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Technology use and profitability analysis of the production system of tejocote (*Crataegus* spp.) in Sierra Nevada, Puebla

Núñez-Ramírez Ramón[1]; Jaramillo-Villanueva José Luis[1]; Carranza-Cerda Ignacio[1]; Barrera-Rodríguez Ariadna I.[1*]; Huerta de la Peña Arturo[2]

[1] Colegio de Postgraduados Campus Puebla, Puebla, México, C.P. 72760.
[2] Universidad Autónoma Chapingo. Chapingo, Estado de México, México, C.P. 56230.
* Correspondence: ariadna.barrera@gmail.com

ABSTRACT

Objective: The objective of this research was to analyze the use of agricultural technology and the profitability of the tejocote (*Crataegus* spp.) production system and its explanatory factors, in order to identify actions to increase the income of fruit growers.

Design/methodology/approach: Two patterns were used (producers who carry out good phytosanitary practices and producers who export). A stratified sample of 90 fruit growers was obtained, with 95% reliability and 10% accuracy. Subsequently, a survey was carried out and the profitability of tejocote production was calculated with the data. In addition, the explanatory factors of profitability were identified using a multiple regression model.

Results: Profitability, measured with the Benefit-Cost indicator, ranged from 0.13 to 2.38, and an average of 0.84. In the scenario of not accounting for family labor or depreciation of infrastructure, a Benefit-Cost Ratio from 0.35 to 6.37 is achieved, with an average of 1.90. The use of technology, measured by the technological index (TI) in the cultivation of tejocote was significant to improve profitability. The average profitability of the high TI stratum is different from the average profitability of the medium and low TI strata. In addition, the explanatory factors of profitability that were significant ($p \leq 0.05$) were technological index, phytosanitary control, training, schooling and size of the plantation.

Study limitations: Most producers do not keep a record of production activities and costs. Likewise, in the analysis of economic profitability it is difficult to assess indirect benefits, intangible benefits and externalities.

Findings/Conclusions: It was found that the tejocote activity is profitable for producers who use more technology and have a greater number of trees in production. The variables that most impact profitability were use of technology, phytosanitary control, size of the plantation, and training.

Keywords: Small-scale producers, production system, financial and economic profitability, benefit-cost ratio.

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INTRODUCTION

Tejocote (*Crataegus* spp.) (Rosaceae) is a native fruit from Mexico that belongs, subfamily of Pomoideae and genus *Crataegus*. Since pre-Hispanic times, tejocote has been used by different indigenous groups in Mexico, which collected their fruits. Then, trees of this type were planted in their gardens, and with the arrival of the Spanish, tejocotes were selected and planted in commercial orchards (Núñez *et al.*, 2012).

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In Mexico, the most important use is as fresh fruit primarily related with culture. For example, in the offerings of the "Todos Santos" festivity, and for use in "piñatas", punch, and tejocote liquor during December Posadas, since it contributes calories to the human body that are necessary due to low temperatures (Nieto *et al.*, 2008).

In Mexico there are 945.37 hectares planted with tejocote and 5,521.82 tons were harvested in 2019 with a production value of 1199.8 thousand USD. The average yield is 5.95 t ha^{-1} per hectare and the price was 217.29 USD per ton. In Puebla there are 897.6 hectares planted with tejocote and 5,336.94 tons were harvested in 2019 with a production value of 1132.91 thousand USD. The average yield is 6.04 tons per hectare and the price was 212.28 USD per ton (SIAP, 2019).

As can be seen from the above paragraph, 97% of the national production comes from Puebla. There are 29 producing municipalities and the following stand out because of their surface planted: Calpan (15%), Huejotzingo (13%), Chiautzingo (12%), Soltepec (9%), San Salvador El Verde (7%), Tlahuapan (7%) and Domingo Arenas (7%) (SIAP, 2019). During the year 2020, 990 tons of tejocote were exported to the United States of America (SAGARPA *et al.*, 2021). According to the National Service for Agrifood Health, Safety and Quality (Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria, SENASICA), out of the 10 exporting companies of tejocote, nine are found in Puebla.

