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Article

Cost-benefit of a protected cultivation system of tomato in San Quintín

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Abstract

This paper explains the benefits of implementing a protected cultivation system for farmers in the San Quintín Valley (Baja California, Mexico) engaged in the production of vegetables, particularly tomatoes. The importance of carrying out this research lies in the fact that the implementation of a protected cultivation system (greenhouse-shade mesh) increases production and improves the quality of tomato crops, while generating an important technological advance for the agricultural sector, allowing the obtaining of benefits for both: the farmer and the industry. The ideal sources of financing to carry out the system of this type of cultivation are also part of this writing. To this end, a methodology that involved the following two steps was developed: collection of theoretical information and data collection through a questionnaire applied to eight tomato-producing companies in the San Quintín Valley in 2020. The results infer that the majority opt for cultivation with shade mesh for the production of the products, but that in turn it is very difficult to obtain government resources. It is concluded that the shade mesh is the type of protected cultivation system with greater use, through which production can be increased and the quality of products can be improved, there are still limitations in the acquisition of government support, and it is for that reason that most use the capital of their company and the financing of a bank for its implementation.

Keywords:

protected cultivation, San Quintín, tomato.

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Introduction

Currently, a wide variety of modified environments are practiced in agriculture, among which greenhouses with or without environmental control with crops in hydroponic systems, inert substrates or in soil stand out, which represent an example of artificial ecosystems to develop intensive agriculture (López *et al*., 2011). According to the Agrifood and Fisheries Information Service (Servicio de Información Agroalimentaria y Pesquera, 2022), it is reported that, of the three production cycles of the year, tomato is one of the most important crops (mainly red tomato).

Due to adverse environmental conditions such as extreme temperatures, high rainfall, as well as diseases and pests, open-field tomato cultivation is increasingly difficult to carry out; so protected agriculture has become a necessity for farmers in order to turn the tomato harvest into a modern and competitive technology (Criollo and Limones, 2018).

In Mexico there are some regions with ideal natural conditions for the establishment of greenhouses, such as Sinaloa, Jalisco, Baja California, State of Mexico, Chihuahua, Sonora, Puebla, Michoacán, San Luis Potosí and Guanajuato, due to this, protected agriculture has developed in an accelerated way since it allows obtaining quality products for both national and export markets. In this way, the use of greenhouses, shade mesh and other protected agriculture systems are contributing widely to food production and the development of several agricultural areas of the country (SAGARPA, 2019).

Precisely, the protected agricultural area is that area in which the development of the crop is carried out under plastic covers, shade mesh or other material and in controlled environmental conditions (temperature, humidity, light, among other factors), classified into three concepts: shade mesh, high tunnel and greenhouse. Data from SAGARPA (2019) infer that in 2017 the agrifood sector had a considerable increase, being the largest increase registered in the last 20 years.

There are different definitions of the concept of protected agriculture. Santos *et al*. (2010) refers to that structure that is covered by transparent or semitransparent materials, which allows obtaining artificial microclimatic conditions for the cultivation of plants and flowers under optimal conditions. This specialized agricultural system is characterized by having a control of the edaphoclimatic environment, which allows altering the conditions of soil, temperature, solar radiation, wind, humidity, among others, which makes it possible to modify the natural environment in which the crops develop, which results in an adequate plant growth with high yields and a high quality of the products.

Thus, the horticultural industry is one of the most recognized in Mexico, covering 15 000 ha of cultivation, of which 70% are allocated to tomato cultivation (Soto *et al*., 2020). The state of Baja California is one of the places where red tomato is mostly grown, which has a participation of 15% of the state agricultural value with just over 3.094 billion pesos, covering a planted area of 2 830 ha. Red tomato is produced in the San Quintín Valley, in the city of Ensenada, since of the 220 847 t produced in Baja California, 99.6% are obtained from that valley, the rest is distributed in the other four municipalities: Mexicali, Rosarito, Tijuana and Tecate (FIRA, 2019).

Nevertheless, the main problem faced by farmers in Baja California is drought, where there are high indicators of humidity deficit, aridity and drought; on the other hand, winter storms also occur in the state, which limits the actions of the protected agriculture component (Moreno *et al*., 2011). Thus, considering the importance of the state of Baja California, but in particular the San Quintín Valley, for tomato cultivation in the face of climatic threats (droughts, high and low temperatures, and heavy rains), a growth opportunity has been detected for farmers through the acquisition of credits and government support for the purchase of protected cultivation systems.

