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Economic Viability of Irrigation and Nitrogen Fertilization in Jambu Production in Brazilian Amazon

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Abstract

This work aimed to analyze the economic feasibility of the irrigation system by dripping and nitrogen fertilization in jambu production. The experiment was conducted at the Experimental Farm of Igarapé-Açu, a site owned by UFRA, in protected cultivation, from May to July in 2016. The treatments consisted in four soil water tensions (12, 18, 24 and 30 kPa) and four nitrogen doses (0, 50, 100 and 150 kg ha^{-1}). The economic analysis of the jambu irrigated production was sustained by the theory of producing costs considering both depreciation cost and alternative cost. The treatment with the highest profit was managed at 18 kPa with a nitrogen dose of 50 kg ha^{-1}, with a profit of R$ 1,548.54 for an area of 1,000 m.^{2}. The drip irrigation and nitrogen fertilization were economically viable for the jambu crop.

Keywords: *Acmella oleracea*, tensiometry, profitableness of jambu, economic analysis

1. Introduction

The jambu (*Acmella oleracea* (L.) R. K. Jansen) is an herbaceous plant that belongs to the family Asteraceae, which has little leaves and yellow colored flowers (Costa, 2014). The leaves are amply utilized in the Amazon regional culinary and have been a part of many typical dishes such as tacacá and duck no tucupí. The jambu is also used in phytotherapy, by the traditional peoples (native Brazilians), and in the pharmaceutical and cosmetics industry (Gusmão & Gusmão, 2013).

The commercialization of jambu is limited by popular festivities in the region, in which there are greater seeks for the product. However, in these periods the price decreases due to the large supply. Thereby, producers seek for strategies to produce in periods that could give them higher profitableness of their production (Homma et al., 2015). Profitableness is the major objective of an agricultural enterprise, and one of the main factors that interfere in the accomplishment of a greater economic yield are nutrients and water, which are fundamental in the success of a production (Silva et al., 2008).

The culture of jambu extremely demands on water. In addition, as it is a leafy vegetable, it requires a greater attention and care regarding its nutrition in order to obtain a competitive production on market (Gusmão & Gusmão, 2013).

Among all the irrigation systems, the dripping one stands out in the production of those leafy vegetables due to several advantages. Higher efficiency on water use, fertilization, lower energy costs and the possibility of automation are examples of such advantages (Vilas Boas et al. 2011). However, any agricultural enterprise requires a cost analysis of the implementation of technologies in the production systems in order to evaluate their economic viability.

Thus, an economic analysis is necessary to evaluate the viability of implementing an irrigation system. Since such a project requires a high investment in the construction and acquisition of equipment for the collection, conduction, control and distribution of water, which must be considered as expenses with energy and labor for the operation and management of the system (Lima Junior et al. 2012).

Besides the water availability for the culture, another factor to get a great productivity is fertilization. In order to achieve higher production levels a considerable application of fertilizers is necessary. Most of vegetables cultures demonstrate linear increase as the use of these agents increases too (Taiz et al., 2017; Cardoso & Ustulin Filho, 2013; Vieira Filho et al., 2017).

However, according to Sousa et al. (2014) the application of fertilizers without a correct recommendation will result in the misuse of nutrients by the crop, which may cause environmental imbalance and economic losses to the producer.

For leafy vegetable production, nitrogen is an essential nutrient because it constitutes amino acids, proteins and nucleic acids. According to Filgueira (2008), an adequate nitrogen supply favors vegetative growth, expands the photosynthetically active area and increases the productive potential of the crop. This mainly benefits the herbaceous vegetables as they consist of leaves, tender stems and inflorescences. Thus, in vegetable production nitrogen is one of the main nutrients, which directly influences productivity.

Nevertheless, in any agricultural enterprise it is necessary to accomplish a viable analysis of technologies that will be introduced into the production systems to verify their economic viability.

Therefore, this study aims to analyze the economic viability of an irrigation system by dripping and the application of nitrogen fertilization for Jambu production.

2. Materials and Methods

This work was performed in protected cultivation, from May to July in 2016 at the Experimental Farm of Igarapé-Açu, a campus of the Federal Rural University of Amazon (UFRA), under the geographical coordinates of 1°07’48.47” S and 47°36’45.31” W, at a height of 54 m, in the municipality of Igarapé-Açu, northeast part of the State of Pará.