From the data presented, it can be stated that Puebla is the main tejocote producer in the country, and that this fruit tree has high economic importance as a source of income for fruit producers in the state. However, there are several problems that families have to deal with, from the productive process to the commercialization of the product, such as: small farms with low technology, high production costs, and scarce resources to invest; adverse climate conditions such as drought, hail and frosts; pests and diseases; as well as low yields, low quality of the product, and unfavorable purchase prices (Núñez *et al.*, 2012).

Several studies have been conducted in tejocote which refer to pests such as fruit fly and fruit borer; also about morphological and phenotypical variability of trees and fruits; biochemical analyses and studies on physiology (López *et al.*, 2008; Nieto *et al.*, 2008; Muñiz, 2011; Núñez *et al.*, 2012; García *et al.*, 2013; Rosas *et al.*, 2017). However, despite these advances, the economic information of this production system is unknown, as well as the factors that influence profitability. Therefore, if the importance of this production system for the state of Puebla is considered, as well as the problems that producers face, it is necessary to carry out an analysis of financial and economic profitability of the tejocote production system, with the aim of identifying actions to increase the returns of producing families, primarily the poorest. Likewise, the hypothesis set out is that the tejocote production system is profitable from the economic and financial point of view. This study was justified because actions were identified through the economic analysis which contributes to a higher profitability for small-scale tejocote producers. Also, this study is relevant to the degree that it will contribute to the construction of strategies to improve the tejocote production system in the Sierra Nevada region of Puebla, Mexico.

MATERIALS AND METHODS

The study was conducted in the Sierra Nevada region in Valle de Puebla, in the municipalities of Huejotzingo, Calpan, Tlahuapan, Chiautzingo and San Salvador el Verde. The predominant climate is temperate sub-humid with summer rains, the average temperature varies between 12 and 16 °C, rainfall ranges from 600 to 800 mm/year, and the altitude between 2,000 and 2,300 masl (Gutiérrez *et al.*, 2003). In the study zone, livestock production and agriculture are important economic activities. Mixed production systems are found that involve fruit trees of temperate climate (including tejocote) and annual crops, primarily basic grains such as maize and bean (Mendoza *et al.*, 2010). Regarding the condition of poverty, the municipality of Huejotzingo presents between 50% and 75% of population in poverty. In contrast, Calpan, Tlahuapan and Chiautzingo have between 75% and 100% of their population in poverty (CONEVAL, 2021).

In the calculation of the sample of producers to interview, the database of producers that carry out good phytosanitary control practices was used, from the State Committee of Plant Health in the State of Puebla (*Comité Estatal de Sanidad Vegetal del Estado de Puebla*, CESAVEP) and the database of producers who exported tejocote from the National Service of Agrifood Health, Safety and Quality (SENASICA). In total, 414 different producers were quantified and based on this sampling universe, a simple probabilistic sample (random) was calculated, with reliability of 95%, accuracy of 10%, and considering maximum variance, a sample of 90 producers to be interviewed was obtained.

Profitability of the tejocote production system

The financial profitability of the production system was analyzed in this study. The financial evaluation assesses, through market prices, the direct benefits and costs of an investment project; that is, the return obtained by the private investor. For their part, the economic evaluation determines the benefits and costs produced by individuals who belong to a system, society or country, evaluating their investment resources at the prices that they really cost, under a perspective of shared welfare (FIRA, 2011).

Benefit - Cost Ratio Calculation (B/C)

The Benefit-Cost Ration was considered in the study, which calculates the present values for each of the years, both of updated costs (C) and updated benefits (V), and adding these they are divided using the following formula:

$$B/C = \frac{\sum_{i=0}^{n} \frac{B_i}{(1+i)^n}}{\sum_{i=0}^{n} \frac{C}{(1+i)^n}}$$

Where: B_i is the value of the benefits; $(1+i)^{n}$ is the updating factor; and C_i are the costs.

