Article

Profitability of the production system integrated management of Mexican lemon in Copalillo, Guerrero

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Abstract

Using the Field Schools methodology, research was conducted to determine the financial efficiency of the integrated lemon management system (MIL) in semi-arid semi-warm climate (BS1hw), which allows higher income from productive activity of rural families compared to their initial situation. The work was carried out in Tlalcozotitlan, Copalillo, Guerrero, classified with a high index of poverty and lack of access to food. The diagnosis of the initial situation was obtained with the application of 30 questionnaires and the profitability of traditional technology was calculated, as well as a survey at the end of the study. School plots were established to evaluate the MIL system and modified integrated management (MIL-M), with recommendations, monitoring, evaluation and control of innovations made by the producer. The variables evaluated were degree of adoption of innovations, yield, production costs, income and B/C ratio. The results indicate a base yield of 2 t ha^{-1} with a production cost of \$3 650 ha^{-1}, gross income of \$14 285.71 ha^{-1}, with a B/C coefficient of 3.91. The MIL and MIL-M system obtained yields of 11.55 and 7.37 t ha^{-1}, with production costs of \$16 927.7 and \$14 106.35 ha^{-1}, gross income of \$134 640.00 and \$97 725.00, B/C coefficient of 7.95 and 6.93 respectively, which was associated with 88% degree of adoption of the innovations. The MIL system showed economic potential, offering farmers an opportunity to increase their income and making the activity more profitable.

Keywords: field schools, integrated management, poverty.

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Introduction

The national cultivated area of Mexican lemon (*Citrus aurantifolia*, Swingle) is 89 795 ha, the main producing states are: Michoacán, Colima, Guerrero and Oaxaca. National production is estimated at 1 120 972.55 t, the main use is fresh consumption, with Colima being the first producer. In Guerrero, approximately 6 723 ha are cultivated, with an annual production of 79 163.9 t, of which an average of 11.9 t ha^{-1} is obtained (SIAP, 2017).

The main cultivar is the Mexican lemon with thorns, where there are technological innovations such as pest and disease management, chemical fertilization, irrigation periods, rootstocks and some management of the production period during the winter, using conventional agrochemicals. However, Huanglongbing (HLB) disease caused by the bacterium (*Candidatus liberibacter* spp.) and spread by the insect *Diaphorina citri* Kuwayama has produced millions in losses to the country (Torres-Pacheco *et al*., 2013; Díaz-Padilla *et al*., 2014).

Given this scenario, the application of Integrated Management (IM) has been sought, which consists of rational and scheduled actions of pruning, nutrition, scheduled irrigation, induction of flowering, increased fruit mooring, management of pests and diseases, harvesting and post-harvest handling of the fruit, among others, which are based on the principles of physiology and biological cycle of the plant and its parasitic and beneficial organisms, its objective being the cultivation and economic solvency of the producer (Téliz, 2000; Noriega-Cantú *et al*., 2012).

Likewise, the search for new producing areas to those traditionally cultivated where there is better management of pests, diseases and agricultural management is applied. Food production must integrate social, economic, natural and ecological resources. With this agricultural perspective, the opportunities of the communities to sustainably use the resources (water, soil, climate, etc.) should be identified, promoting the use of technological and organizational innovations to strengthen production, attending to marketing and making substantial contributions to improvement of food availability and family income.

The town of Tlalcozotitlan, municipality of Copalillo, Guerrero, is a population with a high index of poverty and lack of access to food, where three climatic seasons are identified, the first from June to October, called the rainy season, where annual crops are established, some perennial trees and they have the best conditions of the year for production. The second period, from November to February, where there are thermal conditions for agricultural development and where there are some areas with availability of water for irrigation. The third period, from March-May, characterized by the presence of high temperatures that greatly limit the possibility of crops in open field conditions (Ruiz *et al*., 2013; SMN, 2018).

Faced with these conditions, farmers obtain their basic foods (corn, beans and squash) for food and the production of vegetables and fruits (Mexican lemon, among others) for sale in local and regional markets. This traditional production scheme, with reduced work surfaces, low yields per unit area, little appropriation of technological innovations, which are frequently generated in places with better soil conditions, humidity and availability of economic resources, as well as inadequate methods during the process of dissemination and adoption of technology.

