip fertigation technology, it constitutes in a viable option.

Keywords: fruit growing, profitability, chemigation, fertigation.

3 INTRODUCTION

Brazil plays a prominent role in the national and international papaya production market, being the second largest producer and exporter of fruit, mainly to European countries, and its cultivation is found in production systems throughout the country (PÁDUA, 2019). The main production areas are south of the state of Bahia and north of the state of Espírito Santo, with estimated productivities of 40.5 t.ha $^{-1}$ and 58.7 t.ha $^{-1}$, respectively (BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS, 2019).

Thus, the adoption of new technologies and practices contributes to increased productivity in papaya crops. Fertigation (fertilizer application via irrigation) has the potential to correct soil water deficits by simultaneously maintaining a balanced and constant flow of water and nutrients from the roots to the aerial part of the plant. Maintaining this system in balance significantly contributes to plant growth, development, flowering, and fruiting, resulting in high productivity and improved fruit quality (COELHO *et al*., 2014).

However, despite the numerous benefits associated with the use of irrigation systems in different agricultural systems, it is also necessary to understand the economic factors associated with this technology. In this context, prior studies and analyses are needed to achieve higher yields than the system's implementation costs, understanding the risks and estimated profitability of implementing irrigation or fertigation in production systems (FEITOSA *et al*., 2018; VILLAS BOAS *et al*., 2011; OLIVEIRA *et al.*, 2010; ALMEIDA *et al.*, 2004).

According to Lyra *et al*. (2010), Silva *et al* . (2007), irrigation systems require high initial investments, which are linked mainly to the intense use of inputs, the purchase of equipment, transportation and operational labor, making an economic feasibility study of all the elements contained in the system essential.

In this sense, studies and estimates carried out guide producers in decision-making, mainly in conjunction with the determination of the system's profitability and the analysis of production risk and sensitivity, making the process more efficient (ALMEIDA *et al*., 2017; LYRA *et al*., 2010). In short, the execution of an economic feasibility analysis allows the producer or a group of producers to understand all the costs and values involved in the production process, allowing them to assess whether the return is satisfactory and whether the project is viable (AZEVEDO; ALVES; LACERDA, 2018).

Additionally, studies that determine the economic viability and efficiency of increasing the productivity of a crop with the incorporation of N and K (nitrogen and potassium) doses into the production system are, for the most part, based on the conventional fertilization process, directly into the soil.

Although fertigation, which involves applying fertilizers via irrigation water, has established itself as one of the most promising fertilization techniques, particularly for increasing efficiency and reducing costs, it remains a technology with little use in North Brazil. Therefore, studies on fertilizer applications via fertigation and their optimal amounts need to be conducted in Brazilian production areas (ANDRADE JÚNIOR *et al*., 2012).

In this context, the objective of this work was to evaluate the economic viability of papaya cultivation fertigated by a drip irrigation system with different doses of potassium in the Igarapé-Açu region, northeastern Pará, Brazil.

4 MATERIALS AND METHODS

The study of the economic viability of the fertilized papaya crop was carried out on the basis of data collected in a field study established at the Experimental Farm of the Federal Rural University of the Amazon, UFRA, at the geographic coordinates of 01°07'33” South latitude, 47°37'27” West longitude and altitude of 55 m, municipality of Igarapé-Açu, state of Pará.

A drip irrigation system was designed and sized for one hectare. The experimental design was a randomized complete block design (RBD) with four treatments and four replicates. The treatments consisted of percentages (50, 100, 150, and 200%) of the recommended amount of potassium, which, on the basis of soil analysis, totaled 160, 320, 480, and 640 kg K_2O ha $^{-1}$, respectively, represented as K160, K320, K480, and K640. These potassium doses were applied via fertigation via a 50-liter tank connected to the suction line of a 1.5 hp centrifugal motor pump. The following were used to prepare the nutrient mixture: urea, purified MAP (crystalline monoammonium phosphate), and potassium nitrate. Fertilization via irrigation water began after sexing, which occurred six months after planting. During the fertigation application phase, foliar fertilization was maintained, but one application was applied every 30 days (COELHO *et al*., 2014).

The experimental plots, which were 4 m wide by 7 m long, were systematized with two rows of plants; therefore, the useful area had a spacing of 2 × 2 × 4 m. The plants were arranged alternately between the two rows, which consisted of a total of seven plants, three of which were marked, with which the productivity data were obtained.