The soil of the region was classified as Dystrophic Yellow Argisol, with sandy texture and average density of 1.60 g cm^{-3}. The results of the fertility analyzes at the experimental area were obtained from a composite soil sample collected at a depth of 0 to 0.2 m and are presented in Table 1.

Table 1. Physical and Chemical Properties of Work Area Soil

Granulometry			Soil chemistry							
Sand	Silt	Clay	pH H_2O	M.O	N	P	K	Na	Ca	Mg
	g kg^{-1}			g kg^{-1}	%	mg dm^{-3}			cmolc dm^{-3}	
801	19	180	6,5	13,76	0,08	192	263	44	2,4	1,3

2.1 Seedling Preparation and Cultural Treatment

The Jamburana cultivar was used in the experiment. Its cycle has approximately 70 to 80 days. The seedlings were produced on Styrofoam trays with 128 cells containing organic compost. The transplantation was carried out 32 days after sowing in the spacing of 10 cm x 10 cm. Each parcel had the dimensions of 0.4 m x 0.5 m (0.2 m^2), making up twenty plants. Ten central plants were considered useful.

After the transplantation, the seedlings were irrigated during 10 days before the treatments differentiation in order to provide their adaptation. The amount of water blade 31.9 mm (3.19 mm dia^{-1}). Throughout the crop development, weeds were removed from inside the beds manually. Between the beds, a hoe was used to take them off. There was no significant incidence of pests and diseases during the experiment. The harvest began 62 days after sowing.

2.2 Experimental Design

The adopted experimental design was based on random blocks of 4 x 4, with three repetitions. The treatments consisted in four soil water tensions (12, 18, 24 and 30 kPa) and four nitrogen doses (0, 50, 100 and 150 kg ha^{-1}).

2.3 Fertilization

The fertilization was performed according to a recommendation made by Cravo et al. (2007). The planting fertilization was carried out with triple superphosphate (100 kg of P_2O_5 ha^{-1}), while cover fertilization was done in three plots, with 10, 17 and 24 days after transplantation, using potassium chloride (60 kg of K_2O ha^{-1}) and urea (0, 50, 100 and 150 kg of N ha^{-1}).

2.4 Drip Irrigation System

The plants were irrigated by drip, with a flow of 1.2 L h^{-1}, and with emitters spaced by 20 cm apart. Irrigation was performed through self-compensating drip hoses of additive polyethylene, with a nominal diameter 16 mm, with a working pressure of 6 mca. at the end of the hose, and with in-line emitters. The drip hoses were positioned within the plot. Each hose served two rows of plants (4 plants per dripper). They were connected to the polyethylene derivation lines (DN 16) and these ones to the PVC pipes (DN 50; PN40), which were connected to the main line through electrically operated solenoid valves via the controller installed on the control head. A 5,000 L water tank, a controller-powered 1.5 hp electric pump, a disc filter and a pressure regulating valve to work with 6 mca on the secondary line inserted in the outlet of the main pipe were used for the irrigation system.

After the irrigation system was installed, hydraulic evaluations were performed to determine its performance through the Distribution Uniformity Coefficient (DUC).

To determine the critical tension, two tensiometers were installed in each treatment at 15 cm depth in order to indicate the moment of irrigation.

The tensiometers were positioned in the planting line between two plants. Tension readings were taken once a day at 9:00 am using a digital puncture tensimeter. Irrigations were performed when treatments reached the critical tension according to the average taken by their respective tensiometers. They were done in order to raise the moisture to field capacity that corresponds to 10 kPa (0.240 cm^3 cm^{-3}). The irrigation management was based on the characteristic soil water curve obtained from the 0 to 20 cm depth profile (Figure 1).

