ECONOMIC ANALYSIS OF CASHEW EARLY DWARF CROP BRS – 189 DEPENDING ON WATER LEVELS AND DOSES OF POTASSIUM FERTILIZATION

KELLY N. LEITE[1], RAIMUNDO N. T. COSTA[2], JOÃO R. CRISÓTOMO[3], JOSÉ A. FRIZZONE[4], ALBANISE B. MARINHO[5]

ABSTRACT: Water and fertilizer among the production factors are the elements that most restrict the production of cashew. The precise amount of these factors is essential to the success of the crop yield. This research aimed to determine the best factor-product ratio and analyze technical and economic indicators, of productivity of the cashew clone BRS 189 (Anacardium occidentale) to production factors water and potassium. The experiment was conducted from May 2009 to December 2009 in an experimental area of 56.0 m x 112.0 m in the irrigated Curu - Pentecoste, located in the municipality of Pentecoste, Ceará, Brazil. Production factors water (W) and potassium (K) were the independent variables and productivity (Y), the dependent variable. Ten statistical models that have proven satisfactory for obtaining production function were tested. The marginal rate of substitution was obtained through the ratio of the potassium marginal physical product and the water marginal physical product. The most suited model to the conditions of the experiment was the quadratic polynomial without intercept and interaction. Considering that the price of the water was 0.10 R$ mm $^{-1}$, the price of the potassium 2.19 R$ kg $^{-1}$ and the price of the cashew 0.60 R$ kg^{-1}, the amounts of water and K_2O to obtain the maximum net income were 6,349.1 L plant^{-1} of water and 128.7 g plant $^{-1}$year, $^{-1}$ respectively. Substituting the values obtained in the production function, the maximum net income was achieved with a yield of 7,496.8 kg ha^{-1} of cashew.

KEYWORDS: Anacardiun occidentale, irrigation, potassium.

ANÁLISE ECONÔMICA DA CULTURA DO CAJUEIRO-ANÃO PRECOCE BRS 189 EM FUNÇÃO DOS NÍVEIS DE ÁGUA E DOSES DE ADUBAÇÃO POTÁSSICA

RESUMO: A água e os fertilizantes, entre os fatores de produção, são os elementos que mais restringem a produção do cajueiro. O domínio das quantidades precisas desses fatores é essencial no sucesso do rendimento da cultura. A pesquisa teve como objetivo determinar a melhor relação fator--produto e analisar indicadores técnicos e econômicos da produtividade do clone de cajueiro anão precoce BRS 189 (Anacardium occidentale) aos fatores de produção água e potássio. O experimento foi realizado no período de maio a dezembro de 2009, em uma área experimental de 56,0 m x 112,0 m, no Perímetro Irrigado Curu - Pentecoste, localizado no município de Pentecoste--CE. Os fatores de produção água (W) e potássio (K) constituíram as variáveis independentes e a produtividade (Y), e a variável dependente. Foram testados dez modelos estatísticos que se mostraram satisfatórios para a obtenção da função de produção. A taxa marginal de substituição foi obtida pela relação do produto físico marginal do potássio e do produto físico marginal da água. O modelo mais adequado às condições do experimento foi o polinomial quadrático sem intercepto e sem interação. Considerando que o preço da água era de 0,10 R$ mm^{-1}, o preço do potássio de 2,19 R$ kg^{-1} e o preço do caju de 0,60 R$ kg^{-1}, as quantidades de água e K_20 para se obter a máxima receita líquida foram de 6349,1L planta^{-1} de água e 128,7 g planta^{-1} ano^{-1}, respectivamente. Substituindo os valores obtidos na função de produção, a máxima receita líquida foi alcançada com produtividade de 7496,8 kg ha^{-1} de caju.

PALAVRAS-CHAVE: Anacardiun occidentale, irrigação, potássio.