The cost modality analyzed in this work corresponds to the total expenses (total cost) per hectare of papaya cultivated area, covering the fixed and variable costs of the production process, taking into account the values practiced in the mesoregion of Northeast Pará.

Thus, the costs of the management and production components were calculated in reais (R$) on the basis of price research in the local market, referring to January 2020. These market data were used to calculate the fixed and variable costs for the cultivation of 1 ha of fertigated papaya under the conditions adopted in the development of the experimental unit presented here for a period ranging from the preparation of the area, which occurred in May 2018, until the last harvest, which occurred in the first week of February 2020.

The methodology used in this work was adapted from Reis (2007), Sousa (2017), and Mendonça *et al*. (2009). Reis' (2007) methodology allowed us to assess the project's economic viability on the basis of average revenue, while the methodology used by Sousa (2017) and Mendonça *et al. was used*. (2009) allowed us to analyze economic viability on the basis of the net profitability achieved on the basis of total production costs and total profitability. By establishing these factors, it was possible to understand the level of profitability and the cost–benefit ratio.

The use of Reis's (2007) methodology in this work is justified by the fact that it allows a comparative analysis with the methodology of Sousa (2017) and Mendonça *et al.* (2009); thus, both can function in a summative and nonexclusive way, enriching the analysis carried out.

In summary, after the fertigation project was developed, the technical and economic feasibility of implementing the drip irrigation system was analyzed on the basis of the cost per hectare. The budget, which is based on the project's bill of materials, was calculated on the basis of specialized irrigation market values.

Sousa (2017) and Mendonça *et al.* (2009) used the following financial indicators of project viability to establish profitability and, therefore, the viability of an investment alternative: net present value (NPV), the internal rate of return (IRR) and the benefit/cost ratio (B/C).

Reading Sousa (2017) allows us to understand that NPV refers to the current value of a cash flow from investments, considering future costs and revenues, discounted at the market-determined interest rate, calculated from the sum of revenues, discounted from the sum of costs, both brought to the present. The NPV was calculated via Equation (1).

$$VPL = \sum_{i=0}^{n} \frac{FC}{(1+r)^n} \qquad (1)$$

where NPV is the net present value; *FC* represents cash flow balances; *n* represents the period; and *r* is the discount rate used.

Moreover, the IRR for Mendonça *et al.* (2009) constitutes the internal discount rate of the project that makes the current value of the investment null, which is calculated via Equation 2.

$$VPL = \sum_{i=0}^{n} \frac{FC}{(1+r)^n} = 0 \qquad (2)$$

where NPV is the net present value; FC represents cash flow balances; *n* represents the period; and *r* is the discount rate that makes the NPV equal to 0.

The benefit/cost relationship is defined by the quotient between the current value of inputs and the current value of outputs, that is, by the quotient between the present value of revenues to be obtained and the present value of costs, including investments (SOUSA, 2017; MENDONÇA *et al.*, 2009). The benefit/cost relationship was calculated via Equation 3.

$$B/C = \sum_{i=0}^{n} \frac{\frac{R}{(1+r)^n}}{\frac{D}{(1+r)^n}} \qquad (3)$$

where B/C represents the benefit/cost ratio; *R* represents the revenue in each period; *n* represents the period; *r* represents the discount rate; and *D* represents the expenses in each period.

The production cost, proposed by Reis (2007), was estimated via an economic procedure that considers the calculation of depreciation (Equation (4)) and the alternative cost. For the depreciation calculation, an 18-month period (data collection time in the field) was adopted. As an alternative cost, the cost required to replace capital assets (in this case, the capital assets were the irrigation system and liming) when they became useless was adopted. For the irrigation system, a useful life of 10 years was adopted.

$$D = \left(\frac{Va - Vr}{Vu}\right) * P \tag{4}$$

where D is depreciation (R$); Va is the current value of the resource (R$); Vr is the real residual value (resale value or final value of the asset, after being used rationally in the activity) (R$); Vu is the useful life (period in which a given asset is used in the activity) (years); and P is the analysis period (years).

An interest rate of 5% per year was established to calculate the fixed alternative cost, which was calculated via Equation 5.

$$CA_{fixo} = \left(\frac{Vu - I}{Vu}\right) * Va * Tj * P \tag{5}$$

where $_{\text{Fixed CA}}$ is the fixed alternative cost (R$); Vu is the useful life (years); I is the average age of use of the asset (years); Va is the current value of the resource (R$); Tj is the interest rate (decimal); and P is the analysis period (years).

