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ANÁLISE ECONÔMICA DA UTILIZAÇÃO DE SILÍCIO NO CULTIVO DE COUVE-FLOR EM AMBIENTE PROTEGIDO NA REGIÃO NOROESTE DO PARANÁ

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1 RESUMO

O estudo teve como objetivo analisar a viabilidade econômica do cultivo de couve-flor em ambiente protegido sob diferentes condições de disponibilidade hídrica e quantidades de silício (Si) na região noroeste do Paraná. O trabalho foi desenvolvido em ambiente protegido, com três condições de reposição hídrica (40, 70 e 100% da evapotranspiração diária) e quatro doses de Si (0, 50, 100 e 150 kg ha^{-1}). No levantamento dos custos de produção foram considerados como custos fixos o capital da terra e a depreciação da estrutura, e como custos variáveis as sementes, os insumos, eletricidade, a operação de máquinas, os equipamentos, a mão-de-obra e o Si. O estudo considerou a área produtiva de 175 m². Para determinação do retorno econômico foi considerada a produção de massa fresca da inflorescência e o preço médio anual de venda no estado do Paraná. O retorno econômico variou entre R$185,46 e R$660,81. Os resultados econômicos indicam que a produção de couve-flor em ambiente protegido apresenta viabilidade econômica para região noroeste do Paraná. A aplicação de Si, com exceção da condição de reposição hídrica de 40% da ETc com aplicação de 150 kg ha^{-1} de Si, ocasionou incremento no retorno econômico para couve-flor cultivada em ambiente protegido.

Palavras-chave: *Brassica oleracea* var. *botrytis*, custo produtivo, viabilidade.

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ECONOMIC ANALYSIS OF THE USE OF SILICON ON GREENHOUSE CAULIFLOWER IN THE NORTHWEST PARANÁ REGION

2 ABSTRACT

The study aimed to analyze the economic viability of growing greenhouse cauliflower under different conditions of water availability and quantities of silicon (Si) in the northwestern region of Paraná. The study was conducted in a greenhouse, with three water replacement conditions (40, 70 and 100% of daily evapotranspiration) and four doses of Si (0, 50, 100 and

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150 kg ha^{-1}). In the survey of production costs, land capital and depreciation of the structure was considered fixed costs, and seeds, inputs, electricity, machinery operation, equipment, labor and Si were variable costs. The study considered the productive area of 175 m². To determine the economic return, the production of fresh mass from the inflorescence and the average annual sale price in the state of Paraná was considered. The economic return ranged between R$185.46 and R$660.81. The economic results indicate that the production of greenhouse cauliflower presents economic viability for the northwestern region of Paraná. The application of Si, except for the condition of 40% of ETc with application of 150 kg ha^{-1} of water replacement condition of 40% of ETc with application of 150 kg ha^{-1} of Si, increased the economic return for cauliflower grown on greenhouse.

Keywords: *Brassica oleracea* var. *botrytis*, production cost, viability.

3 INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is important for family farming and is an economically profitable option, providing a productivity greater than 9 Mg ha $^{-1}$ in soil conditions with low fertility and with a productive potential greater than 20 Mg ha $^{-1}$ in properly managed areas (BEZERRA; COSTA; SANTOS, 2020; OLIVEIRA et al., 2018).

In Brazil, between 2016 and 2018, approximately 80,000 t year $^{-1}$ were sold on the wholesale market, with the main producing states being São Paulo, Minas Gerais, Rio Grande do Sul, Rio de Janeiro, and Paraná, accounting for 86% of the total production (RIBEIRO et al., 2019). In Paraná, the gross production value of cauliflower was R$272 million in 2018, with the cultivation area remaining stable between 2009 and 2018, reaching approximately 3,000 hectares (SALVADOR, 2020).

Protected environment cultivation is growing due to the possibility of off-season production and the control of environmental variables, which provides a reduction in pathogen attacks and a decrease in foliar diseases, as well as increased productivity and final product quality (CASAIS et al., 2018; GALATI et al., 2015; LOZANO et al., 2018). In combination with these factors, production in a protected environment allows for adequate water and nutrient management, which is a future trend for the production of species of the *Brassica* genus, targeting opportunities due to price seasonality (MELO et al., 2017).