Therefore, Morales *et al*. (2015) propose an educational model of field schools, where new technologies are implemented in combination with empirical knowledge, with the premise of Learning-Doing, which allows information, interest, acceptance and adoption of technologies. With this background, the objective of this work was to determine the financial efficiency of the integrated lemon management system (MIL), with the field school model, in a semi-arid semi-warm climate (BS1hw), which allows higher income from productive activity of the peasant families compared to their initial situation.

Materials and methods

The work was carried out in the town of Tlalcozotitlan, Mpio. from Copalillo Guerrero, in producer-promoter plots, located at 17° 52’ 47.13’’ north latitude and 99° 9’ 6.79’’ west longitude, at 580 m altitude, presents semi-arid semi-arid climate (BS1hw) (Garcia, 1988). The total population of the locality is 1 052 inhabitants, of which 482 men and 547 women. 99% of the population is indigenous, 84% of whom speak Nahuatl.

In Copalillo, the measurement of poverty in 2015 was 94.7%, in extreme poverty 62.2% and in moderate poverty 32.5%; in terms of lack of access to food, it was 25.7%. These data indicate that it is one of the poorest municipalities in the state (CONEVAL, 2019).

The diagnosis was made during the 2016-2017 production cycle and the implementation of the innovations were during the 2017-2018 and 2018-2019 cycles. The target population was 170 producers from the organization El Copalillo, SPR de RL de CV. In the first cycle, the diagnosis was made with 30 interviews with local farmers through surveys to find out, among others, the general data, agricultural production, production costs, family income and organization.

With this information, the traditional technology and base production were known, which allowed the elaboration of recommendations analyzed together with the producer, to propose some practices that increase the profitability of the orchards, these innovations were: use of a certified plant, dosage and form of application of fertilization balanced chemistry with the use of biofertilizers; flowering induction, health pruning, fruiting, training and rejuvenation and pest and disease management program.

The analyzes were carried out in four participatory workshops; through the methodology of Field Schools (Ruiz *et al*., 2012), with the intervention of producers, producers-promoters and professional service providers, the latter remained in his habitat for better communication, adapting to the cultural, technical space, economic and ecological of the producers, with the intention that the innovations are applied on time and effectively.

The degree of adoption of agronomic innovations or activities was obtained for each producer (Damian *et al*., 2015; Merino, 2018); through the survey applied at the end of the training. Firstly, each innovation was assigned a weighting factor according to ease of understanding and application, the values are presented in Table 1, where a value of 1.5 was assigned to the highly elaborated and complex activity for the producer and 0.5 to the simpler where the producer makes them easily. With which the degree of complexity by agronomic innovation with maximum value was determined.

Table 1. Agronomic innovations with weighting factors and maximum value.

Agronomic innovation (AI)	Weighting factor	Maximum value per AI (%)
Use of certified plant	1.5	20
Training pruning and rejuvenation	0.5	7
Pruning for healing and fruiting	1	13
Balanced chemical fertilization	1.5	20
Induction to flowering	1.5	20
Pest management	0.5	7
Disease management	1	13
Total	7.5	100

The effort and number of repetitions that the producer made to master (= adopt) the innovation was taken into account.

To obtain the degree of technology adoption for each of the innovations, an assessment was made based on the questionnaires, considering five basic questions and giving numerical value: a) If you knew the use of the innovation (yes= 2, no= 0); b) If you learned to apply the activity (yes= 6, little= 4, minimum= 2); c) If you applied the innovation in your garden (yes= 3, no= 2), d) If it has been useful (yes= 6, little= 4, minimum= 2); and e) If you will use what you have learned (yes= 3, no= 1). The average of the answers to each question was multiplied by the maximum value and divided by 100 to arrive at the adoption grade values (Damian *et al*., 2015; Merino, 2018).

