Economic profitability analysis of husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) under different silicon dioxide concentrations

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ABSTRACT

Objective: To evaluate the effect of different doses of foliar and soil silicon dioxide fertilization on the economic profitability of husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) cv. 'Querétaro' cultivation under plastic paddings and macro-tunnel conditions.

Design/methodology/approach: Ten treatments were evaluated at different concentrations of silicon dioxide fertilization on soil and foliar application: T1: Control treatment (T), T2: Fertilization with silicon dioxide 20, 40, 60 g on soil and 100, 150, and 200 ppm foliar (S20/100F), T3: S20/150F, T4: S20/200F, T5: S40/100F, T6: S40/150F, T7: S40/200F, T8: S60/100F, T9: S60/150F and T10: S60/200, distributed in random blocks. Economic profitability indicators such as Benefit/Cost ratio (B/C), Net Present Value (NPV), and Internal Rate of Return (IRR) were determined.

Results: The research established that the S60/150F treatment was the one with the highest economic profitability because it promoted the highest production per hectare, which was reflected in the NPV (MX\$ 336,932.97 pesos), the IRR (77.3%), and a B/C of MX\$ 1.16 pesos. Also, treatments S40/200F and S60/100F (where SiO_2 was applied) reported positive cash flow, unlike the T.

Limitations of the study/implications: With all research facilities closed due to the COVID-19 pandemic, no evidence related to the contribution of foliar and soil silicon bioassay has been verified.

Findings/conclusions: Using SiO_2 leads to a financial appreciable rebound of vital importance to be included in economic studies to facilitate the efficient management of the available capital to establish a crop whose field productivity is profitable for the producers.

Keywords: Benefit/Cost ratio (B/C), Net Present Value (NPV), Internal Rate of Return (IRR), yields.

INTRODUCTION

In 2019, husk tomato (*Physalis philadelphica*) production in Mexico was 834,274 t, out of which 160,771 t were produced in Sinaloa, 147,023 t in Zacatecas, and 88,637 t in Jalisco. These three states are where the highest national production was recorded (SIAP, 2020a), while in Veracruz 12,311 t were harvested with a yield of 15.525 t·ha^{-1} (SIAP, 2020b).

Among the main problems that restrict this crop's field productivity increase is the lack of improved varieties (Peña-Lomelí *et al.*, 2020), phytosanitary problems (Ayala-Armenta *et al.*, 2020), and inadequate agronomic management (López-Ramos *et al.*, 2020). Under protected agriculture conditions, there is greater control of environmental variables compared to open field agriculture conditions (Machorro, 2020). Silicon is a beneficial element for both, open field and greenhouse crops (Tubana *et al.*, 2016; Gómez-Merino *et al.*, 2020) improving growth, development, and production indicators (Asadpour *et al.*, 2020; Bukhari *et al.*, 2020; Shahzad *et al.*, 2021). Silicon is applied to optimize crops profitability beyond the net present value (NPV), payback period (PRI), internal rate of return (IRR), and cost structure, among others. This analysis provides an important point of reference and comparison to assess whether the management implemented for a crop provides adequate returns on the investment made, considering the involved risk (Cano *et al.*, 2013). From such analysis, it is possible to gain certain benefits from the project. The objective of this research was to evaluate the effect different doses of foliar and soil fertilization with silicon dioxide had on the economic profitability of husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) cv. 'Querétaro' cultivation under plastic paddings and macrotunnel conditions.

MATERIALS AND METHODS

Location of the experimental area

The research took place from February to June 2020 in a property near Xalapa, Veracruz state, Mexico, at the geographical coordinates 19° 33' 05.37" N, 96° 56' 40.64" W, and 1,428 m a.s.l. elevation.

The husk tomato crop was established with a drip irrigation system with plastic padding in a macro-tunnel. The production costs and yields of 10 treatments were evaluated and extrapolated to 1 ha, taking into account two production cycles per year. The seeds used were of the cv 'Querétaro' (Optimus Seeds), sown in 200-cavity unicel trays containing peat as substrate (COSMOPEAT®). Thirty days after sowing (DDS) the seedlings were transplanted to the field, placing them at a 0.4 m distance between plants and 1.2 m between rows, with a planting density of 20,833 plants. ha^{-1}. The technological package applied in its cultivation was the one recommended by AgroScience (AgroScience®, 2019).