To increase production efficiency, it is also necessary to adopt cultivation techniques associated with water management, aiming at the use of resources, such as beneficial elements. The use of silicon in vegetables has positive effects, especially in unfavorable physical and chemical environments, and has a significant effect on the postharvest quality of cauliflower (CURVELO et al., 2019) and other crops of commercial interest (LOZANO et al., 2018; GALATI et al., 2015).

However, studies are still needed on the agronomic and economic profitability of cauliflower cultivation in protected environments and the impact of Si use on these variables. Therefore, this study aimed to analyze the economic viability of cauliflower cultivation in protected environments under different conditions of water availability and silicon (Si) levels in the northwestern region of Paraná.

4 MATERIALS AND METHODS

The economic analysis was based on a study developed at the Irrigation Technical Center (CTI) located at 23°25'S, 51°57'W and 542 m above sea level in the municipality of Maringá-PR, belonging to the State University of Maringá (UEM). The climate here is characterized as Cfa, with total annual rainfall between 1,400 and 1,600 mm, average temperature between 21.1 and 22°C, total annual evapotranspiration of 1,000 and 1,100 mm, and solar radiation of 14.5 to 15 MJ m $^{-2}$ day $^{-1}$ (NITSCHE et al., 2019).

Sharon hybrid cauliflower was cultivated in a protected environment. The structure was 25 m long, 7 m wide, and 3.5 m high. It had an arched roof made of transparent polyethylene film (150 μm) and sides made of white nylon mesh. The soil inside was classified as Dystroferric Red Nitosol according to Santos et al. (2018).

Irrigation was carried out via drippers (Irritec PDCS) with a flow rate of 5 L h $^{-1}$ and a spacing of 0.25 m. Water was collected from a semiartesian well via a pumping system consisting of a centrifugal pump with a 0.5 hp electric motor. The amount of water for water replacement was estimated by determining the daily crop evapotranspiration (ETc) via constant-level water table lysimeters located inside the protected environment.

Cauliflower was sown in polyethylene trays (128 cells) in commercial substrate (MecPlant®) and transplanted after 30 days to seedbeds, with a spacing of 0.5 m between plants and 1 m between rows. The experimental units consisted of six plants, three of which were evaluated. The plants were subjected to three water replacement conditions (40, 70, and 100% of daily evapotranspiration) and four silicon rates (0, 50, 100, and 150 kg ha $^{-1}$) in a factorial design with four replicates. Silicon was applied via Si oxide as a source in three periods (vegetative, intermediate, and reproductive stages), and the product AgriSil® (98% SiO_2) was used. Cultivation took place from October 2019 to February 2020.

The economic analysis considered the entire protected environment, with average productivity values in each condition extrapolated to the total area of the environment, which corresponds to 175 m². Fixed costs were calculated according to the methodology described by the National Supply Company (CONAB, 2010), considering linear depreciation of the structure and land capital as 3% of the sales value, on the basis of value data from the Paraná Department of Rural Economy (DERAL) (SALVADOR, 2020). To estimate the fixed costs involved in cultivation, values proportional to the time and area used were considered.

Variable costs refer to the market value of seeds, substrate, fertilizers, and materials. The cost of operating machinery and equipment refers to fuel consumption for soil preparation. Electricity costs were calculated on the basis of booster pump consumption (kW), irrigation time under each water replenishment condition, and the rates charged by Companhia Paranaense de Energia (COPEL) for rural areas in 2019, in accordance with National Electric Energy Agency (ANEEL) Resolution No. 2,559. Labor costs were calculated on the basis of working time and the current minimum wage (R$1,045.00). The total cost was calculated considering fixed costs, variable costs, and the cost of silicon application in different scenarios, depending on the water replenishment condition.

