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ECONOMIC ANALYSIS OF DIFFERENT IRRIGATION DEPTHS IN FORAGE SORGHUM CROPS

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Abstract - The objective of this work was to evaluate the production costs and profitability indexes of sorghum crop for silage production under different irrigation depths. The work was conducted at the Federal Institute of Education, Science and Technology of Ceará (IFCE) – Umirim Campus, from September to December 2016. The treatments were arranged in 5 x 5 split plots with 5 replications. Irrigations were performed on a daily basis, and the applied depths were calculated based on crop evapotranspiration (ETc). The primary treatments were 50, 75, 100, 125 and 150% of ETc, associated with different levels of carnauba bagana mulch (0.00, 2.50, 3.75, 5.00, and 6.25 cm). Effective Operating Cost (EOC), Total Operating Cost (TOC), Gross Revenue (GR), Operating Profit (OP), Profitability Index (PI) and Break-Even Price (BEP) were estimated. According to the indicators analyzed, it was found that this is a promising crop within the different agricultural production schools, with favorable rates for the producer. The variety evaluated presents high resistance as to the water limitation factor, showing positive indicators such as break-even point below the average prices practiced in the region.

Keywords: *Sorghum bicolor* (L.) Moench; Water application; Profitability indicators

ANÁLISE ECONÔMICA DE DIFERENTES LÂMINAS DE IRRIGAÇÃO NO CULTIVO DE SORGO FORRAGEIRO

Resumo - Objetivou-se nesse trabalho avaliar os custos de produção e os índices de lucratividade sob as diferentes lâminas de irrigação na cultura do sorgo para a produção de silagem. O trabalho foi conduzido no Instituto Federal de Educação, Ciência e Tecnologia do Ceará (IFCE) - Campus de Umirim, no período de setembro a dezembro de 2016. Os tratamentos foram dispostos em parcelas subdivididas 5 x 5 com 5 repetições. As irrigações foram realizadas diariamente e as lâminas aplicadas foram calculadas com base na evapotranspiração da cultura (ETc). Os tratamentos primários foram 50, 75, 100, 125 e 150% da ETc, associados a diferentes níveis de cobertura morta com bagana de carnaúba (0,00; 2,50; 3,75; 5,00 e 6,25 cm). Foram estimados custo operacional efetivo (COE), custo operacional total (COT), receita bruta (RB), lucro operacional (LO), índice de lucratividade (IL) e preço de equilíbrio (PE). De acordo com os indicadores analisados, foi possível constatar que essa é uma cultura promissora dentro das diferentes escolas de produção e que ela gerou índices favoráveis ao produtor. Percebe-se também que a variedade trabalhada apresenta uma elevada resistência quanto ao fator limitação hídrica, uma vez que essa apresentou indicadores positivos, como ponto de equilíbrio dos preços abaixo dos preços médios praticados na região.

Palavras-chave: *Sorghum Bicolor* (L.) Moench, aplicação de água, indicadores de rentabilidade.

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The sorghum (*Sorghum bicolor* (L.) Moench) is a tropical C4 plant, which stands outs for its high biomass production, disease resistance and high tolerance to water deficit, being one of the most versatile and efficient forage species concerning production of food items (Magalhães et al., 2007; Andrade Neto et al., 2010). In the last decades, this crop has been increasingly used in the ensiling process, mainly due to its ease of cultivation, high biomass yield, tolerance to water deficit, good root system development, regrowth potential when submitted to appropriate management, especially because of the quality of the silage produced, with no need of additive to stimulate fermentation (Rodrigues et al., 2008; Xin et al., 2009).

However, water use optimization is necessary, since the irrigation planning requires special care in order to reconcile water balance and demand, so that the plant water requirement shall be the main means to that end. The plant water requirement can vary according to the plant development stage along the cycle, thus being important to know that information for sizing and managing the irrigation projects, and also for quantifying the amount of groundwater that shall be replenished in order to meet the crop demand (Freire et al., 2011; Santos Júnior et al., 2014).

In this context, the evaluation of different irrigation depths has been carried out to determine the water requirements of a crop under specific conditions of cultivation, observing the limits imposed by its genetic potential. It is then critical to optimize yield and increase efficiency in the use of water, since the growing process is significantly impacted by water availability, either by the lack or excess of it (Simões et al., 2016; Fernandes et al., 2014).