In this sense, the following research questions arise: what is the cost-benefit of implementing a protected cultivation system for vegetable farmers in San Quintín? What are the ideal sources of financing to obtain a protected cultivation system? To answer these questions, the main objective

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of this research is to analyze the cost-benefit of the implementation of a protected cultivation system for tomato farmers in the San Quintín Valley, in Baja California (Mexico), since with this, it is intended to know the advantages of the implementation of protected cultivation and identify the different options of sources of financing and government support.

Protected cultivation

The first attempts at protected cultivation date back to the Roman Empire, a time with documented attempts at protected cultivation by using small mobile structures for the cultivation of cucumber by employing sheets of mica and alabaster as covering material. These methods ceased after the fall of the Roman Empire when the new precursors of greenhouses appeared in England, Holland, France, Japan and China (Wittwer and Castilla, 1995). The appearance of plastics was what caused an expansion of the area of greenhouses, mainly in Japan and China. In Europe, the introduction of plastics in greenhouses allowed the reduction of the cost of cultivating vegetables out of season (Castilla, 2007).

In Mexico, protected horticulture is still in extensive growth and development. From 1980, 300 ha with this production system were reported, and in 2008 around 10 000 ha. This production system has shown high growth in recent years, which has generated a large increase in planted area and improved its production processes, improved seeds, fertigation, computerized greenhouses and packing plants that guarantee product quality (López *et al*., 2011). According to the Secretariat of Agricultural Promotion (Secretaría de Fomento Agropecuario, 2015), the San Quintín Valley is an agricultural area that has had an unusual development in the last 15 years, becoming an area eminently exporting tomatoes and vegetables such as: tomato, cucumber, squash, cauliflower, broccoli and strawberry.

Here modern technology in terms of irrigation is used, with labor from states such as Oaxaca, Chiapas and Puebla. According to data from INEGI (2020), this area is located 190 km south of the city of Ensenada (Baja California), with an approximate population of 42 111 inhabitants, characterized by being a semidesert region with a Mediterranean climate, ideal for harvesting fruits and vegetables almost all year round. In the San Quintín Valley there are three types of cultivation: greenhouse, high tunnel and shade mesh, with tomato having the largest area planted in greenhouse and shade mesh, followed by blueberry and raspberry.

Protected cultivation is a specialized agricultural system in which some control of the environment is carried out, modifying or altering the conditions of soil, temperature, solar radiation, wind, humidity and atmospheric composition. Through these protection techniques, plants are cultivated, modifying their natural environment to prolong the harvesting period, increase yields and improve quality (Cih-Dzul *et al*., 2011). Thus, protected agriculture is carried out under well-built structures to avoid the restrictions that the environment imposes on the development of plants. A protected cultivation system involves placing a screen or protection next to plants, which alters the environmental conditions that partially or totally affect them.

Protected cultivation systems can be classified as: greenhouse, shade mesh, high tunnels and floating covers. The greenhouses and shade mesh are sufficiently high and wide to allow the cultivation of species of different height; high tunnels are those that allow the passage of a person inside and the cultivation of a certain height; and the floating covers are directly supported on the plants, without structure to support it (Castilla, 2007).

General objectives of protected agriculture (greenhouses and shade mesh)

A greenhouse is an agricultural construction with a translucent cover that simulates climatic conditions suitable for the growth and development of crop plants established inside. Greenhouses allow modifying and controlling more efficiently the main environmental factors involved in the growth and development of plant species (Ortega-Martínez *et al*., 2014). Greenhouses must be built with various materials specified by the Mexican Standards for the design of structures (NMX-E-255-CNCP-2008), which stipulates that these must be economical,

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light, resistant and slender materials, in such a way that they form bulky structures to avoid shadows on the plants, easy to maintain and conserve, modifiable and adaptable (López *et al*., 2011).

Greenhouses can be classified according to the technology they have: i) low technology, it totally depends on the environment as it uses simple technologies; ii) medium technology, they are modular or battery structures that are semi-climatized and can be in soil or hydroponics; and iii) high technology, they include facilities with automated, computerized and precision climate control, with CO_2 injection and with devices that operate irrigation and ventilation, as well as thermal screens for lighting and cultivation in substrates (Saynes *et al*., 2016).