To calculate the economic return, the average price of inflorescences in each scenario was R$4.29 kg $^{-1}$, as per Salvador (2020), and the average productivity (kg) for each condition was calculated. The minimum expected return was calculated on the basis of the minimum attractiveness rate, considering the Selic rate for the period analyzed (1.9%), according to data from Tesouro Direto (2020). The profitability index was calculated considering the economic return and the initial investment. The minimum expected return defines a baseline value that the economic return on production must exceed for the business to be considered financially attractive.

With respect to the economic results, under the different conditions analyzed, the profitability of production, the return index and the financial increase caused by the application of silicon in cauliflower grown in a protected environment were determined.

5 RESULTS AND DISCUSSION

Table 1 shows the costs of cauliflower production in a protected environment under different water replenishment conditions. Among the fixed costs for cauliflower production, depreciation of the structure represents 87.69% of the total, whereas among the variable costs, inputs and labor were the most expensive.

Table 1. Costs for cauliflower production in a protected environment with different water replacement conditions (40, 70 and 100% of ETc), Maringá-PR, 2019/2020.

Variable analyzed	Cost (R$)			Cost share (%)		
	40	70	100	40	70	100
Fixed costs						
Capital of the land	28.08	28.08	28.08	12.31	12.31	12.31
Structural depreciation	200.00	200.00	200.00	87.69	87.69	87.69
Total	228.08	228.08	228.08	100.00	100.00	100.00
Variable costs						
Seed	25.20	25.20	25.20	12.84	12.18	11.29
Inputs	60.00	60.00	60.00	30.57	29.00	26.87
Electricity cost	5.13	15.76	32.16	2.61	7.62	14.40
Machine/Equipment Operation	24.00	24.00	24.00	12.23	11.60	10.75
Labor	81.92	81.92	81.92	41.74	39.60	36.69
Total	196.25	206.88	223.28	100.00	100.00	100.00
Total Cost*	424.33	434.96	451.36	100.00	100.00	100.00

*Total cost = fixed cost + variable cost.

Although vegetable production in a protected environment offers quality conditions and scaled cultivation (CASAIS et al., 2018), it has a significant effect on production costs. In this study, Table 1 shows that the fixed cost was higher than the variable cost, associated with the depreciation of the protected environment structure, which represented the largest expenditure in the total cost, also considering the cost of the silicon source.

In field cultivation, variable costs represent a greater percentage of the final cost of cauliflower production (PEREIRA et al., 2018). However, it is worth highlighting that costs are still a bottleneck for the production of species of the *Brassica genus* and require producers to take measures to increase productivity and reduce costs to make the activity viable (MELO et al., 2017; MARQUES; MONTANHA, 2019; PONCIANO et al., 2004).

Cultivation also allows for good productivity in times of lower product supply and better control of adverse conditions; therefore, better cauliflower prices on the market, even if it presents seasonality, that is, the commercial value may vary according to productivity and the average annual price of the product.

Table 2 shows that the final result was positive for all conditions, with a profit margin ranging from R$ 185.46 to R$ 660.81. According to the minimum expected return and the return index (Table 2), the cultivation of cauliflower in a protected environment showed financial viability, considering that the economic return was higher than the minimum expected return for all conditions analyzed, according to the investment for production.

Table 2. Economic balance of cauliflower cultivation in a protected environment under different doses of silicon (0, 50, 100 and 150 kg ha^{-1}) and water replacement (40, 70 and 100% of ETc), Maringá-PR, 2019/2020.

Replacement	**Yes**	**Cost Si** [1]	**Final cost** [2]	**Economic return**	**Profit**	**RME**[3]	**IR** [4]
% ETc	kg ha^{-1}			R$			-
40	0	0.00	424.33	784.43	360.1	432.39	1.85
	50	45.96	470.29	922.38	452.09	479.23	1.96
	100	93.10	517.43	888.45	371.02	527.26	1.72
	150	139.65	563.98	749.44	185.46	574.70	1.33
70	0	0.00	434.96	765.20	330.24	443.22	1.76
	50	46.55	481.51	925.99	444.48	490.66	1.92
	100	93.10	528.06	1,151.34	623.28	538.09	2.18
	150	139.65	574.61	1,142.90	568.29	585.53	1.99
100	0	0.00	451.36	1,038.62	587.26	459.94	2.30
	50	46.55	497.91	1,085.38	587.47	507.37	2.18
	100	93.10	544.46	1,147.81	603.35	554.80	2.11
	150	139.65	591.01	1,251.82	660.81	602.24	2.12

[1] Using silicon oxide as a source; [2] Final cost = total fixed cost + total variable cost + cost of the silicon source; [3] RME = minimum expected return (initial investment + Selic); [4] IR = return index.