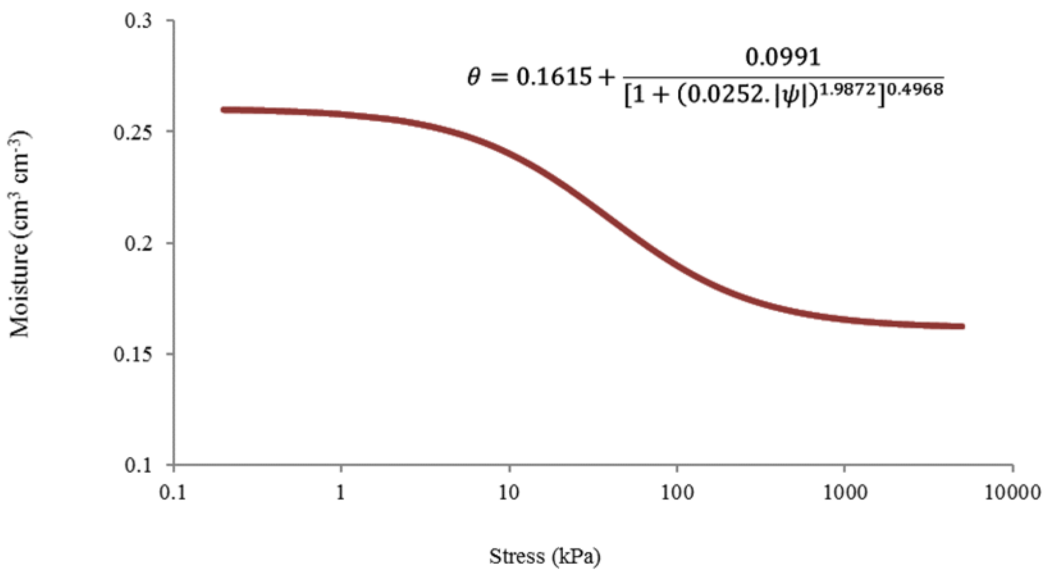

Figure 1. Soil water retention curve

The water blades applied in the treatment differentiation and the irrigation system working time were calculated according to Cabello (1996). The effective depth of the root system was considered to be equal to 20 cm, according to Gusmão & Gusmão (2013) and the water application efficiency of the drip irrigation system equal to 95%.

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2.5 Production Cost

The production cost was estimated using an economic procedure that considers the calculation of depreciation and alternative cost (Reis, 2007).

In order to estimate the production cost of this work, we used approximate values in reais (R$), based on the following information: cultivated area with jambu of 1,000 m², period of a harvest, fixed and variable costs.

$$D = \left(\frac{Cv - Rv}{Ul}\right) \cdot Ap \tag{1}$$

In which: D - depreciation (R$); Cv – current value of the resource (R$), Rv - residual value (resale value or final value of the good after rational use) (R$), Ul - useful life (period in which a certain good is used in the activity) (years) and Ap - analysis period (years).

For the purpose of analyzing the alternative cost of fixed production resources allocated in the jambu cultivation, an interest rate of 6% a year was considered. In its calculation we used.

$$Afc = \left(\frac{Ul - Au}{Ul}\right) \cdot Cv\,.Ir.Ap \tag{2}$$

In which: Afc - alternative fixed cost (R$); Au – average using age of the good (years) and Ir - interest rate (decimal).

For the calculation of the alternative cost of the variable resources applied to the jambu cultivation, the real interest rate of 6% a year was considered and applied in the Eq. 3.

$$Vac = \frac{Vspend}{2} \cdot Ir \tag{3}$$

In which: Vac - variable alternative cost (R$) and V_{spend} - financial spend made by the producer to acquire inputs and services required for agricultural production (R$).

In order to calculate each fixed resource, the depreciation and the alternative cost of the productive factor were added. The commercial values (prices) used were based on the local market. The items considered in the fixed costs and the operationalization procedure were:

a) Land: based on the premise that the farmer will adopt a proper soil management, no depreciation will occur. Thereby, the value considered was the alternative cost based on the rent of R$ 80,00 for one hectare per month;

b) Liming: liming expenses were R$ 63.85, with a useful life of 2 years;

c) Localized Irrigation System: the amount spent per year was R$ 252.99, with a useful life of 8 years.

d) Rural Territorial Tax (RTT): According to the law governing the RTT, Law 9,393/1996, regarding the immunity and tax exemption, we decided to do not take it into account;

e) Greenhouse: an average value of R$ 20,000.00 was considered for 1,000 m² of greenhouse, with a useful life of 10 years;

f) Alternative cost: It was applied on the basis of fixed costs, and for each good acquired, an interest rate of 6% a year was added. This is the same rate used to remunerate government bonds or savings account in Brazil.