On the other hand, shade mesh is used to reduce the amount of radiant energy that reaches the crops. Its function is to reduce the incidence of sunlight during the day and moderate the temperature during cold nights through the use of black or colored meshes, which shade from 30% to 50%. The meshes are not only used as a shading element but are also used in the windows of greenhouses with the aim of preventing the entry of insects and reducing the use of pesticides (Lugo-Sánchez *et al*., 2019). In addition, shade mesh prevents the heat and water stress of the crop, providing more favorable conditions for its development and productivity.

The meshes are fabrics of transparent threads of round monofilament, with a mesh size that prevents the passage of all types of insects (Santos *et al*., 2010). It is for this reason that the use of a protected cultivation system goes beyond a simple irrigation system, this type of mechanism provides protection to agriculture and crops against drought, in addition to other benefits such as: reduction of water needs, protection of crops in low temperatures, reduction of wind speed, it limits the impact of arid and desert climates, reduces damage from pests and predators, allows the extension of production and cultivation areas, increases the quality and preservation of resources, and optimizes climate control in favor of greater productivity (Ramírez-Vargas, 2019).

Government support plans and programs

The main government programs to support agriculture in Mexico are offered by the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA, for its acronym in Spanish) and the Secretariat of Agricultural Promotion (SFA, for its acronym in Spanish), which are institutions engaged in supporting micro, small, medium and large farmers who want to implement technology, agricultural machinery, added value to their products, among other concepts. For its part, SAGARPA (2019) offers programs for the promotion of agriculture in order to capitalize agricultural production, aimed at all those legally constituted natural and juridical persons who intend to acquire equipment or infrastructure, the programs it promotes are shown in (Table 1).

Table 1.Incentives from the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food for infrastructure and equipment.

Incentive concepts	Incentive amounts and maximum percentages
I) acquisition of vegetative material, infrastructure, equipment and machinery	Juridical persons: up to 50% of the value of the authorized concepts, without exceeding $4 500 000.00 (four million five hundred thousand pesos 00/100 NC). It does not apply to natural persons.
II) high tunnel	Up to $150 000.00 (one hundred and fifty thousand pesos 00/100 NC) per hectare. Natural persons: not exceeding 6 ha. Juridical persons: not exceeding 18 ha.
III) shade mesh	Up to $300 000.00 (three hundred thousand pesos 00/100 NC) per hectare. Natural persons:

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Incentive concepts	Incentive amounts and maximum percentages
	not exceeding 3 ha.Juridical persons: not exceeding 9 ha.
IV) anti-hail mesh	Up to $100 000.00 (one hundred thousand pesos 00/100 NC) per hectare. Natural persons: not exceeding 9 ha. Juridical persons: not exceeding 27 ha.
V) greenhouses	Up to $900 000.00 (nine hundred thousand pesos 00/100 NC) per hectare. Natural persons: not exceeding 1 ha. Juridical persons: not exceeding 3 ha.

SAGARPA (2019).

The Secretariat of Agricultural Promotion (Secretaría de Fomento Agropecuario, 2015) also offers support to protected agriculture, some oriented to the installation and equipment of greenhouses and shade mesh, as shown in Table 2. Among the main requirements that are requested are: concession title of the Comision Nacional del Agua (CONAGUA), planting permit, applications for infrastructure works and facilities, broken down budget, legal accreditation of the property, positive opinion regarding social security, among other requirements.

Table 2. Maximum amounts for protected agriculture, tractors and technification systems.

Concept	Maximum Amount
Tractors from 40 hp to 125 hp at the power take-off, certified by the Certification Agency for Agricultural Implements and Machinery	From 40 to 75 hp at the power take-off, without exceeding $150 000.00. Greater than 75 to 90 hp at the power take-off, without exceeding $175 000.00. Greater than 90 hp to 125 hp at the power take-off, without exceeding $200 000.00.
Tractors with less than 40 hp at the power take-off, validated by the responsible unit	Without exceeding $100 000.00 (one hundred thousand pesos 00/100 NC).
Technified irrigation systems	For technified irrigation systems, maximum amounts per hectare are applied, depending on the type of system, ranging from $10 000.00 pesos ha^{-1} for multi-gate irrigation systems and up to $17 000.00 pesos ha^{-1} for irrigation systems by sprinkler; left pivot, front advance, side roll, fixed sprinkler, portable sprinkler, gun and traveling gun (indicative and not limiting); by micro-sprinkler and drip.
Protected agriculture	For requests for support of protected agriculture, the maximum amounts of support per project will be: high tunnel up to $150 000.00 pesos ha^{-1}, shade mesh up to $300 000.00 pesos ha^{-1} and for greenhouses $500 000.00 pesos ha^{-1}.