With a $_{\text{fixed}}$ CA, the average age of use of fixed resources was considered to be 50% of the useful life (Vu), which results in half the current value of the resource (Va), multiplied by the interest rate (Tj) and the analysis period (P), according to Equation (6).

$$CA_{fixo} = \left(\frac{Va}{2}\right) * Tj * P \tag{6}$$

where $_{\text{Fixed CA}}$ is the fixed alternative cost (R$); Va is the current value of the resource (R$); Tj is the interest rate (decimal); and P is the analysis period (years).

To calculate the variable alternative cost, an interest rate of 5% per year was considered, as per Equation 7.

$$CA_{var} = \frac{V_{gasto}}{2} . Tj \tag{7}$$

where CA $_{\text{var}}$ is the variable alternative cost (R$); V $_{\text{expenditure}}$ is the financial disbursement made by the producer to acquire the input and services necessary for agricultural production (R$); and Tj is the interest rate (decimal).

Fixed costs are not easily changed in the short term; they determine production capacity. To perform the calculations, depreciation and the alternative cost of the production factor were added. The items considered for the analysis were as follows: a) Land: Assuming that the farmer will adopt appropriate soil management, there will be no depreciation. Therefore, the value considered was the alternative cost based on a rent of R$1,760.00 per hectare over a two-year period; b) liming: liming costs in the experimental area were R$272.80 per hectare, with a useful life of two years; c) localized irrigation system: the amount spent on implementing and maintaining the irrigation system in the experimental area over two years was R$1,350.00 per hectare, representing the value proportional to a useful life of ten years; and d) rural land tax (ITR): this resource does not change in the short term; its value remains constant throughout the year. According to Silva and Barreto (2014), the value practiced in Pará is R$ 0.12 per hectare for one year.

The results for variable costs were based on the sum of the alternative cost added to the value of each product or service purchased. The variable resources and operational methods used were as follows: a) inputs: mineral fertilizers and organic compost, herbicide, acaricide, insecticide, fungicide, and adhesive spreader. The quantities used for the calculations were based on the quantities and types used in the experiment; b) seedling cost: for the acquisition of 2,000 units (considering a 20% premium to ensure the seedlings needed for transplanting), the cost per hectare is R$2,000.00; c) labor: refers to the daily wages required for operational activities, such as seedling production, crop establishment in the field, crop management, pest and disease control, irrigation system operation, harvesting, transportation, and storage; d) expenses with machinery and implements: expenses with the rental of machinery and implements used in the activities of area preparation, liming, fertilization, and transportation during the harvest period, based on the quantities produced in each treatment; e) administrative expenses: refers to specialized labor during the implementation and vegetative cycle of the crop and taxes, adopting the value of 2.3% of the total revenue produced, which is the percentage recommended in the Rural Credit Manual (CMR) adopted by technical assistance and rural extension companies in the preparation and provision of technical assistance in projects of the Program to Strengthening Family Farming (Pronaf); f) general expenses: This group includes the acquisition of bags for conditioning the harvested fruit, which is carried out on the basis

$$CE = V_{kWh} * T * \left(\frac{736*Pot}{1000*\eta}\right) \quad (8)$$

where CE is the energy cost (R$); V_{kWh} is the value of kWh in (R$); T is the total operating time of the irrigation system (h); Pot is the power of the motor pump set (hp); and η is the efficiency of the motor pump set.

By adding the total operating cost (CopT) and the alternative cost, the economic cost of fertigated papaya production was obtained. The total operating cost was divided into fixed operating cost (CopF), consisting of depreciation, and variable operating cost (CopV), consisting of disbursements. When added together, these factors result in the total operating cost.