The results found 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 forms of operation used were:

a) Inputs: correspond to the expenses occurred in the purchase of seeds, mineral fertilizers and pesticides in general. The quantities used for the calculations were based on the quantities and types used in the experiment;

b) Labor: refers to the daily payments required to perform operational activities such as: seedling production, field crop implantation, crop treatment, pest and disease control, irrigation system operation, and harvesting;

c) Expenses with machines and implements: expenses with the rent of machines and implements used by the activities of area preparation.

d) Expenses with administration: refers to specialized labor during the implementation, growing season and taxes, adopting the value of 2.3% of the total revenue produced, recommended in the rural credit manual (RCM) and adopted by the technical assistance and rural extension companies in the elaboration and rendering of technical assistance in the projects through the Family Agriculture Strengthening Program (Pronaf);

e) Overheads: this group includes the purchase of packaging bags, wheelbarrow, cleaning tank for conditioning the harvested bundles based on the average productivity of each treatment.

f) Energy: it was calculated according to Eq. 4.

$$EC = V.T\,\frac{736.Pot}{1000.\eta} \tag{4}$$

In which: EC - energy cost (R$); V - kWh value in (R$); T - total irrigation system operating time (h); Pot - pump set power (hp); η - efficiency of the pump set power.

g) Alternative cost: each item of variable resources had a real interest rate of 6% a year considered. It is the rate used for interest on risk-free assets that in our country refers to the one that remunerates the public bonds or the savings account.

The economic cost was obtained by summing the operating cost and the alternative cost (TC = TFC + TVC). The operating cost was divided into fixed operating cost (FOC) that consists

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of depreciation and variable operating cost (VOC) that refers to disbursements. Total operating cost (TOC) consisted in the sum of fixed operating and variable operating cost. In order to transform it into average cost (ATC, ATOC), the TC and TOC were divided by the amount produced by each treatment in this crop (cycle). For the interpretation of the economic analysis of the productive activity, the situations of economic and operational analysis described by Reis (2007) were considered.

The revenue was obtained by multiplying the quantity produced by each treatment by the price of the product on a given date, which in this case was July 2016, when the price was R$ 0.79 per pack of 600g, as suggested by the Pará Supply Centers - CEASA. The profit was obtained by subtracting the total cost from total revenue.

The effects of tension and nitrogen fertilization on the evaluated variables were deferred through the analysis of variance achieved by the Tukey test. The program used to perform the calculus was the assistat 7.7. In addition, for those cases that a statistical significance was noticed, a regression analysis was carried out.

3. Results and Discussion

After the analysis of variance and the turkey test (p <0.05) for jambu yield, we found that there was a difference for the soil water tension and nitrogen doses factors. However, there was no interaction between the factors (Table 2).

Table 2. Variance analysis for yield according to soil water tension and nitrogen doses

Source of variation	DF	F - Value
		Productivity
Tension	3	28.7366 **
Nitrogen	3	61.0821 **
Tension × Nitrogen	9	1.2222 ns
Treatments	15	18.6971 **
Blocks	2	0.2191 ns
Residual	30	
CV%		8.94

The total water blades applied (mm) and the productivity (g m²) of the treatments are shown in Table 3. It is noteworthy that the total water depth described in the treatments refers to the sum of the water applied in the treatment differentiation and the water initially applied to provide better plant adaptation (31.9 mm).

Table 3. Total water blade applied (mm) and productivity (g m²) of jambu undergone to different soil water tensions and nitrogen doses

Handling	Water Blade (mm)	Productivity (g m²)
T12N0	45,64	3000
T12N50	45,64	3416,66
T12N100	45,64	3366,66
T12N150	45,64	2855,33
T18N0	43,33	2277,55
T18N50	43,33	3777,68
T18N100	43,33	3700
T18N150	43,33	2902,55
T24N0	42,33	1975
T24N50	42,33	2091,66
T24N100	42,33	2241,66
T24N150	42,33	2283,33
T30N0	40,74	1100
T30N50	40,74	1200
T30N100	40,74	1300
T30N150	40,74	1411,11

We observed that the total blades applied decreased as the tension increased. The treatment with 12 kPa presented the highest total applied blade, since the tension is close to the field capacity (Table 3).

The maximum yield of jambu was achieved at the tension of 18 kPa and nitrogen dose of 50 kg ha^{-1}, with 3,777.68 g m². This treatment has provided an enough water blade to supply the water demands of the plants (43.33 mm), which favored the vegetative development. The irrigation shift presented by the tension of 18 kPa favored the nitrogen dose of 50 kg ha^{-1}, in which the 4-day interval between irrigations maximized the use of nitrogen fertilizer.

The treatment with soil water tension of 18 kPa kept the soil close to the moisture of the field capacity, demonstrating that water availability is a fundamental matter for the increase of fresh mass and productivity in jambu crop. This feature is very sensitive to water variation. The productivity behavior was similar to the results found by Geisenhoff et al. (2016)

working with lettuce, Vilas Boas et al. (2012) evaluating onion and Lima Junior et al. (2012) evaluating carrots, which obtained maximum yield at tensions close to field capacity.