The result obtained in the previous operation indicates the profit obtained for each peso invested. If the B/C ratio is higher than 1, it means that the benefits exceed the costs and the greater the result, the benefits will be higher; for example, if the result was 1.5, it means that 1.5 pesos of benefits are obtained for each peso spent (Morales and Salinas, 2010).

The profitability was also analyzed considering the producers that use different levels of technology use, represented by the technological index (TI), measured in a scale of zero to one. The TI was constructed considering seven technological components applied to the crop, which are: number of productive assets, fertilization, producer's abilities, pruning, irrigation, pest control, and plantation density. The value of the technological index was obtained by adding the value of all the variables mentioned and then dividing the result by seven.

RESULTS AND DISCUSSION

The average age of the producers was 54 years and a schooling level of 7.3 years (secondary school). On average, they own 0.96 ha, 267 trees, have a production of 8.44 tons annually, a yield of 9.6 t ha^{-1} of tejocote, and average technology use index of 0.57 (Table 1). These characteristics indicate a type of small-scale fruit production of family type. The technological components with lowest values were irrigation (0.30) and pruning (0.31), then the use of machinery and equipment (0.56), fertilization (0.63), and pest control (0.71), and the highest was training of the producer (0.84).

The average profitability, represented by the Benefit-Cost Ratio was 0.84, and median of 0.82, with a minimum of 0.13 and maximum of 2.38. However, it is important to mention that 68% of the producers interviewed obtained a B/C ratio with a value of 1.0 or less (not profitable), due to the strong hail storms, drought, low market prices, and high annual costs from the depreciation of assets (machinery and infrastructure). These results are close to those reported in the technological package of the tejocote crop presented by Ríos (2018), who calculated a B/C ratio of 0.71.

Within the cost structure, the fixed costs represent 30% and the variables 70%, and within the latter, the workforce represented 56%. The establishment of the crop (preparation of the soil, fertilizer and workdays) had a cost, on average, of 842.85 USD (Table 2). Among the variable costs (consumables, irrigation, workforce, fuel and payment of services), and after

Table 1. Summary of sociodemographic and technological variables.

Variables	Number of observations	Media	Standard deviation	Minimum	Maximum
Age	90	53.53	12.43	21	85
Schooling (years)	90	7.26	4.03	0	16
Land (ha)	87	0.96	0.67	0.25	4
Number of trees	90	267	245.19	30	1300
Production (ton)	89	8.44	6.32	0.61	28
Yield (ton ha^{-1})	87	9.6	5.86	0.61	31.7
Technological index	90	0.58	0.1543	0.271	0.931

Table 2. Principal concepts of production costs of Tejocote (USD).

Cost component	N	Minimum	Maximum	Media	Standard deviation
Establising costs	90	125.05	3547.5	842.845	688.91
Depreciation	90	159.5	5400	491	1037.425
Fixed costs	90	308.9	5782.1	1283.03	1222.045
Labour cost	89	180	17598	1813.35	1267.505
Variable cost	90	215.35	40217	3146.9	4457.655
Total cost	90	524.25	45999.1	4429.95	2945.005
Sales income	90	258.75	46710	3727.565	5677.375

subtracting the fixed and variable costs from the income from the tejocote sales, returns were obtained from −7268.0 USD to 9604.3 USD. Therefore, there are production units that are having losses.

According to the National Council of Social Development Policy Evaluation (*Consejo Nacional de Evaluación de la Política de Desarrollo Social*, CONEVAL), the monthly value per person of the basic food basket and non-food rural basket of the month of July 2021 was 111.93 USD. Therefore, for most of the tejocote producers, the return obtained is not enough to satisfy family needs.

Benefit-Cost Ratio and returns obtained (without considering family workforce or expenditure from depreciation of high-value assets)

In a scenario where the costs for family workforce or depreciation of infrastructure were not considered, a B/C ratio was achieved from 0.35 to 6.37, an average of 1.90 and median of 1.73. Thus, 7.78% of the producers obtain a B/C ratio with value of 1.0 or less (non-profitable) and 92.22% a higher value at 1.0 (profitable).