[1] Doutora em Ciencia em Engenharia Agraria, UCLM: kellyleite14@hotmail.com.
[2] Professor adjunto, doutor, Departamento de Engenharia Agrícola, UFC, Fortaleza,CE, e-mail: rntcosta@secrel.com.br.
[3] Pesquisador, Embrapa Agroindústria Tropical, Fortaleza, CE, e-mail: crisóstomo@cnpat.embrapa.br.
[4] Professor Titular. Doutor, Departamento de Engenharia de Biossistemas Área de Hidráulica ESALQ - USP: frizzone@usp.br.
[5] Eng. Agricola. Profa. Doutora. Instituto de Desenvolvimento Rural IDR/UNILAB, Redenção - CE.
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INTRODUCTION

The Cashew (Anacardiun occidentale L.) due to its socioeconomic importance is widespread in almost all the national territory (OLIVEIRA et al., 2000).The favorable condition in the northeastern Brazil, has allowed the expansion of cashew cultivation, mainly in the states of Piauí, Ceará and Rio Grande do Norte (PAULA PESSOA et al., 1995; ARAÚJO & FERRAZ, 2006). In Brazil, the production of cashew nuts intended traditionally to the foreign market. In 2007 were exported 59,000 tons of nuts, equivalent to U.S. $ 225 million dollars, expressive value in relation to the total collected with foreign agricultural products in the Brazilian Northeast (16.2 billion dollars) (CARVALHO, 2009; BALASUBRAMANIAN, 2001). The stalk or pseudo fruit represents about 90% of the overall weight of the fruit, yet, until the mid-1990s, its use was only 5% of the production. However, currently, the stalk is gradually becoming an important segment of cashew agribusiness, pointing to the achievements of new markets with 30 sub-products (PAIVA & BARROS, 2004; OLOSO & CLARKE, 1993).

Spite of the socioeconomic importance of the cashew tree, it is observed that in most common cashew plantations have not been adopted technologies related to the production system, resulting in average productivity of 220 kg ha^{-1}. (BARROS et al. 1993; ARAÚJO & FERRAZ, 2008)

The water and nutrients, among the production factors are those that most frequently restrict income (CARVALHO et al., 2010; SOUSA et al., 2010; MION et. al., 2012). As BERNARD et al. (2005), in irrigated agriculture, water factor must be optimized, also allowing better use of other production factors and as a consequence, to obtain higher productivity with better application of other inputs. For this purpose, the knowledge of the production functions constitute important information analysis, that it is possible to determine the interactions between factors and selecting the most suitable solutions to the local conditions for rational irrigation management on technical and economic bases (BERNARDO, 1998)

On the basis of this assumption, the aim of this study was to determine the best factor-product ratio and analyze technical and economic indicators of the productivity of cashew clones BRS 189 to production factors water and potassium.

MATERIAL AND METHODS

The experiment was conducted from June to December 2009 in an area of 56.0 m x 112.0 m in the irrigated place of Curu Pentecoste, located in the municipality of Pentecoste, State of Ceará, geographically located between 3^o 51’ 18” South latitude and the meridian of 39^o 10’ 19” West longitude at an altitude of 47 m. During the execution of the experiment the average annual temperature was 26ºC and the relative humidity of 73.8%.

The experimental design was randomized blocks in a split-plot with four replications. The treatments were combinations of four levels of irrigation and four doses of potassium fertilization. The irrigation levels (W_1, W_2, W_3, W_4) corresponded to the percentage of 25%, 50% 100% and 200% of crop evapotranspiration corresponding to a volume of water per plant, 1659, 3318, 6636, 12847L $plant^{-1}$ and the potassium doses (K_0, K_1, K_2 and K_3) corresponding to 0, 50, 100 and 200 g K_2O $plant^{-1}$ $year^{-1}$ .It was used a localized irrigation system, type micro-sprinkler with a lateral line per row of plants.

The system was composed of 16 side lines of polyethylene of 49.0 m in length and nominal diameter of 16 mm, having at the end of the bypass line an "easel" with four records for the control of the water slides applied to the plots that received the treatments. Micro-sprinklers self-compensating were used with a flow rate of 45 L h^{-1} at a pressure of 250 kPa, arranged in line on the same lateral spacing of the crop.

The cashew orchard was installed in September 2005, and this survey in the fourth year after planting, at which time the culture reached its production potential. It was used at planting, certified cashew seedlings (Anacardiun occidentale L.) BRS 189, spaced 7.0 m between row and 7.0 m between plants.

The soil of the experiment has sandy texture for the profile from 0 to 0.90 m, typically plane relief, whose physic-chemical characteristics are presented in Table 1. The soil does not present problems of salinity, however, exchangeable sodium percentage increased with depth and almost neutral ph.

TABLE 1. Phisico-chemical characteristics of the soil of the experimental area.