SFOA (2015).

According to Lezama (2018), through the concurrence program, in 2017 just over 19 million pesos were applied in the Baja California Coastal Zone in support of agricultural and livestock producers. These funds also helped improve irrigation systems, strengthen protected agriculture with the use of shade mesh, acquire tractors and other machinery for the field. On the other hand, the Fideicomiso de Riesgo Compartido (FIRCO) has the task of redirecting its efforts in order to detonate agribusiness with incentives, as well as support rural companies and producer

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organizations, in addition to supporting productive activities for the benefit of the environment with social impact.

However, this agency does not have support for protected agriculture every year, its support varies from year to year (Secretaría de Fomento Agropecuario, 2015). There are other trusts instituted in relation to agriculture, these four public trusts having the character of entities of the Federal public administration, in which the Secretaria de Hacienda y Credito Publico (SHCP,) serves as a trust and the Bank of Mexico (BM, for its acronym in Spanish) as trustee, whose purpose is to facilitate access to credit through credit and discount operations, as well as the granting of credit guarantees to projects related to agriculture, livestock farming, poultry, agroindustry, fishing and other connected or related activities carried out in rural areas.

FIRCO is made up of: i) the Fund of Guarantee and Promotion for Agriculture, Livestock farming and Poultry; ii) the Special Fund for Agricultural Financing; iii) the Special Fund of Technical Assistance and Guarantee for Agricultural Credits; and iv) the Fund of Guarantee and Promotion for Fishing Activities. It is worth mentioning that FIRA (2019) also grants support for business training activities, technical assistance, consultancy, technology transfer and skills strengthening, with the purpose of improving the competitiveness and sustainability of rural companies.

Materials and methods

The methodological work consisted of two stages: i) the first began with the collection of bibliographic information regarding the implementation of a protected cultivation system and tomato production in Mexico, but particularly in the San Quintín Valley; ii) the second stage was oriented towards the collection of data through questionnaires, limiting the study to small and medium tomato producers under a protected cultivation system in the San Quintín Valley; and iii) the third stage consisted of the analysis of calculations and historical figures of a company engaged in protected agriculture, located in San Quintín (Baja California), which was taken as a case study to obtain the cost-benefit calculation and determine its profitability.

The questionnaires were applied in person to eight producers affiliated and registered in the register of producers and food products of Baja California of the Secretariat of Countryside and Food Security of 2020, being the total of the sample. It is worth mentioning that only five are registered, but for the convenience of the sample three more were added, which did not give consent to mention them in this work.

The questionnaire was structured in two sections: the first consisted of collecting information on the company in question, including aspects of main activity, type of company, size of the company, majority control, independent company or part of a group of partners, number of boxes produced during the last three years and age of the same. In the second section, the interviewees were asked to give their opinion on the implementation of a protected cultivation system and their possible forms of financing. Finally, the analysis of the data was done through the Excel software, which made it possible to obtain reliable and orderly information.

Results and discussion

Regarding the results of this research and considering all the producers surveyed, it was found that 87% are family companies engaged in agriculture, of which 56% have 11 to 20 ha of protected crops, 22% have 1 to 10 ha and 22% have 21 to 30 ha. It is important to mention that all the farmers used as a sample in this work currently have a protected cultivation system. In relation to the main crops that are grown under shade mesh systems, tomato is the most prevalent with 42%, followed by cucumber with 40%, in third position squash with 14% (planted from December to February due to cold weather), and finally peas with 4%.

As for the financing of the cost of the shade mesh, most respondents said that for each new shade mesh house acquired they used different ways of obtaining resources, so the results were determined considering the number of hectares and the form of purchase. In this sense, the

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results infer that 36% obtained it by paying a percentage with the company's capital and another percentage through bank credit, in 29% it was fully covered by the company; 14% with support from a client; that is, through the settlement of the purchase and sale of products (tomatoes, cucumbers, squashes and peas), another 14% by using a percentage of the company's capital, another percentage with government support and another from bank credit and finally, the remaining 7% used a percentage of the company's capital and another percentage of government support.