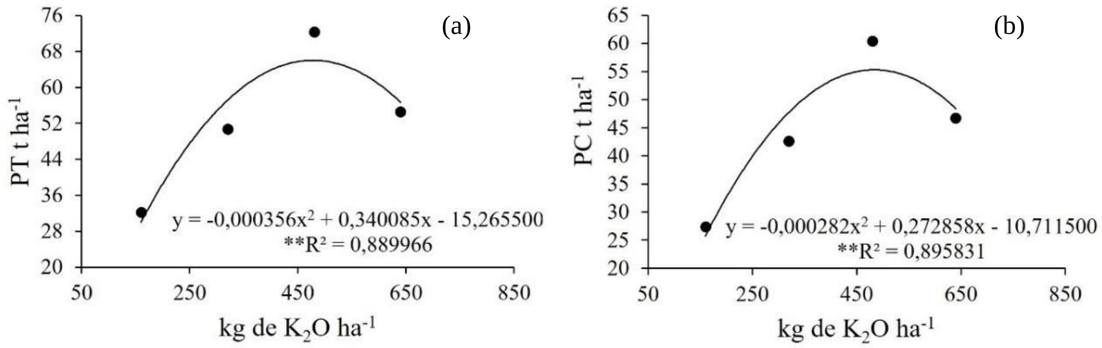
To perform a simplified economic analysis of productive activity, the average price or revenue was adopted, which, compared with the average total cost (CTMe), allowed conclusions regarding the economic viability of the activity. In the analysis of this production cost, the economic and operational situations of the productive activity proposed by Reis (2007) were considered.

In this study, the adopted quantities of the items that were used in the production system were multiplied by the value of each item according to a price survey carried out in the local market in January 2020. The price adopted for the commercialization of the fruits was checked at the Center for Advanced Studies in Applied Economics (CEPEA) of the University of São Paulo (USP) and at the Pará Supply Center (Ceasa-PA). The price study was carried out at both institutions throughout 2019. Both studies allowed for decision-making more in line with the local reality.

5 RESULTS AND DISCUSSION

The results were obtained from 20 harvests, which were carried out between April 2019 and early February 2020 (10 months and eight days), and all the harvests were maintained at 15-day intervals. The data were then systematized to visualize the total fruit productivity (TP) and commercial fruit productivity (PC), as shown in Figure 1.

Figure 1. Representation of production data, total production (PT) and commercial production (PC), in response to different potassium doses, Igarapé-Açu, Pará, April 2019 to February 2020.



**= 1% significance.
Source: Authors (2022).

Within this analysis (Figure 1), both variables showed significant differences between treatments ($P < 0.0001$), while the F value and coefficient of variation for PT and PC were 89.92 and 1.48, 37.69 and 4.0, respectively. Therefore, the maximum productivity values achieved for both the PT and PC variables were 66.0 t ha $^{-1,}$ with 477.6 kg of K_2O ha $^{-1,}$ and 55.3 t ha $^{-1,}$ with 483.8 kg of K_2O ha $^{-1}$, respectively.

Here, it is interesting to highlight the value of total fruit productivity (TP). According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2020), the national average papaya productivity between 2013 and 2019 was 44.0 t ha $^{-1}$, whereas in the state of Pará, the average productivity was 16.65 t ha $^{-1.}$ In the municipality of Igarapé-Açu, the average productivity for this time period was 20.63 t ha $^{-1}$. When these data, specifically the average papaya productivity value in Igarapé-Açu, are compared with the results of this study, it is possible to demonstrate a 219% increase in total papaya productivity in Igarapé-Açu when the crop was fertigated with potassium doses equal to or greater than 477.6 kg K2O $_{ha}$ - ^{1}.

For the analysis proposed here, the observed increase in the productivity of papaya harvested in the experimental area in relation to the national, state, and municipal averages that hosted the experiment can be attributed to the use of fertigation technology associated with potassium supplementation, as well as to the management and cultural and phytosanitary treatments adopted. These results were similar to those reported by Feitosa *et al.* (2018) and Marinho *et al.* (2008), who analyzed the productivity and quality responses of the papaya fruit cultivar Golden during the harvest period of 11 months and 21 days and reported a productivity of 79.4 t ha $^{-1}$.

For the economic feasibility study, it was necessary to establish the average price of papaya. From this perspective, the value corresponding to the local market was adopted in the calculations for revenue generation, which was R$ 1.00 per kilogram, paid to the producer, according to data accessed by the Pará Supply Center - Ceasa-PA (2019). Notably, when considering the main papaya-producing states in Brazil, in 2019, the average value was R$ 2.59 (CENTER FOR ADVANCED STUDIES IN APPLIED ECONOMICS, 2019).

In addition, given the need to accurately assess the total costs for establishing 1 ha of fertigated papaya, the values (R$) corresponding to the items that make up the total costs of papaya production according to the four treatments studied were systematized (Table 1).