Granulometric composition ($g\ kg^{-1}$)						Tex.	Soil density ($kg\ m^{-3}$)	PH	CE (Dsm^{-1})	CC (%)	PMP (%)
Depth (cm)	Thick sand	Fine sand	Silte	Clay	Natural clay						
0-30	640	300	40	20	10	Sand	1450	6.5	0.23	3.9	2.56
30-60	720	240	20	20	10	Sand	1490	7.1	0.15	2.2	1.44
60-90	780	780	10	20	10	Sand	1530	7.2	0.15	2.1	1.36

Sorption complex (cmolc.L-1)								PST	O.M. ($mg\ kg^{-1}$)	Passimilavel ($mg\ kg^{-1}$)
Ca^{2+}	Mg^{2+}	Na^{-}	K^{+}	$H^{+}Al^{-}$	Al^{3+}	S	T			
1.40	0.80	0.13	0.11	0.66	0.00	2.40	3.10	4.00	4.55	152
0.90	0.60	0.10	0.04	0.16	0.00	1.60	1.80	5.00	0.40	109
0.60	0.40	0.10	0.04	0.33	0.00	1.10	1.30	7.00	0.29	105

Source: Laboratory of Soil / Water UFC

In the fertilization was used 330 g $plant^{-1}$ of superphosphate, applied once at the beginning of irrigation, 310 g plant $^{-1}$ of urea divided into three monthly applications (30, 60 and 90 days after the beginning of the experiment) applied along with doses of potassium chloride and vary according to specific process: 0, 50, 100 and 200 g K_2O $plant^{--1}$ which corresponded to 0, 83, 166 and 333 g KCl plant $^{-1}$, respectively.

During the experiment it was realized phytosanitary controls through fungicides copper oxychloride base, with the aim of controlling the black mold and anthracnose diseases relatively common in cashew orchards in the region. The weeding was manually, performing the crowning ever after fertilization, preventing weed competition with the crop for nutrients and water.

In this study, the production factors water (W) and potassium (K) were the independent variables and crop yield (Y), the dependent variable. To obtain the production function were tested ten statistical models that according to Aguiar (2005) showed to be quite satisfactory from field researches to represent a production function of a culture. It is important the test of several models and not only the quadratic model, because the factors leading to the rise of the curve to the left until the maximum point is different from the factors that cause the fall of the curve after this same point (FRIZZONE & ANDRADE JUNIOR, 2005). Among these models tested from regression analyzes using SAS software SYSTEM it was chosen the best that adjusted to the experiment data, considering the coefficients of determination r² and r² adjusted, the value of f test of the analysis of variance, the values of the t test for all coefficients and the signs of the variables models analyzed. The statistical models tested were:

$$\overline{Y} = b_0 + b_1 W + b_2 A + b_3 W^{0,5} + b_4 A^{0,5} + b_5 W^{0,5} A^{0,5} + e_i \quad (a)$$

$$Y = b_0 + b_1 W + b_2 A + b_3 W^{0,5} + b_4 A^{0,5} + b_5 WA + e_i \quad (b)$$

$$Y = b_0 + b_1 W + b_2 A + b_3 W^{0,5} + b_4 A^{0,5} + e_i \quad (c)$$

$$\overline{Y} = b_0 + b_1 W + b_2 A + b_3 W^{2} + b_4 A^{2} + b_5 WA + e_i \quad (d)$$

$$\overline{Y} = b_0 + b_1 W + b_2 A + b_3 W^{2} + b_4 A^{2} + e_i \quad (e)$$

$$\overline{Y} = b_0 + b_1 W + b_2 A + b_3 W^{1,5} + b_4 A^{1,5} + b_5 WA + e_i \quad (f)$$

$$\overline{Y} = b_0 + b_1 W + b_2 A + b_3 W^{1,5} + b_4 A^{1,5} + e_i \quad \text{(g)}$$

$$\overline{Y} = b_0 + b_1 W + b_2 W^2 + b_3 A^2 + e_i \quad \text{(h)}$$

$$\overline{Y} = b_1 W + b_2 A + b_3 W^2 + b_4 A^2 + b_5 WA + e_i \quad \text{(i)}$$

$$\overline{Y} = b_1 W + b_2 A + b_3 W^2 + b_4 A^2 + e_i \quad \text{(j)}$$

The marginal rate for the replacement of the factor-water levels by the factor-doses of potassium ($MRS_{w\,/\,k}$) corresponds to the quantity of the factor-water that is offered to leave to use one more unit of the factor-potassium, keeping the same level of productivity. It is obtained by the ratio of potassium marginal physical product and the water marginal physical product, being represented by equation 1:

$$MRS_{W/K} = -\frac{PMgK}{PMgW} \quad (1)$$

Being $MRS_{W\,/\,K}$: marginal rate of substitution of the factor-water (W) by the factor-potassium (K), PMgK: potassium marginal physical product and PMgW, water marginal physical product.