Traditionally, agricultural researches have focused on the obtainment of maximum yields. However, investigations carried out by some authors (Geerts; Raes, 2009; Klocke et al., 2010) have pointed out limitations in land and water resources, reason why deficit irrigation strategies have been indicated for regions with low rainfall associated with irregular precipitation distribution.

The deficit irrigation can be applied in irrigated agriculture, resulting in minimum yield losses, reaching high levels in water use efficiency, which can be achieved when the crop is submitted to water deficit, and maintaining the economic feasibility of the production (Geerts; Raes, 2009; Du et al., 2010; Pereira et al., 2012).

Lima Júnior et al. (2011) say that the maximum crop yield often does not correspond to larger net revenue, due to the fact that the irrigation system presents high costs associated with implementation and even operation. In this case, the irrigation depth shall be recommended in order to provide larger net income.

However, business decisions are not made without taking into account the specific project goals. An economic and financial feasibility approach is required for analysis of any project, being of vital importance to understand the cash flow time of those projects, that is, the value of money in time, which is based on the idea that the

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monetary unit today is worth more than another that will be received in a future date (Gitman, 2001; Macedo et al., 2007).

Therefore, the purpose of the present work was to assess the production costs and profitability indexes, under different irrigation depths, in sorghum crop, BRS Ponta Negra cultivar.

Material and Methods

The experiment was conducted from September 2016 to January 2017 in "Fazenda Floresta' (Forest Ranch), at the Federal Institute of Education, Science and Technology of Ceará (IFCE) – Umirim Campus, located in the municipality of Umirim-CE (3°41'7.96"S; 39°20'25.52"W), with altitude of 76 m. According to the Köppen climate classification, local climate is BSw'h', which corresponds to semiarid climate, with irregular precipitations and high temperatures. The total average annual precipitation is 807.1 mm (1978-2016). No rainfall was registered during the period when the research was being conducted.

Reference evapotranspiration (ETo) was calculated using the FAO (1991) Penman-Monteih method, with the use of CROPWAT software. Input data for ETo calculation were obtained from a historical series for the municipality of Pentecoste, in the period from 1970 to 1998 (Cabral, 2000), in the following sequence: January, February, March, April, May, June, July, August, September, October, November, December (6.15, 5.33, 4.14, 4.14, 4.28, 4.61, 5.21, 6.85, 7.83, 7.97, 7.77, 7.27 mm, respectively).

Allen et al. (1998) obtained the crop coefficients (Kc) in the various phenological stages (Stage I, Stage II, Stage III, and Stage IV; 0.40, 0.68, 1.14, 1.10).

Therefore, the Kr factor, suggested by Keller & Karmeli (1974), was applied to the calculation of water consumption using Equation 1:

$$Kr = \frac{\%AC}{0.85} \qquad (01)$$

Where: Kr = ground cover reduction factor, smaller value shall be adopted (Kr ≤ 1); %AC = percentage of area covered by crown projection, being that formed by the plant crown projection (shadow) at noon.

Irrigation depths were equivalent to 50%, 75%, 100%, 125% and 150% of ETC, which resulted, along the cycle (102 days), in total depths of 273.71, 410.57, 547.42, 684.28, 821.14 mm, respectively. They were calculated using Equation 2:

$$ETc = Kc * ETo \qquad (02)$$

Where: ETc = crop evapotranspiration in mm day^{-1}; Kc = crop coefficient, dimensionless, tabulated; and ETo = reference evapotranspiration in mm day^{-1}.

Figure 1 represents the required irrigation depths based on the ETc and depths applied according to the treatments.

The secondary factor, cover levels, was evaluated based on the response of the heights of applied carnauba bagana (residual straw after wax extraction). These heights were 0.0, 2.5, 3.75, 5.00 and 6.25 cm, with cover levels referred to as C1, C2, C3, C4 and C5, respectively. That generated volumes of 0.00, 250.00, 375.00, 500.00 and 625.00 m^3 ha^{-1}, respectively, in relation to each level applied along a production cycle.

The total experiment area cultivated with sorghum was 1,000 m^2 (40 x 25 m). The experimental design consisted of a split-plot scheme, with treatments arranged based on the combination of five irrigation depths (plots) and five levels of mulch (subplots), totalizing 25 treatments with five replications.

The experimental plots (blocks) measured 200 m^2 (25 m x 8 m) and consisted of 5 subplots of 40 m^2 (5 m x 8 m), with ten rows of plants with 0.8 m spacing between lines, and an average density of 12 plants per linear meter.