In this study, the financial analysis of the cauliflower variables considered the price per kg of product. This can also be marketed per unit and/or on the basis of market classification (SASAKI; GOTO; MEIRELLES, 2020). Thus, variations in fresh mass may not generate economic bonuses within a certain range of mass increases. As a reference, the National School Feeding Program (PNAE) is an alternative to the commercialization of production, whose table for the state of Paraná (GOVERNO DO ESTADO O PARANÁ, 2020) presents an acquisition value of R$ 4.98 kg $^{-1}$ for conventional production and R$ 5.57 kg $^{-1}$ for organic production, which is 16.08% and 29.83% higher than the value adopted in this study (R$ 4.29 kg $^{-1}$).

Supplemental fertilizer application should be based on clear management objectives, for example, in the biofortification of vegetables, with the goal of improving nutritional, sensory, and postharvest characteristics (LIMA; NASCIMENTO; SOUSA, 2015). However, the adoption of a technique or management strategy must be justified by considering the impact on variable costs and the technical-economic benefits.

Silicon is cited in the literature as a beneficial element in unfavorable physical–chemical conditions (CURVELO et al., 2019; LOZANO et al., 2018; GALATI et al., 2015), such as water deficit in replacement conditions of 40% (60% water deficit) and 70% (30% water deficit), and its use is justified mainly in conditions of low water availability or high irrigation costs, acting on plant metabolism and compensating for production conditions. However, with the application of 150 kg ha $^{-1}$ Si, under a water replacement condition of 40% daily evapotranspiration, the financial increase was negative (Table 3), making its adoption in the production model unfeasible.

Table 3. Effects of silicon application (0, 50, 100 and 150 kg ha $^{-1}$) on the total cost of cauliflower production and percentage increase in economic return under each water replacement condition (40, 70 and 100% of ETc), Maringá-PR, 2019/2020.

Replacement*	**Yes**	**Participation in the final cost**	**Increase in financial return****
%	kg ha $^{-1}$	(%)	
40	0	0.00	0.00
	50	9.77	20.35
	100	17.99	2.94
	150	24.76	-94.17
70	0	0.00	0.00
	50	9.67	25.70
	100	17.63	47.02
	150	24:30	41.89
100	0	0.00	0.00
	50	9.35	0.04
	100	17.10	2.67
	150	23.63	11,13

*Water replacement according to ETc; **Increase based on the economic return in cultivation without silicon application (0 kg ha $^{-1}$) under the respective water replacement conditions.

The water replacement condition of 40% ETc with the application of 50 kg ha $^{-1}$ silicon provided the best potential for financial increase, whereas under 70% conditions, the best result was obtained through doses of 100 and 150 kg ha $^{-1,}$ and under the condition of 100% replacement of ETc, a dose of 150 kg ha $^{-1 \text{ was used}}$ (Table 3), with the use of silicon aiming at a productive increase in cauliflower under these conditions being viable.

Considering the high production costs of protected environment cultivation systems, according to the study data, it is necessary to increase the production area and adopt management techniques to maintain production viability, thus diluting costs and increasing resource efficiency. Furthermore, considering that investments in value-added crops are a trend among producers of *Brassica* species (MELO et al., 2017), the crop also offers conditions for maximizing returns and economic potential.

6 CONCLUSIONS

The economic results indicate that cauliflower production in a protected environment is economically viable in the northwestern region of Paraná.

With the exception of the water replacement condition of 40% ETc with the application of 150 kg ha $^{-1}$ Si, under the other cultivation conditions, there was an increase in the economic return due to the addition of silicon to cauliflower grown in a protected environment.

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