For purposes of analysis, data of maintenance cost of the fourth year of cultivation were used corresponding to R$ 2,957.83 per ha, product price of R$ 0.60 per kg and the price of potassium fertilizer R $ 2.19 per kg. As for the cost of irrigation (R$$L^{-1}$) was considered as equal to the electricity rate, since the implementation costs are included in cost of production, as suggested FRIZZONE et al. (1994).

The value of the electricity rates was formed by the sum of the cost of the actual consumption of energy and the cost of electric power demand. According to the rules of ANEEL (National Electric Energy Agency) Resolution No. 456 of December 29, 2000, only exists when the rate of demand exceeding installed capacity is 75 KVA. Considering that for the conditions of this study the system operated with a much lower installed power, using an electric motor for 2cv, the cost of demand was zero, and the electricity rates comprised only the cost of consumption.

RESULTS AND DISCUSSION

The reference evapotranspiration from July to November 2009, total period of the experiment, was 536.9 mm and 91 mm of rainfall, according to data presented in TABLE 2.

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TABLE 2. Average evapotranspiration during the experiment.

Month	Days	ETo (mm)	ETc (mm)
Jul./09	15	50	32.4
Aug./09	31	116.4	75.7
Sept./09	30	124.3	81.2
Oct./09	31	130.4	84.8
Nov./09	30	115.8	75.3
Total	137	536.9	349.3

For purposes of economic analysis, we chose to quantify the applied water in liters per plant, in order to be more consistent with the form of charging the water by the Irrigation Districts.

The maximum productivity of cashew (stalk + nut), 6474.5 kg ha^{-1} was obtained with treatment W_3K_3, equivalent to applying 6636 L $plant^{-1}$ and a dose of K_2O of 200 g $plant^{-1}$ $year^{-1}$ (TABLE 3). According to CRISÓSTOMO et al., (2001) the precocious cashew tree when irrigated can produce up to 4600 kg ha^{-1} of nut in the fourth year of production, however is to emphasize that the clone studied BRS - 189 does not possess the nut characteristics good for marketing and its weight is much lower than the other clones, whose exploitation is in order to the nut market. RIBEIRO et al., (2006), testing different replacements of water in clone CCP-09 in Teresina, Piaui-Brazil had the highest nut productivity to treat 100% replacement of evaporation from a Class A tank.

TABLE 3. Average yield (AY), average weight (AW), total soluble solids (TSS), and efficiency of water use (EWU) as a function of water levels and potassium fertilizer applied.

Factor	Treatment	AY (Mg ha^{-1})	AW (g)	TSS (ºBrix)	EWU(kg m^{-3})
Irrigation (% ETc_{corr})	25	44.02	120.1	12.5	13.0
	50	43.71	93.2	11.5	6.4
	100	49.48	132.0	12.2	3.7
	200	43.46	134.2	12.5	1.9
Potassium (g $plant^{-1}year^{-1}$)	0	44.50	113.3	12.2	6.77
	50	38.19	131.9	11.8	5.16
	100	48.34	111.5	13.0	6.60
	200	49.64	122.9	12.0	6.45
Interaction (I x P)		Sig*.	Ns**	Sig*.	Sig*.

* Interaction significant at the 5% level of probability ** interaction not significant at 5% level of probability.

The model that best adjusted to the experimental data was the quadratic polynomial model without intercept and interaction, according to equation 2.

$$Y = 1.23941\ W + 43.47K - 0.00008448W^2 - 0.15468\ K^2 \quad (2)$$

The coefficients of determination (r2) of 0.89 means that 89% of the cashew yield variations are explained by the variation in the volume of water and potassium levels. The t-test showed probability higher than t of 0.0027, 0.0673, 0.0050 and 0.1604 for the parameters W, K, W_2 and K_2 respectively. According to the test, the variables that indicate water (W and W_2) significantly influence at levels below 1% and the variables K and K^2 related to the fertilization influence on levels of 6.7% and 16.04%. Although these are variables are with a significance level higher than recommended by the statistics, they were incorporated into the model, given the physical behavior of the factor-product ratios, beside the consistency of the variables signs.