Treatments and experimental design

Different doses of silicon dioxide (SiO_2) applied to the soil (g·plant^{-1}) and foliage (ppm) were evaluated. The doses applied in the soil were 0, 20, 40 and 60 g SiO_2 per plant, while the doses applied to the foliage were 100, 150, and 200 ppm SiO_2 per plant. There were 10 treatments in total, as described in Table 1.

The experimental design was a completely randomized block. The treatments were distributed in three blocks with 12 plants spaced every 40 cm, in a linear topological arrangement, with a total of 360 experimental units.

Economic profitability analysis

Production costs were classified into fixed and variable costs, and at the same time, fixed assets, deferred assets, and working capital were considered. Depreciation was calculated

Table 1. Silicon dioxide (SiO$_2$) treatments applied on soil (S) and foliage (F) in husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) in a microtunnel production system at Xalapa, Veracruz, Mexico.

Treatment	Application of SiO$_2$ to the soil (g plant^{-1})	Application of SiO$_2$ to the foliage (ppm)	Key to treatments
T1	0	0	T1 (S00/F00)
T2	20	100	T2 (S20/F100)
T3	20	150	T3 (S20/F150)
T4	20	200	T4 (S20/F200)
T5	40	100	T5 (S40/F100)
T6	40	150	T6 (S40/F150)
T7	40	200	T7 (S40/F200)
T8	60	100	T8 (S60/F100)
T9	60	150	T9 (S60/F150)
T10	60	200	T10 (S60/F200)

T1: Control (without silicon dioxide), T2: Application of 20 g of SiO$_2$ on soil and 100 ppm of SiO$_2$ sprayed on foliage, T3: Application of 20 g of SiO$_2$ on soil and 150 ppm of SiO$_2$ sprayed on foliage, T4: Application of 20 g of SiO$_2$ on soil and 200 ppm of SiO$_2$ sprayed on foliage, T5: Application of 40 g of SiO$_2$ on soil and 100 ppm of SiO$_2$ sprayed on foliage, T6: Application of 40 g of SiO$_2$ on soil and 150 ppm of SiO$_2$ sprayed on foliage, T7: Application of 40 g of SiO$_2$ on soil and 200 ppm of SiO$_2$ sprayed on foliage, T8: Application of 60 g of SiO$_2$ on soil and 100 ppm of SiO$_2$ sprayed on foliage, T9: Application of 60 g of SiO$_2$ on soil and 150 ppm of SiO$_2$ sprayed on foliage, T10. Application of 60 g of SiO$_2$ on soil and 200 ppm of SiO$_2$ sprayed on foliage.

using a linear method, yield and costs were projected to 1 ha area, calculating a five-year production period in the same area unit, based on this, the following indicators were estimated:

Cost/benefit ratio (C/B): this indicator allows valuing investments, considering economic, social and environmental aspects that are considered in the purely financial evaluation (Arévalo *et al.*, 2016). Net present value (NPV): This refers to the monetary value resulting from subtracting the sum of the discounted cash flows from the initial investment (Fajardo *et al.*, 2019). Internal rate of return or internal return rate (IRR): This is the rate that makes the NPV equal to zero (Fajardo *et al.*, 2019), knowing that this does not mean the non-existence of benefits, but that these are barely enough to cover the project's expectations (Mete, 2014). The above-mentioned indicators were determined with the Office software using the Excel program, based on the analysis of the costs of inputs that were used in the production, the generated income based on the yields per treatment, the rest of the production costs, and the depreciation of the assets.

RESULTS AND DISCUSSION

The highest yield (43.8 t·ha^{-1}) was achieved in the S60/150F treatment (T9), which is above the previously reported in 2019 for husk tomatoes (22.75 t·ha^{-1}) grown in irrigated systems (FIRA, 2020). Similarly, the remaining treatments exceeded both, the tonnage referred by the FIRA and that of plants without silicon dioxide (SiO$_2$) (T1, S00/F00) (Table 2).

Table 2. Yield per plant and unit area of husk tomato fruits (*Physalis ixocarpa* Brot. ex Hornem.) as a response to silicon dioxide (SiO_2) applications on soil (S) and the foliage (F) in a microtunnel production system at Xalapa, Veracruz, Mexico.