Only five out of the ten rows were considered useful for purposes of data obtainment, being the others regarded as border rows. In those deemed useful, the plants at the end portions were also considered border plants, that is, out of the five meters of each subplot, only the two central meters of each row were used for analysis, which means that 1.5 m at the beginning and at the end were regarded as borders.

The soil physical-chemical attributes in the 0 - 0.2 m layer were determined in the Soil and Water Laboratory of the Department of Soil Sciences, which belongs to the Agricultural Science Center of the Federal University of Ceará. The chemical attributes in the 0 - 0.2 m layer were: P mg kg^{-1} = 1.00; K cmolc kg^{-1} = 0.36; Na cmolc kg^{-1} = 0.09; Ca $cmol_c$ kg^{-1} = 1.80; Mg $cmol_c$ kg^{-1} = 1.20; Al $cmol_c$ kg^{-1} = 0.20; M.O. g kg^{-1} = 16.96; C/N = 11.00; pH = 5.60; CE dS m^{-1} = 0.09; PST = 1.00. Physical attributes were: Sand % = 53.80; Silt % = 22.40; Clay % = 23.80. Adapted from Silva (2016).

A drip irrigation system was used, with emitters spaced every 0.3 m, operating at 1.6 L h^{-1} flow rate, with 1 kgf cm^{-2} pressure. The system consisted of a main PVC pipeline (50 mm diameter), with lateral lines made of polyethylene tubes (16 mm diameter).

The crop water requirement was calculated for the different months and stages, according to Equation 3:

$$Ti = 60.\frac{fi.\,ETo.\,Kc.\,Ap.\,Kr}{N.\,qe} \qquad (03)$$

Where: Ti = irrigation period in minutes; fi = factor of adjustment in compliance with the treatments with depths of 0.50, 0.75, 1.00, 1.25, and 1.50, dimensionless; ETo = daily reference evapotranspiration in mm; Kc = crop coefficient, dimensionless; Ap = useful area per plant in m^2; Kr = reduction coefficient in percentage, dimensionless; N = number of emitters per plant, dimensionless; and qe = emitter flow rate in L h^{-1}.

Before the sorghum crop was planted in the field, liming requirement for soil pH correction was verified, using as reference the recommendation guide for fertilization and liming for the State of Pernambuco, by approximations.

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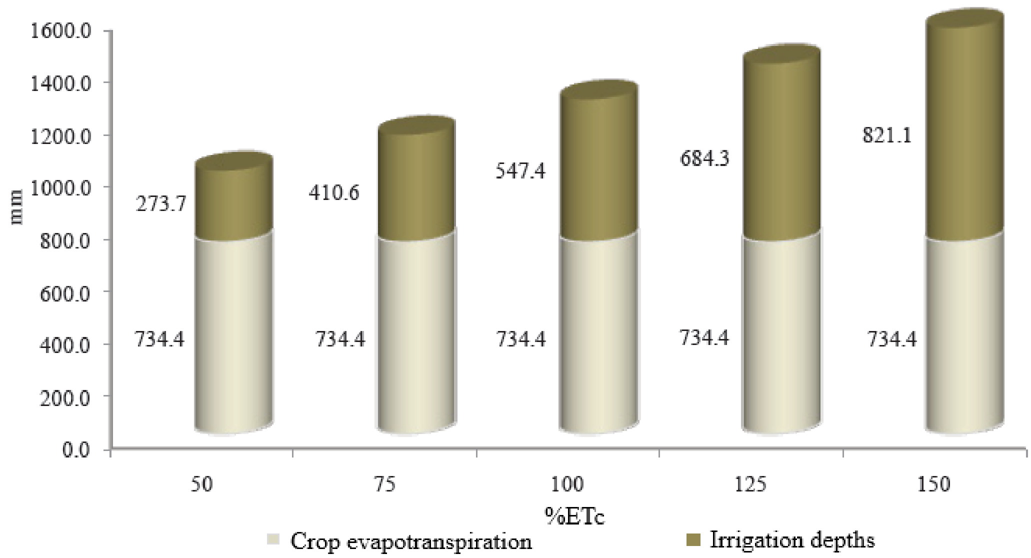

Figure 1. Irrigation depths required by the crop based on the ETc and depths applied in the different irrigation treatments along a production cycle.

Topdressing was done through fertirrigation with the following fertilizers: urea, monoammonium phosphate (MAP) and white potassium chloride.