According to the statistical model chosen the maximum productivity of the studied clone would be 7600.9 kg ha^{-1}obtained with the application of 140.5 g $plant^{-1}$ $year^{-1}$ of K_2O and a water volume of 7335.3 L $plant^{-1}$. FIGURE 1 graphically represents the function of the estimated production, demonstrating that both were limiting factors in determining the productivity.

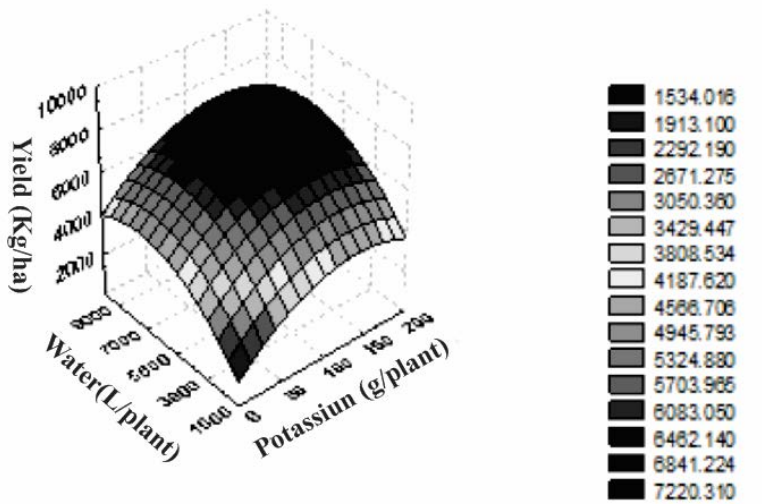

FIGURE 1. Surface response of the productivity of cashew as a function of the volume of water and potassium.

The isoquants represent various combinations of production factors that result in the same productivity. FIGURE 2 shows the isoquants obtained from the production function, isolating the water factor for different productivity and fertilization levels, previously fixed. The gradual decrease in slope between two consecutive curves as it increases productivity, considering that the levels are equidistant indicates that there is an increase in productivity with increasing the amount of the factors W and K. It is observed that the higher the productivity the lower the amount of combinations of the production factors, to the point that only one combination is possible, which offers the higher productivity (7600.96 kg ha^{-1}).

It is noticed that the water factor can be replaced by the potassium factor to a certain point allowing obtain the same productivity after which the applied volume of water begins to rise out of the area of rational production. According to Aguiar (2005), each point on a isoquant corresponds to a particular technology that can be adopted, represented by the relation W/X When an isoquant moves to the right it has an increase in the amount produced and vice versa.

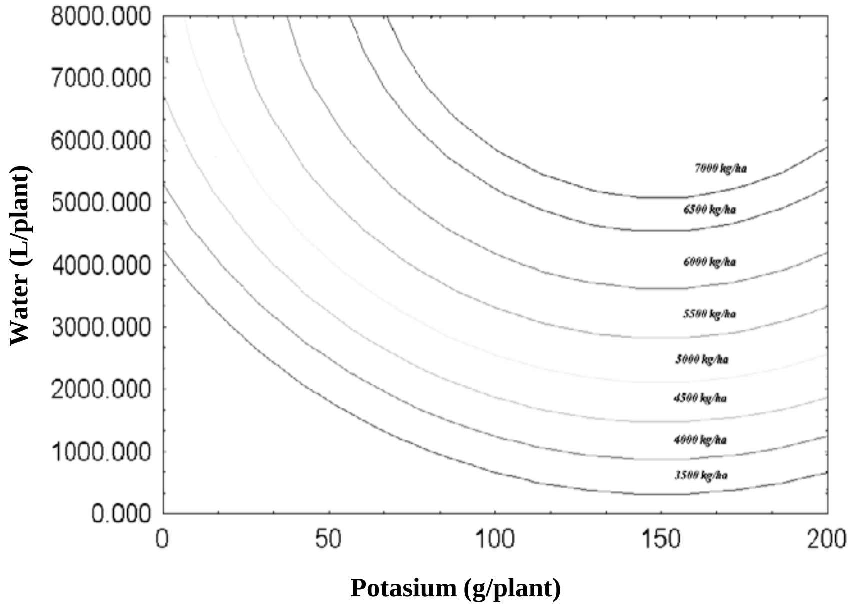

FIGURE 2. Isoquants for the productivity of cashew as a function of the volume of water and doses of K_2O.