Table 1. Values in R$ of fixed and variable costs of fertigated papaya production under different potassium doses, in R$ per [8] kg box, Igarapé-Açu, Pará, May 2018 to February 2020.

Fixed and Variable Costs	**Costs (R$.ha $^{-1}$)**			
	K160	**K320**	**K480**	**K640**
Earth	1760.00	1760.00	1760.00	1760.00
Liming	272.80	272.80	272.80	272.80
ITR	0.12	0.12	0.12	0.12
Irrigation system	1350.00	1350.00	1350.00	1350.00
Total Fixed Cost [1]	3,382.91	3,382.91	3,382.91	3,382.91
Inputs	7355.23	8650.28	9945.28	11240.28
Labor	2360.00	2920.00	3080.00	3000.00
Machines and implements	2450.00	2450.00	2850.00	2450.00
Administration expenses	2305.75	2655.72	3063.65	2749.74
General expenses	2444.80	3586.00	4916.20	3892.60
Energy	733.32	733.32	733.32	733.32
Total Variable Cost	17,649.15	20,995.32	24,588.45	24,065.94
[1] Total Cost (TC)	21,032.07	24,378.23	27,971.36	26,448.86
[1] Total cost (R$ box $^{-1}$)	6.14	4.57	3.71	4.70
Total Revenue (R$ ha $^{-1}$)	27424.00	42,640.00	60,376.00	46,728.00
Profit (R$ ha $^{-1}$)	6,391.93	18,261.77	32,404.64	19,279.14

[1] CT reflects both the total production and the equivalent of an 8 kg box; ITR = rural land tax; K160 = application of 160 kg K_2O ha $^{-1}$; K320 = application of 320 kg K_2O ha $^{-1}$; K480 = application of 480 kg K_2O ha $^{-1}$; and K640 = application of 640 kg K_2O ha $^{-1}$.

Source: Authors (2022).

On the basis of the data provided and via the methodology of Reis (2007), increasing total variable cost (CVT) values were observed as a function of the increase in potassium dose applied per treatment; however, the total fixed cost (CFT) remained unchanged as a function of the treatment.

Notably, compared with the K320 treatment, the K480 treatment resulted in an increase in total cost (TC) of 12.84%; however, the first treatment resulted in an increase in productivity of 29.37% in relation to that of the K320 treatment, which involved the application of 320 kg ha $^{-1}$ of the recommended potassium. On the other hand, by increasing the potassium dose represented by K640, the profit decreased by 40.50% compared with that of K480 (Table 1).

The cost of box-type packaging, corresponding to R$0.60 per unit, which is part of the general expenses item, is noteworthy, as it was observed that as crop productivity increased, there was also an increase in the demand for packaging, indicating a directly proportional relationship between fruit and packaging. Therefore, packaging costs ranged from 11.65% to 18.42% of the total variable operating cost (TVOC).

Notably, the fixed and variable costs of fertigated papaya production, the item inputs and general expenses, for treatments K320 and K480, when added together, represent more than 50% of the total variable costs, with an emphasis on treatment K480, which had a value corresponding to 52.97% of the total costs.

Based on the four treatments studied, the item that had the largest share of total variable costs was inputs. This is because the value of fertilizers suitable for fertigation is still very high on the local market. Thus, potassium nitrate, together with purified MAP, accounted for 8.55%, 15.24%, 18.71%, and 24.93% of the CT values of the K160, K320, K480, and K640 treatments, respectively. Melo *et al.* (2009), when working with potatoes in the irrigated perimeter of Sergipe, also reported that inputs were the most representative variable (60.7%) of production costs. The total cost of fertigated papaya production under the conditions of this research ranged from R$21,032.07 (K160) to R$27,971.36 (K480), while the profit percentage verified by the treatment that obtained the highest productivity (K480) was 53.67% in relation to the total revenue; similar values were reported by Feitosa *et al*. When analyzing the costs and profitability of the production of irrigated papaya in Northeast China, (2018) identified the total cost of the irrigated production system as R$21,888.82 per hectare, with a profit percentage equal to 60.8%.

In the simplified economic analysis, which was carried out on the basis of the methodology adopted by Reis (2007), both the average fixed cost (CFMe) and the variable cost (CVMe) for the production of an 8 kg box of papaya decreased as the recommended percentage of potassium fertilization increased. However, upon reaching the K640 treatment, the values increased, with the lowest CFMe and CVMe values corresponding to R$ 0.45 cx $^{-1}$ and R$ 3.26, respectively (Table 2).