Production cost was calculated by using the structure of the total operating cost of production adopted by the Institute of Agricultural Economics (IAE), proposed by Martin et al. (1998). The total operating cost (TOC) was calculated taking into account the effective operating cost (EOC) added to the expenses with investment maintenance, direct social charges, social security contribution on gross revenue (CESSR), technical assistance, and financial charges.

In the investment analysis, it was considered that the farmer obtained a loan from the Banco do Nordeste do Brasil – BNB (Brazilian Northeast Bank), being considered eligible for the credit line "Pronaf Semiárido" (National Program to strengthen family farming in the semiarid region) for family farmers who belong to A, A/C, B and V (variable income) groups. The objective of this program is to provide credit for investment intended for coexistence with the semiarid, prioritizing water infrastructure. Therefore, this credit line presents a form of loan with a term of up to ten years for payment and grace period of up to three years, at an interest rate of 2.5% per year (Banco do Nordeste, 2016).

The fact that the investment was made to be paid in a period of ten years was the reason for making the decision to analyze an average value in rates for this period.

Costs were obtained based on the items below. Prices of inputs and equipment were surveyed in stores that sell agricultural products in the municipality of Maracanaú- CE and in the research development region in June 2016.

- Acquisition of material for irrigation, tools (hoe, sickle, hand held seed planter, etc.), and fencing around the area can be pointed out as the initial cost.
- For manual operations, the hiring of a worker was considered, with costs consisting of salary plus labor rights, added to daily rates for sowing and harvesting operations.
- Expenses with inputs and materials were obtained by the product of the amount of materials used and their respective market prices.
- Cost with machine hours was obtained by the product of the number of hours required for all operations and the machine market price.
- For investment maintenance, a rate of 3% per year was considered on the investment value.
- The land lease value of R$ 1,200.00 was considered an opportunity cost for that asset.
- Water cost was calculated by the product of the water volume in m^{-3} used during the year and its value, being considered a minimum opportunity cost of R$ 0.15.
- A 6% rate over 80% of the gross revenue obtained in the year was considered for costs with technical assistance, association charges and "Funrural" (Assistance Fund for Rural Workers).
- The electricity tariff value was formed as a result of the sum of the actual electric energy consumption cost and electric power demand cost. According to regulations of ANEEL (Brazilian Electricity Regulatory Agency), the demand tariff applies only when the installed capacity is superior to 75 KVA. Thus, to meet the research conditions, the system operated with an installed capacity quite inferior, with a 4.0 CV electric motor to irrigate one hectare. The demand cost was null and the electricity tariff was composed of consumption cost only, as shown in Equation 4 (Frizzone et al., 1994).

$$CE = 0.7457 * Pot * Tf * Pkwh \tag{04}$$

Where: CE = cost of electrical energy during crop cycle in R$; 0.7457 = cv to kw conversion factor; Pot = motor power in cv; Tf = required system operation period in hours, during one year and considering 1.0 ha irrigated area, which varied with the treatments depending on the ETc percentages; Pkwh = kwh price in R$.

- Acquisition cost of bagana for mulch was formed by the product of the price charged of R$ 62.50 per m^{-3} and the volume used in the different treatments. An average value among all treatments was considered in this analysis.In order to determine the profitability of the treatments applied, using the methodology described by Martin et al. (1998), the following items were calculated.
- The gross revenue (GR) in R$ was obtained by the product of the yield in tons of sorghum silage and the average prices charged for this product from April to December 2016. The yield estimated for three cycles along one production year was considered, bearing in mind that each cycle has 100 days on ave-

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rage.

- The operating profit (OP) was calculated with the difference between gross revenue and total operating cost.
- The profitability index (PI), which is understood as the gross revenue ratio, consisting of resources available after coverage of total operating cost of production:

PI = (OP/GR) x 100

- The break-even price (BEP) was determined by the level of total operating cost of production, as the minimum price that needs to be obtained in order to cover the TOC, considering the average yield obtained in each treatment:
  BEP = TOC/ average yield obtained in each treatment.

Therefore, for purposes of economic and financial analysis, each treatment was regarded as a commercial crop with an area of one hectare, where all inputs were considered the same, with cost variance only regarding implementation of the different depths applied. With respect to operating costs, a variance was considered in the number of harvesting machine hours, based on the estimation of biomass collected per service hour.

It should be noted that the calculations were estimated among the average values for a planning horizon of a ten-year project.

Results and Discussion

Table 1 presents the estimates for effective operating cost, total operating cost, as well as the gross revenue obtained with forage sorghum crop in the different treatments with irrigation depths. The profitability indexes of the “economic and financial analysis” are organized according to the factors of different irrigation depths.