Fixed costs represent approximately 10% of the total costs of all treatments (Table 4). Among the fixed costs, the greenhouse had the largest share of the total cost, which was around of 9%, followed by land (0.5%) and the irrigation system (0.2%).

Table 4. Total fixed cost (TFC%) in percentage for jambu production, under different soil water tensions and nitrogen doses

Handling	Land	Liming	Vegetation House	Irrigation System	TFC%
T12N0	0,51	0,18	9,36	0,22	10,3
T12N50	0,5	0,17	9,22	0,21	10,1
T12N100	0,5	0,17	9,19	0,21	10,1
T12N150	0,5	0,17	9,28	0,22	10,2
T18N0	0,51	0,18	9,42	0,22	10,3
T18N50	0,5	0,17	9,19	0,21	10,1
T18N100	0,5	0,17	9,17	0,21	10
T18N150	0,5	0,17	9,27	0,22	10,2
T24N0	0,52	0,18	9,52	0,22	10,4
T24N50	0,51	0,18	9,41	0,22	10,3
T24N100	0,51	0,18	9,36	0,22	10,3
T24N150	0,51	0,18	9,33	0,22	10,2
T30N0	0,52	0,18	9,6	0,22	10,5
T30N50	0,52	0,18	9,56	0,22	10,5
T30N100	0,52	0,18	9,52	0,22	10,4
T30N150	0,51	0,18	9,48	0,22	10,4

The total cost represented by the sum of fixed and variable costs had the largest contribution of variable costs, representing approximately 90% for all treatments (Table 5). In all treatments, we highlight the labor that reached approximately 56% of costs, followed by the overhead cost (17%) and inputs (15%). Lima Junior et al. (2014) in a study carried out in Lavras – MG with two carrot cultivars under different soil water tensions, differently from what was found in this study, shows that the inputs represented the largest impacts on the total cost, reaching up to 64% of the total costs. The results found in this paper are in agreement with the results obtained by Pereira et al. (2018) and Lima et al. (2016), who found a greater participation in the variable costs of inputs followed by labor, studying the cauliflower and green pepper irrigated in Igarapé-açu.

Table 5. Total variable cost (TVC%) in percentage for jambu production under different soil water tensions and nitrogen doses

Handling	Inputs	Manpower	Engine	Administration	General	Energy	Alternative Cost	TVC %
T12N0	13,99	54,61	2,4	2,73	15,78	0,02	0,45	90
T12N50	14,03	53,49	2,36	3,05	16,81	0,02	0,45	90,2
T12N100	14,32	53,38	2,35	3	16,7	0,02	0,45	90,2
T12N150	14,89	54,26	2,39	2,58	15,46	0,02	0,45	90
T18N0	14,24	55,58	2,45	2,11	14,96	0,01	0,45	89,8
T18N50	13,91	53,03	2,34	3,34	17,19	0,01	0,45	90,3
T18N100	14,21	52,96	2,33	3,27	17,05	0,01	0,45	90,3
T18N150	14,87	54,2	2,39	2,62	15,52	0,01	0,45	90,1
T24N0	14,46	56,44	2,49	1,86	13,94	0,01	0,45	89,6
T24N50	14,59	55,65	2,45	1,94	14,69	0,01	0,45	89,8
T24N100	14,83	55,26	2,43	2,07	14,82	0,01	0,45	89,9
T24N150	15,09	55,02	2,42	2,09	14,82	0,01	0,45	89,9
T30N0	14,78	57,71	2,54	1,06	12,87	0,01	0,44	89,4
T30N50	15,04	57,36	2,53	1,15	12,95	0,01	0,45	89,5
T30N100	15,3	57,01	2,51	1,24	13,02	0,01	0,45	89,5
T30N150	15,54	56,66	2,5	1,33	13,12	0,01	0,45	89,6

Among the inputs, fertilizers (chemical and organic) were the most expensive ones. They accounted for about 66% of the total input, followed by the acquisition of seeds with 15%.

Machine and implement costs accounted for less than 3% of the total cost in all treatments. On the other hand, regarding overheads, which accounted for around 17% of variable costs, with transportation having the largest share (31%), followed by the jambu sanitation tank (29%), tools (22%) and packaging bags. (18%).

Similarly to what happened with fixed and total variable costs, the average total cost and average total operating cost presented the largest contribution of variable costs (Table 6).