Table 2. Average economic and operational costs of fertigated papaya production under different potassium doses, in R$ per ^{8} kg box, Igarapé-Açu, Pará, May 2018 to February 2020.

Treatments	CFMe	CVMe	CTMe	CopFMe	CopVMe	CopTMe
K160	0.99	5.15	6.14	0.47	5.15	5.61
K320	0.63	3.94	4.57	0.30	3.94	4.24
K480	0.45	3.26	3.71	0.21	3.26	3.47
K640	0.58	4.12	4.70	0.27	4.12	4.39
Average	0.66	4.12	4.78	0.31	4.12	4.43

[1] CFMe = average fixed cost; CVMe = average variable cost; CTMe = average total cost; CopFMe = average fixed operating cost; CopVMe = average variable operating cost; CopTMe = average total operating cost; K160 = application of 160 kg K_2O ha $^{-1}$; K320 = application of 320 kg K_2O ha $^{-1}$; K480 = application of 480 kg K_2O ha $^{-1}$; and K640 = application of 640 kg K_2O ha $^{-1}$.
Source: Authors (2022).

All experimental treatments presented average revenue (RMe) higher than average total costs (CTMe), indicating a situation of supernormal economic profit (RMe > CTMe). This trend, according to Reis (2007) and Vilas Boas *et al.* (2011), implies the following interpretation: the investment made pays for all resources applied to the economic activity and provides additional profit higher than the market alternative used in the study.

In this context, the medium- and long-term trend is toward expansion and the inflow of new foreign currency into the activity, attracting competitive investment. Since the K480 treatment had the lowest CTMe, applying a dose of 480 kg of K2O $_{ha}$ $^{-1}$ to papaya crops via fertigation yielded the highest net revenue.

Another point: the analysis aligns with the author's experience, which suggests that the low remuneration paid to producers in the local market is due to the type of papaya production system used in the region. This production system relies on low technology, which ultimately plays a decisive role in the commercial value of the fruit.

The results presented in Table 3 refer to the indicators net present value, internal rate of return and benefit–cost ratio, which were calculated for a two-year cash flow period on the basis of the period in which the papaya experiment was maintained in the field.

Table 3. Economic viability indicators for the four fertigation treatments carried out in Igarapé-Açu, Pará, May 2018 to February 2020.

	Economic Viability Indicators		
Treatments	**NPV**	**TIR**	**B/C ratio**
K160	R$ 4,548.89	15.40%	1.22
K320	R$ 15,146.44	33.50%	1.63
K480	R$ 27,806.33	48.10%	2.01
K640	R$ 15,822.00	31.52%	1.59

NPV = net present value; IRR = internal rate of return; B/C = benefit cost ratio; K160 = application of 160 kg K_2O ha $^{-1}$; K320 = application of 320 kg K_2O ha $^{-1}$; K480 = application of 480 kg K_2O ha $^{-1}$; and K640 = application of 640 kg K_2O ha $^{-1}$.
Source: Authors (2022).

Following the example of the research developed by Mendonça *et al.* (2009), the results of this work were also generated through deterministic cash flows, that is, considering all variables (revenues and costs) constant over time.

In terms of NPV, the project will be viable if it presents NPV positive and unfeasible if it presents NPV negative. According to the values expressed in Table 3, all the treatments presented high economic and financial viability, with the most promising treatment being K480, which presented a positive NPV of $27,806.33. This high NPV viability indicates that there is a possibility of paying back all the invested capital plus operating costs and the opportunity cost rate under investment, assumed to be 5% per year over the two-year project horizon.

With respect to the IRR, the project will be viable if it exceeds the opportunity cost or the cost of raising capital. The K480 treatment presented the highest IRR, whereas the K160 treatment presented the lowest IRR (Table 3). Thus, all the treatments were highly viable, which should be considered when making decisions about implementing or maintaining fertigated papaya cultivation projects in the region under study.

With respect to the B/C ratio, the decision criterion used was that the investment would be considered viable if this ratio was > 1. In these terms, of the four treatments performed (K160, K320, K480 and K640), the one that was most viable was K480. The result of this ratio for K480 (2.01) implies that for every R$ 1.00 spent on the project, it returns R$ 2.01 gross and R$ 1.01 net.