Treatment	Yield (kg plant^{-1})	Yield (t plant^{-1})
T1 (S00/F00)	0.558	15.5
T2 (S20/F100)	1.007	27.7
T3 (S20/F150)	1.474	40.9
T4 (S20/F200)	1.138	31.6
T5 (S40/F100)	0.971	26.9
T6 (S40/F150)	1.052	29.2
T7 (S40/F200)	1.365	37.9
T8 (S60/100)	1.522	42.2
T9 (S60/F150)	1.580	43.8
T10 (S60/F200)	1.184	32.8

T1: Control (without silicon dioxide), T2: Application of 20 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T3: Application of 20 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T4: Application of 20 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T5: Application of 40 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T6: Application of 40 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage; T7: Application of 40 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T8: Application of 60 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T9: Application of 60 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T10. Application of 60 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage.

The exogenous application of silicon improves plant performance due to its participation in regulating proteins related to photosynthesis, photosynthetic pigments, increasing nutrient uptake, and activating antioxidant defense systems in plant cells (Liu *et al.*, 2019; Abdelaal *et al.*, 2020). The basic total cost of production represents the total amount of fixed and variable costs that were required in each treatment and is not affected by costs derived from procurement, silicon application, or direct harvesting and packing costs. This variable includes costs that were the same for all treatments: MX $269,172.00 (Table 3).

Table 3. Variable and fixed costs of husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) cultivation in the control (T1) in a microtunnel production system at Xalapa, Veracruz, Mexico.

Variable Costs	Amount (MX$)	Fixed Costs	Amount (MX$)
Insecticides and fungicides	$28,188	Renta de terreno	$15,000
Fertilizers*	$49,684	Renta de tractor	$2,000
Herbicides	$1,400	Servicios	$26,700
Seedlings	$122,500		
Wooden box and plastic padding	$8,700		
Land workers	$15,000		
Temporary landworkers	$19,800		
Total costs	$245,272	Total costs	$43,700.00

* The cost changes depending on each treatment. Costs in Mexican pesos as of June 2020.

Table 4 shows the variation in costs depending on the silicon concentration of each treatment and the yield obtained in each one.

Labor represents the highest expenditure percentage in the costs of production, which, according to the SiO_2 applied dose, was around 33.07%, depending on each treatment's yield. This coincides with the results obtained in other assessments of the economic profitability, such as the one by Ayala *et al.* (2014) in amaranth (*Amaranthus* spp.) cultivation at the central region of Mexico, which influenced jobs generation and prevented migration.

Villa and Barrientos (2012) reported a costs production increase in creole potato (*Solanum tuberosum* Andigena group) crops per unit area due to manganese application, which increased yields and demanded more labor for harvesting and packaging, as well as the direct and indirect costs of using this micronutrient.

It is important to note that in this research, the use of silicon increased yields above the average reported for Veracruz by both SIAP (15.525 t·ha^{-1}) (SIAP, 2020b) and FIRA (22.75 t·ha^{-1}) (FIRA, 2020) (Table 2).

Assets costs were classified as fixed, variable, and working capital (Table 3). Regard the concept of fixed cost, Baca (2010) states that they are those done by the company and that in short term, or for certain production levels, do not depend on the production volume. The total cost of the assets was MX $57,042.00, with the irrigation system accounting for 70% of the total. All fixed assets were depreciated using the straight-line method with a useful life of five years, which is the estimated time of the project.

For the scale, a salvage value of MX$ 1,197.50 pesos was achieved, since its useful life is of 10 years, unlike the rest of the fixed assets whose useful life is equal to or less than five

Table 4. Costs increase by silicon dioxide (SiO_2) application per year of production in a hectare of husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) in the Control (T1) in a microtunnel production system at Xalapa, Veracruz, Mexico.

Treatments	SiO$_2$ (Cost)	Land workers	Wooden box
T1 (S00/F00)	$0.00	$19,800	$62,080
T2 (S20/F100)	$600	$35,400	$111,600
T3 (S20/F150)	$600	$40,500	$126,120
T4 (S20/F200)	$600	$40,500	$126,120
T5 (S40/F100)	$600	$33,900	$107,600
T6 (S40/F150)	$600	$33,200	$116,560
T7 (S40/F200)	$1,200	$48,000	$151,240
T8 (S60/100)	$1,200	$54,600	$171,960
T9 (S60/F150)	$1,200	$55,500	$175,040
T10 (S60/F200)	$1,200	$41700	$131,000

T1: Control (without silicon dioxide), T2: Application of 20 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T3: Application of 20 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T4: Application of 20 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T5: Application of 40 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T6: Application of 40 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T7: Application of 40 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T8: Application of 60 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T9: Application of 60 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T10. Application of 60 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage. Costs in Mexican pesos (MX$) as of June 2020.

years. Working capital was estimated at MX$ 173,294.67 pesos. The total income for the five years of the project was restated at a 20% rate, as shown in Table 5.