The treatment with the combination of soil water tension of 18 kPa and nitrogen dose of 50 kg ha^{-1} presented the lowest average total cost and average total operating cost. In other words, this treatment required the lowest cost to produce 1 pack (600 g) of jambu. This evidences that the higher productivity is, lower the costs are, since there is the maximization of the resources employed in the cultivation system.

The average total and average total operating costs were higher in treatments that were subjected to 30 kPa tension, regardless of nitrogen dose. This result demonstrates the sensitivity of the crop to water restriction, since in this treatment, the watering shifts were larger and the applied water blade was the smallest.

Table 6. Average economic and operational costs of producing a pack of jambu (600g) at different soil water tensions and nitrogen doses

Handling	AFC	AVC	ATC	AFOC	AVOC	ATOC
T12N0	0,07	0,6	0,67	0,04	0,6	0,63
T12N50	0,06	0,54	0,6	0,03	0,54	0,57
T12N100	0,06	0,55	0,61	0,03	0,54	0,58
T12N150	0,07	0,63	0,7	0,04	0,63	0,67
T18N0	0,09	0,77	0,86	0,05	0,77	0,82
T18N50	0,05	0,49	0,54	0,03	0,49	0,52
T18N100	0,05	0,5	0,56	0,03	0,5	0,53
T18N150	0,07	0,62	0,69	0,04	0,62	0,66
T24N0	0,1	0,88	0,98	0,05	0,87	0,93
T24N50	0,1	0,84	0,94	0,05	0,84	0,89
T24N100	0,09	0,79	0,88	0,05	0,79	0,84
T24N150	0,09	0,78	0,87	0,05	0,78	0,82
T30N0	0,18	1,54	1,72	0,1	1,53	1,63
T30N50	0,17	1,42	1,58	0,09	1,41	1,5
T30N100	0,15	1,32	1,47	0,08	1,31	1,39
T30N150	0,14	1,22	1,36	0,08	1,22	1,29

Notes: AFC - average fixed cost; AVC - average variable cost; ATC - average total cost; AFOC - average fixed operating cost; AVOC - average variable operating cost; ATOC - average total operating cost.

According to the (Table 7), not all treatments presented a total revenue higher than total costs. Therefore, under some situations there was no profit in some treatments.

The T18N50 treatment accomplished the highest profit among all treatments, followed by the T18N100 treatment. The superior profitability of the T18N50 treatment is due to its higher productivity achieved and consequently higher total revenue, since this treatment provided the best development of jambu culture.

Table 7. Productivity in 600g bundles, total cost (TC), total revenue (TR) of jambu production under different soil water tensions and nitrogen doses in 1000 m²

Handling	Packet Productivity (600 g)	TC	TR	Lucre
			R$	
T12N0	5000	3326,59	3950	623,41
T12N50	5694,43	3396,39	4498,6	1102,21
T12N100	5611,1	3403,41	4432,77	1029,36
T12N150	4758,88	3348,08	3759,52	411,44
T18N0	3795,92	3268,19	2998,77	-269,42
T18N50	6296,13	3425,41	4973,95	1548,54
T18N100	6166,67	3430,19	4871,67	1441,48
T18N150	4837,58	3351,78	3821,69	469,91
T24N0	3291,67	3218,64	2600,42	-618,22
T24N50	3486,1	3264,24	2754,02	-510,22
T24N100	3736,1	3287,39	2951,52	-335,87
T24N150	3805,55	3301,81	3006,38	-295,43
T30N0	1833,33	3147,98	1448,33	-1699,65
T30N50	2000	3167,11	1580	-1587,11
T30N100	2166,67	3186,23	1711,67	-1474,56
T30N150	2351,85	3206,25	1857,96	-1348,29

All treatments submitted to 30 kPa and 24 kPa tensions achieved negative profitability because these tensions provide low yields and the lowest applied water blades.

On the other hand, the treatments submitted to the tension of 12 kPa, even if it is the tension that provides the largest water blade applied, presented productivity and total revenue lower than the 18 kPa treatments. This behavior highlights the importance of using an appropriate water blade for any crop.

Adopting the tension of 18 kPa and nitrogen fertilization at a dose of 50 kg ha¹, a yield of 3,777.68 g m² was obtained with a profit of R$ 1,548.54 considering an area of 1,000 m² and a period of 62 days.

4. Conclusion

We concluded that the drip irrigation in a jambu crop in a protected cultivation is economically viable when adopting the soil with a water tension of 18 kPa and a nitrogen dose of 50 kg ha^{-1}.

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