Borba (2019), when studying the irrigated cultivation of papaya in the Itapuranga region in the state of Goiás, concluded that for all the scenarios evaluated, there was a return to the invested capital, portraying the profitable possibility of using irrigation in the cultivation of this fruit. This result, in a way, corroborates the economic study of the fertigated cultivation of papaya presented in this study, which indicated the viability and profitability of this practice for the municipality of Igarapé-Açu, Pará.

On the basis of the results, the correlation between the total cost for the production of papaya fertigated with potassium and the total revenue generated was evaluated (Table 4), considering two minimum prices per kg of papaya paid to the producer and the implementation of the crop in an area of 1 ha, with the aim of providing a more specific and simplified analysis of the minimum financial return (profit) and the total cost for the production of 1 kg of papaya (CT kg $^{-1}$) (Table 4) to better support the decision of the farmer, especially family farmers, whether or not to invest in this cultivation practice.

Table 4. Results of the correlation (Profit), total cost (TC), total revenue (TR) and total cost to produce 1 kg of papaya (TC kg $^{-1}$) in the production of papaya fertilized with different doses of potassium, considering two values paid to the producer per kg and the implementation of the crop in an area of 1 ha, Igarapé-Açu, Pará, May 2018 to February 2020.

Treatments	**Amount R$ 0.75 kg $^{-1}$ paid to the Producer**			**Amount R$ 0.50 kg $^{-1}$ paid to the Producer**			**CT kg $^{-1}$**
	CT	**RT**	**Profit**	**CT**	**RT**	**Profit**	
	Value in thousand (R$)			**Value in thousand (R$)**			**(R$)**
K160	20.4	20.6	0.2	20.2	13.7	-6.5	0.74
K320	23.7	32.0	8.3	23.4	21.2	-2.1	0.55
K480	27.2	45.3	18.1	26.8	30.2	3.4	0.44
K640	27.7	35.1	7.3	27.5	23.4	-4.1	0.59

K160 = application of 160 kg K_2O ha $^{-1}$; K320 = application of 320 kg K_2O ha $^{-1}$; K480 = application of 480 kg K_2O ha $^{-1}$; and K640 = application of 640 kg K_2O ha $^{-1}$.
Source: Authors (2022).

The results presented in Table 4 indicate that the price of 0.50 cents paid to the producer in the K480 treatment generated a profit of only R$3,343.74. This value can be considered negligible compared with the investment costs, which allows a simpler interpretation by the producer as to the viability or not of implementing the papaya cultivation fertigated with doses of potassium.

The total revenue observed in the four treatments indicates the economic viability of implementing the practice proposed in this study in both methodologies employed in the analyses. Using production cost data from the field experiment, which were projected for cultivation in a 1-ha area, revenues were higher than production costs, with a supernormal economic profit RMe > CTMe and a positive NPV. The best NPV of R$ 27,806.33 (Table 3) was obtained in the K480 treatment. Furthermore, this treatment presented the highest total and commercial productivity, 57.0 t ha $^{-1}$ with 425.1 kg of K_2O ha $^{-1}$ and 51.4 t ha $^{-1}$ with 454.8 kg of K_2O ha $^{-1}$, respectively (Figure 1). It was also found that for this treatment, the profit corresponded to 53.67% of the total revenue and that the amount paid to the producer of R$ 0.50 presented a positive profit (R$ 3,343.74) only for the same. Compared with the values obtained in K480, the K640 treatment (corresponding to the application of a higher dose of potassium) resulted in a 40.50% reduction in the profit rate (Table 4).

6 CONCLUSION

On the basis of the analyses performed, it is possible to conclude that the use of fertigation technology with a drip irrigation system for applying potassium to papaya crops under soil and climate conditions similar to those used in this study constitutes a viable and profitable option.

Therefore, the recommended application of 480 kg of K2O ha - [1] is to obtain a total annual revenue of R$60,376.00 and a profitability of R$32,404.64, which corresponds to the highest profitability associated with maximum productivity.

Moreover, the price of R$ 0.50 kg $^{-1}$, paid to the producer, is profitable only with the application of 480 kg of K_2O ha $^{-1}$, but the profitability (R$ 3,343.74) is considered very low, which may lead to the interpretation that for locations where this price is used, the investment is unfeasible.

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