Also, for the project purposes, the selling price recorded by the producer was MX$ 9.00 pesos according to the fruit and vegetable marketing margins reported by the FIRA (2020) for peel tomato for October 2020, giving a total of MX$ 9,000.00 pesos per ton of fruit. Although the highest yield treatment, and therefore the one with the highest income was T9 (S60/150F), all treatments reported higher cash flows than that of the control.

The NPV of the treatment with the highest income (T9) was MX$ 336,932.97 pesos, which indicates the gains with regard to the initial investment amount (Table 5) at a discount rate of 20%. Thus, and according to this indicator criteria, the project is profitable, considering that an NPV of less than zero indicates that the project is not.

The economic IRR of a project is the discount rate that makes the present value of the stream of benefits equal to the present value of the stream of costs (Baca, 2010). Then, the IRR for this treatment was 77.3% and is acceptable since it is higher than the expected return rate (20%), so that during the useful life of the project, for each invested peso, a profit of 0.16 Mexican pesos will be obtained (B/C=MX$ 1.16), so that this treatment does not support a price lower than MX$ 8,000.00 pesos per ton of fruit.

Table 5 shows that treatments T9 and T8, where high doses of silicon (S60/150F and S60/100F) were used, positive cash flows are obtained. These results concur with those by Mejía and Lopez (2019), who indicate that by applying Si in high doses on King Grass texas-25 (*Pennisetum purpureum*), the gain is higher compared to the absolute control.

Table 5. Total updated income and expenses for each treatment projected to five years, and calculation of NPV, IRR and B/C in different treatments with silicon dioxide (SiO_2) in husk tomato (*Physalis ixocarpa* Brot. ex Hornem.) cultivation in a microtunnel production system at Xalapa, Veracruz, Mexico.

Treatments	Income ($)	Expenses ($)	Cash Flow ($)	Updated income ($)	Updated expenses ($)	NPV ($)	IRR (%)	B/C ($)
T1	1,436,646	2,493,476	2,493,476	856,670	1,554,573	−697,903.71	%[¥]	0.55
T2	2,582,443	2,867,811	285,368	1,540,092	1,784,655	−244,563.00	%[¥]	0.86
T3	2,918,235	2,979,565	−61,329	1,740,379	1,853,343	−112,964.32	−13.3	0.94
T4	2,918,235	2,979,565	61,329	1,740,379	1,853,343	−112,964.32	−13.3	0.94
T5	2,490,164	2,836,484	346,319	1,485,051	1,765,400	−280,348.57	%[¥]	0.84
T6	2,697,791	2,906,315	208,524	1,608,893	1,808,321	−199,428.44	%[¥]	0.89
T7	3,500,105	3,168,783	331,322	2,087,441	1,969,644	117,796.88	43.1	1.06
T8	3,979,443	3,324,395	655,047	2,373,347	2,065,290	308,057.25	73.2	1.15
T9	4,051,215	3,347,064	704,150	2,416,156	2,079,223	336,932.97	77.3	1.16
T10	3,036,147	3,018,753	17,394	1,810,708	1,877,429	−66,720.95	3.1	0.96

T1: Control (without silicon dioxide); T2: Application of 20 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T3: Application of 20 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T4: Application of 20 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T5: Application of 40 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T6: Application of 40 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T7: Application of 40 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage, T8: Application of 60 g of SiO_2 on soil and 100 ppm of SiO_2 sprayed on foliage, T9: Application of 60 g of SiO_2 on soil and 150 ppm of SiO_2 sprayed on foliage, T10. Application of 60 g of SiO_2 on soil and 200 ppm of SiO_2 sprayed on foliage.
Benefit / cost ratio (B/C); Net present value (NPV); Internal rate of return (IRR).
[¥]Project data without a return value. Costs in Mexican pesos (MX$) as of June 2020.

CONCLUSIONS

Product price and yield per hectare represent the main factors affecting the economic profitability of treatments applied to crops. In our research, the best treatment was T9 (S60/150F), reporting a higher cash flow than that of the control treatment. Also, because the present research only considered one price per kilogram of husk tomato, without considering quality variables that could contribute to the commercialization of the fruit of this Solanaceae in specific markets at higher prices, it is recommended to continue with the economic evaluation for several cycles, to corroborate the yield data per treatment and therefore compare the results obtained in the present results.

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