It is important to note that 86% of respondents have requested government support, but only 38% have been accepted for the farmer, the other 72% were rejected. In this sense, they were asked to assign a value from highest to lowest importance of the benefits of agriculture protected with shade mesh for tomato production, obtaining the following result: higher production volumes (33%), increased quality in production (27%), pest and disease control (19%), climate control (12%), reduction of use of water (7%) and others (2%).

It should be added that cucumber production was not the subject of study, but the total of respondents stated that the advantages are the same for both tomato and cucumber production, which is related to the study by López *et al*. (2011) in Mexico, which also highlights the importance of the use and employment of protected cultivation through greenhouses, shade mesh and high tunnel.

As for the results of the analysis of the figures of the agricultural company of the San Quintín Valley, it is necessary to mention that it had projected a profit of $3 000 000.00 for the acquisition of a shade mesh house with an area of approximately four hectares. In this order of ideas, considering the result of the calculation of the cost-benefit ratio, it is determined that it is a project that is feasible and necessary to be carried out. In this study it was found that: i) the cash flow indicator foresees that the company can meet its obligations without problem, since it showed a balance of $4 863 363.00 at the end of the cycle, the amount of monthly flow is higher than its minimum fixed cost needs; ii) the results of the annual flows showed a positive net present value of $21 621 090.00, which means that the project is a generator of dividends, this affects profitability, making the company grow; iii) the internal rate of return was 54%, which is higher than the minimum acceptable rate of return of 15%.

These indicators make the project viable. Consequently: iv) the utility/cost or cost/benefit ratio is 1:8 or otherwise called 1 to 8, this means that the company generates eight units for each unit invested; and v) regarding the economic break-even point, it is indicated that the company will be able to recover its costs when it reaches 13 148 boxes sold or also when its sales revenues reach$2 169 409.00.

Among other aspects, the implementation of the project will allow the company to expand the agricultural horizon, face competition, be part of technological innovation in terms of protected agriculture, since daily technified agriculture acquires a greater market given the conditions of quality and productivity that are handled both nationally and internationally. In this sense and taking into consideration Ro *et al*. (2021); Cih-Dzul *et al*. (2011), greenhouse tomatoes may be more profitable than other agronomic crops; that is, greenhouse tomatoes aim to achieve high yields per unit area, as well as excellent quality through climate and nutrition control.

Tomato is easier to grow compared to cucumber or lettuce, and yields can be very high. Worldwide, the demand for tomato is high because of its quality of consumption due to the nutrients and health benefits.

It should be mentioned that, according to Armendariz-Erives (2007), advances in agricultural activity have contributed to environmental degradation and in the next 30 years food needs will double, representing a great challenge to meet the demand of a greater population with less agricultural land and water. It is for this reason that the company can have breath of future success in terms of the development of protected agriculture, at the same time that technology reaches high levels that increase and improve the quality and production of both products and services offered, which is related to what Ramírez-Vargas (2019) affirms.

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The largest plantings are led by tomato crops through protected agriculture with about 89% of the area planted and the rest in the open field; it should also be noted that tomato crops grown around the world are vulnerable to various diseases and pest attacks and with it the losses caused by these insects, which is related to the study by Lugo-Sánchez *et al*. (2019) in the municipality of Sinaloa. Likewise, rescuing the affirmation by Ro *et al*. (2021) that the use of crops protected with shade mesh in greenhouses reduces the use of pesticides or pesticides, so this leads to the protection of crops in a sustainable manner and biological products free of these compounds, reducing the adverse impact on human health by consumers and the environment in general.

Conclusions

In conclusion, it is highlighted that the main benefits of the implementation of a protected cultivation system in the San Quintín Valley are that higher production volumes are obtained, and the quality of products is improved. Regarding the financing to obtain this protected cultivation system, it was found that most choose to use the capital of their company and the financing of a bank, and government support as another option; nevertheless, farmers find it difficult to access government support, in addition to the fact that they are very scarce, and the procedures are cumbersome.

One of the most relevant aspects when presenting a project is to structure the payment method well, so it is recommended that it be: 50% support from the government and 50% from the company, bank or financial support. Likewise, the implementation of a project for an agricultural company that grows tomatoes will allow it to broaden its horizon and face competition, adapt to modern production processes through a technified agriculture, being able to reach new consumer markets with higher quality products.

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