Level of technology use and yields

The level of technology use in the tejocote production process is a factor that showed strong association with the level of profitability. The analysis of variance revealed that the level of technology use, represented by the "low" and "medium" technological index (TI), belongs to the same group, which means that the group of producers with "low" and "medium" TI have a tejocote mean yield (ton/ha) that is statistically equal. Instead, "low" TI and "high" TI have different means (Table 3). These results are similar to those reported by Vázquez *et al*. (2020) in a study carried out in Guerrero, Mexico, in lime cultivation.

Explicative factors of profitability

The explicative factors of the profitability of tejocote are shown in Table 4. Regarding the goodness of fit of the model, taking independent variables together, they explain 74% of the behavior of profitability of tejocote production. The values of the F(14.2) statistics reject the null hypothesis that the population value of R^2 is zero. Therefore, there is a significant linear relation ($p \leq 0.05$). Values of colinearity lower than 10 denote absence of correlation between explicative variables.

Table 4. Explicative factors of profitability of tejocote.

Variables	Coefficients	Typical error	t-value	Collineality
(Constante)	−0.185	0.259	−0.71	−0.71
Age	0.001	0.003	0.41	0.33
Training	0.431	0.137	3.14	3.15
Safety	0.573	0.165	3.47	3.47
Familiar labour	−0.107	0.126	−0.85	−0.85
Organization	0.141	0.08	1.75	1.76
Monetary transfers	−0.062	0.074	−0.84	−0.84
Technological index	0.795	0.242	3.29	3.29
Technical assistance	0.05	0.077	0.64	0.65
Schooling	0.299	0.142	1.97	2.11
Size of farm	0.249	0.124	1.6	2.01
R-squared/Adjusted		0.74-0.725		
F-value		14.2		
Durwin-Watson		2.08		

In order of importance, the technological index, phytosanitary control, training, schooling and size of the plantation are variables that are significant ($p \leq 0.05$) to explain the behavior of the profitability of the crop. The literature review performed did not result in any previous study that has studied the explicative factors of the profitability of this crop, so what was found in this study is discussed with what has been reported in the literature for other fruit trees.

The technological index represents the incorporation of the practices of management, nutrition and phytosanitary control to the crop. The positive and significant effect of the use of agricultural technology on the profitability of tejocote was also reported by Ma and Abdulai (2019) in a study on adoption of technology in apple growing in China, by Wambua *et al.* (2019) in a study about coffee in Kenya, and by Vásquez *et al.* (2020) in a study about lime in the state of Guerrero.

Schooling was reported as a variable associated to the incorporation of higher levels of technology, yields and profitability. In this regard, Xu *et al.* (2009) report that in a study conducted in Zambia, schooling had a positive effect on profitability. The size of the agriculture and livestock production units also has a positive effect on profitability, and therefore on the income of producers. This result refers to producers with more surface planted or higher number of producing trees who obtain higher profitability, by having lower unitary costs (Bravo-Monroy *et al.*, 2016).

CONCLUSIONS

The tejocote production system in the Sierra Nevada region of Puebla is profitable from the financial point of view for producers who use more technology and have a higher number of producing trees. The workforce represents the most important cost in the annual production process. Of all the workdays required, the activity of harvesting, selecting and packaging is the one that generates the highest cost. Therefore, it is important to increase the level of technology, primarily the investment in machinery and equipment for the application of agrichemicals, weed control, land preparation, and fruit selection, as well as the design of orchards with formation systems that keep trees that are small and with shapes that ease harvesting, since these actions significantly decrease the number of workdays used.

The use of technology is directly related to higher profitability. The mean of profitability in the strata with low and medium technological index belongs to the same group, while the stratum of producers with high and low TI has a significant difference in the mean. Finally, the explicative variables of profitability were technological index, phytosanitary control, training, schooling and plantation size. This is why these variables could be used in the design of a strategy that tends to improve the yields and the profitability of tejocote in the study region.

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