As shown in Table 1, the average values of gross revenue exceeded the total operating costs in all treatments. It was possible to verify that the increase in costs with irrigation turned in the order of 0.82% among the treatments with smaller depth applied (D1) and with larger depth applied (D5) along one production year. It should be noted that the costs associated with water application in irrigation refer to the cost of electrical energy consumed by the motor pump set and water applied along one production year.

Therefore, it can be noticed that the effective operating costs represented a larger portion against the total operating costs, since they are represented by the average annual cost of R$ 8,750.00 with application of bagana.

The increase was inferior to the proportional increase obtained in gross revenue, which was of 22.93% among the same treatments, indicating that irrigation becomes a cost that causes less concern to the producer. It is necessary to carefully examine water availability in the region because that is most often the main limiting factor to the production in the semiarid region.

Zwirtes et al. (2015), when assessing the

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Table 1. Technical, economic and financial indicators of sorghum crop as a result of irrigation depths in the municipality of Umirim-CE, 2016.

	Treatment				
	D1	D2	D3	D4	D5
EOC (R$ ha^{-1} $year^{-1}$)	35,255.96	36,280.79	37,035.85	37,481.30	38,342.64
TOC (R$ ha^{-1} $year^{-1}$)	41,825.71	42,854.77	42,216.59	41,308.61	42,169.95
GR (R$ ha^{-1} $year^{-1}$)	43,324.48	47,593.60	47,715.20	54,323.20	56,211.20
OP (R$ ha^{-1} $year^{-1}$)	1,498.77	4,738.83	5,498.61	13,014.59	14,041.25
PI (%)	3.46	9.96	11.52	23.96	24.98
BEP (R$ t^{-1})	308.95	288.14	283.12	243.34	240.07

productive performance and economic return of sorghum crop submitted to deficit irrigation, affirm that the total revenue, referring to grain commercialization, obtained with sorghum crop, showed negative linear response in relation to increase in deficit irrigation. The largest total revenue observed was R$ 2,349.66, with ETc replacement of 100%. The authors also state that every ETc decrease of 25% results in reduction of R$ 416.25 in the total revenue value.

It was also noted that the operating profit achieved the highest average with the treatment with the largest irrigation depth applied (Figure 2). Even though the D_1 average is equal to R$ 1,498.77 ha^{-1} $year^{-1}$, it still can be evaluated as a good indicator and used in low water availability conditions. The estimated regression shows that a variation of 1% in the ETc % produces an average variation of 133.44% in the operating profit.

The values estimated with a profitability index were inferior to the results obtained by Silva et al., 2013, working with economic analysis from different sources and nitrogen doses in the grain sorghum crop. The authors affirm that the profitability index was positive in all treatments. However, as the nitrogen doses are increased, there is a reduction in the operating profit. The results are opposite to the ones obtained with irrigation depths in the present work.

Zwirtes et al. (2015) state that the simulation of net revenue for irrigation presented a quadratic behavior in relation to the applied deficit irrigations of 25 to 100% of ETc, which is opposite to what was observed in the present work with a positive linear model. The maximum economic efficiency observed was of R$ 1,375.00 with application of deficit irrigation of 75% of ETc. This deficit irrigation with replacement of 75% of ETc presented reduction in grain yield, but even so it presented higher net yield because of the lower cost with irrigation.

With respect to the break-even price for a ton of sorghum, it can be noted in Figure 3 that there was a decrease in values with the increase in irrigation. That was considered a positive result from an economic perspective since the highest value was estimated in D1, and even in those planting conditions, it presents a behavior still below the average prices practiced in the region during the survey period, which was R$ 320.00. The results found in the treatments with superior depths were more favorable to the producer, since they indicate more security for the investment.

A reduction in break-even prices can be noticed due to the fact that the increase generated in the total operating costs, as a result of depths applied, was in a proportion lower than the increase produced in the gross revenue obtained by the sorghum biomass production with increase in irrigation depths. In general, the treatments presented very different behaviors, with the lowest break-even price being obtained in treatment D5 150% of ETc, with larger irrigation depth.

Therefore, the indicator of break-even point demonstrated to be favorable to the cultivation of sorghum for the producer, since all activities were remunerated, investment was paid in the period of ten years, required reinvestments in the useful life of equipment were made along the period, and workforce was paid, including all labor rights to the worker, and also resulting in prices below the average values practiced in the region.