The marginal rates of substitution ($MRS_{W/K}$) of water to potassium, that is, the amount of water which must replace a unit of factor K and obtain the same productivity is presented in Tables 1 and 2. The MRS initially are negative, indicating that water is being replaced by potassium in decreasing proportions. From the moment that becomes positive indicating that it is uneconomical, because the water starts to be replaced by potassium in increasing amounts.

The more water and less potassium is used to obtain the same level of productivity, it becomes more difficult to replace the fertilizer to water, as may be seen in isoquants (FIGURE 2). For productivity levels analyzed it is possible the replacement of potassium by water until the potassium level corresponding to 100 g plant^{-1} year^{-1} where the factors behaves as substitutes. For productivity of 7000 kg ha^{-1} and the K_2O dose corresponding to 100 g plant^{-1} year $^{-1}$ would be possible to save 36.6 liters of water for each unit of K_2O introduced. The positive marginal rates mean that from there, it would be necessary to apply more fertilizer to each unit of water behaving as complementary factors, instead of saving water, would spend more water to each potassium unit added.

TABLE 4. MRS $_{W/K}$, of water for potassium by different productivities in kg ha^{-1}.

K_2O g $plant^{-1}$	4500		5000		5500	
	W (L $plant^{-1}$)	MRS	W (L $plant^{-1}$)	MRS	W(L $plant^{-1}$)	MRS
0	6598.7	-349.2	**	**	**	**
50	2677.5	-35.5	3363.2	-41.7	4195.4	-52.8
100	1530.6	-12.8	2064.9	-14.1	2660.0	-15.9
150	1290.5	2.9	1801.6	3.1	2365.1	3.5
200	1837.1	19.8	2404.6	22.1	3046.5	25.4

TABLE 5. MRS $_{W/K}$, of water for potassium by different productivities in kg ha^{-1}.

K_2O g $plant^{-1}$	6000		6500		7000	
	W (L $plant^{-1}$)	MRS	W (L $plant^{-1}$)	MRS	W (L $plant^{-1}$)	MRS
0	**	**	**	**	**	**
50	5350.1	-83.5	**	**	**	**
100	3342.8	-18.6	4169.6	-23.4	5309.5	-36.6
150	3001.1	3.9	3748.3	4.8	4629.9	6.4
200	3803.2	30.8	4774.6	42.5	6535.5	136.1

The amounts of water and potassium that maximize net income per unit area was obtained by equating the partial derivatives of the production function in relation to water and fertilizer, the price ratio of water relative to the product price (Pw / PY) and the ratio of fertilizer price relative to the price of the product (PK/PY).

$$PMgW = 1.23941 - 0.00016896W = \frac{P_W}{P_Y} \quad (3)$$

$$PMgK = 43.47702 - 0.30936K = \frac{P_K}{P_Y} \quad (4)$$

Considering that the price of the water was R$ 0.10 mm^{-1}, the potassium R$ 2.19 kg^{-1} and the price of cashew R$ 0.60 kg^{-1}, the quantities of water and fertilizer (K_2O) to give the maximum profit is 6349.1 L $plant^{-1}$(129.6 mm) and 128.7 g $plant^{-1}$ $year^{-1}$. Substituting the values obtained in the production function, the maximum profit would be achieved with the productivity of 7496.8 kg ha^{-1} of cashew (stalk + nut).

Considering the total cost of production plus interest rates of the culture for the fourth year of cultivation of R$ 2,957.83 plus costs with additional water and potassium, to maximize the net income it would be R$ 70.2, the max net income would be R$ 1,470.05 per hectare.

CONCLUSSIONS

The maximum observed physical productivity of 6,474.5 kg ha^{-1} was obtained with the treatment W_3K_3 referring to 100% of maximum crop evapotranspiration (6636 L plant-1) and 200 g $plant^{-1}$ $year^{-1}$ of K_2O or 40, 8 kg ha^{-1} yr^{-1}. The estimated maximum productivity (7,600.9 kg ha^{-1}) corresponded to a higher need for water treatment in 14.5% to the W_3 treatment and 140.5 g $plant^{-1}$ $year^{-1}$ of K_2O, an equal amount to that recommended by analysis of the soil.

The economically optimal level of water that provided the maximum productivity is 4.5% below the observed value. Since the economic productivity was lower by only 1.4% to the estimated productivity by the statistical model, and provides a water savings of 15.5%.

Although the maximum productivity achieved had occurred with the application of water greater than the crop needs, economic analysis shows that the management with greater economic return would be the irrigation with a deficit.

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