Conclusions

According to the indicators analyzed, it was found that this is a promising crop within

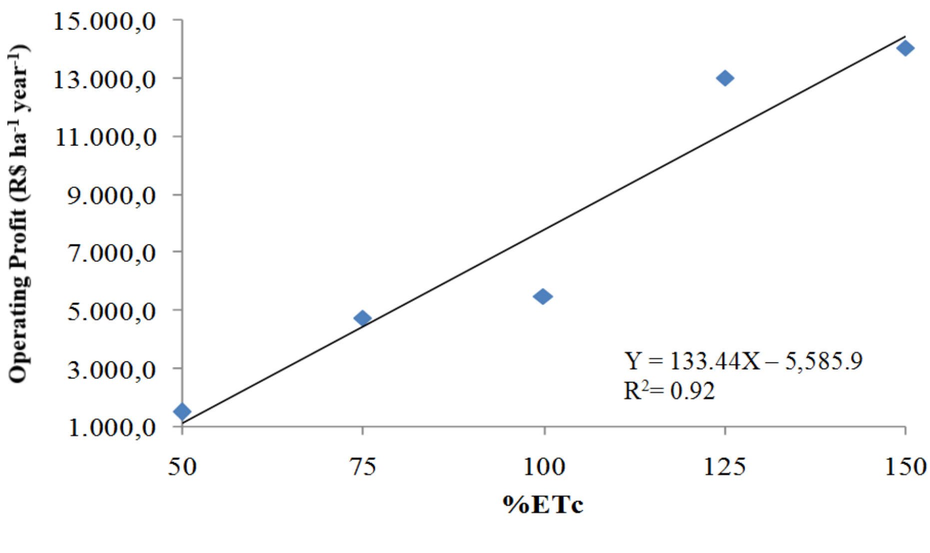

Figure 2. Operating profit obtained in reais per hectare per year as a result of irrigation depths applied by ETc ratio.

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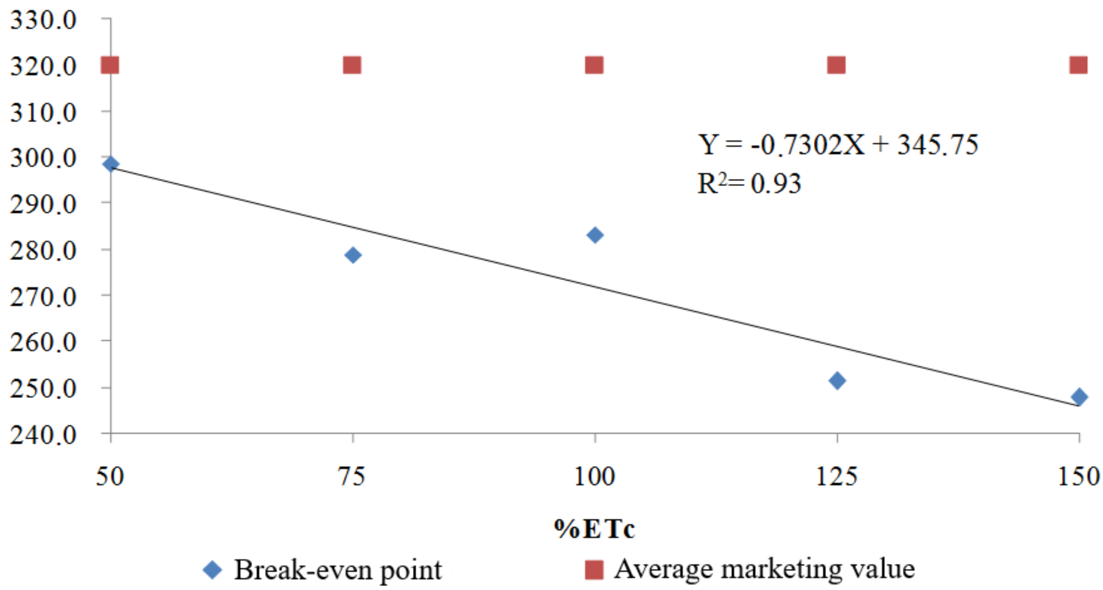

Figure 3. Break-even point in reais per ton of sorghum, based on irrigation depths and average marketing value in the region where the research was conducted.

the different agricultural production schools, with favorable rates for the producer. It can also be noticed that the evaluated sorghum variety "Ponta Negra" presents high resistance regarding the water limitation factor, showing positive indicators such as break-even point below the average prices practiced in the region.

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