The innovations were applied in two plantations of Mexican lemon (*C. aurantifolia*), grafted on Macrophylla (*Citrus macrophylla*, Wester), eight years old, with a distance between trees of 8 x 8 m and average density of 150 trees per ha, management was applied Mexican lemon (MIL) integrated with producer-promoter 'A' following the indications of the professional service provider, while producer 'B' used MIL-modified management (MIL-M) (Table 2).

Table 2. Application of products and doses per hectare of the integrated management system of Mexican lemon (MIL) in the school plots of Tlalcozotitlan, Copalillo, Guerrero. 2017-2019.

Activities	Application date	Specifications	Dose ha^{-1}
Soil fertilization	September, November, January, March and May	Phosphonitrate 31-4-0 (N, P, K) Monoammonium phosphate 12-61-0 (N, P, K) Ultrasol 13-6-40 (N, P, K)	100-50-50
Foliar fertilization	October and December	Chelates: Mg 1.0%; S 4.0%; boron 4%; Cu 0.04%; Fe 30%; Mg 3.0%; Mo 0.25%; Zn 0.005%	2 L
	September	Urea (46%)	4 kg
Pruning*	June and September		
Use of biofertilizers	September	*Glomus intraradices*, *Azospirillum brasilensis*	1.3 kg
Plague and illness management	May	Bordeaux pasta on the trunk	40 L
	June	Tribasic copper + elemental sulfur	500 g ai. 725 g ai.

Activities	Application date	Specifications	Dose ha^{-1}
	October	Mancozeb	800 g ai.
	November	Copper oxychloride + elemental sulfur	500 g ai.
			725 g ia.
	December	Copper oxychloride + elemental sulfur	500 g ai.
			725 g ai.

*= activity not carried out by Producer 'B' in the 2018-2019 cycle (MIL-M).

This management included: fertilization with the formula 100-50-50 divided into five applications in both cycles; foliar fertilizer, 2 L ha^{-1} of chelated micronutrients, with two sprays; periodic irrigation management, every 15 days during October to May, by dripping (producer A) and rolled irrigation (producer B), humidifying the tree's drip area with field capacity; Sanitation and production pruning's in September only producer 'A' carried out in both 2017-2019 cycles, pest and disease management with four applications of chemical fungicides and insecticides. The producer 'B' applied foliar fertilization to induce flowering in September and the producer 'A' started one and a half months late in the first cycle 2017-2018 and in the second cycle 2018-2019 it was in September.

To find out the pests and diseases present in both orchards, samplings were carried out during the crop cycle, five trees were randomly selected per orchard, four cardinal points were located in each tree, where the sampling for pests was carried out, with a brush moistened with alcohol, three to five mature leaves, new shoots and flower buds were scraped to determine the presence of pests. The captured individuals were deposited in plastic bottles of 100 ml capacity, with 30 ml of 70% alcohol.

For diseases, the plant material was placed in a cooler in the field and stored at 5 to 6 °C to be processed in the laboratory, the affected parts were cut into 2 mm pieces, the surface was disinfected with sodium hypochlorite at 1 % for 30 s and rinsed in three successive changes of sterile distilled water, seeded in potato-dextrose-agar (PDA) culture medium and incubated for six days at 26 °C. Subcultures were obtained from growing colonies to proceed to identify them.

In the comparative-descriptive analyzes, proportions and arithmetic means were used (Briones 2002). The variables evaluated were yield, production costs, income, the B/C ratio and percentage of adoption of innovations. The harvest was carried out on the fruits with physiological maturity, when they were $\geq$ 31 mm in diameter, smooth peel, intense green color and juice content $\geq$ 45% (SAGARPA, 2001).

To measure the profitability of the MIL technology of producer-promoter 'A' and producer 'B', contrasted with traditional technology, yield was evaluated, by weekly cuts during the period from November 2017 to January 2019, accounting for the weight of the fruit (t ha^{-1}), in this same period the production costs were calculated by applying the MIL and MIL-M with the participating producers. The economic indicators: profit per sale of the crop, production costs and the benefit-cost ratio (B/C) to know if what the producer-promoters are investing in the MIL and MIL-M system has generated profits in monetary terms.

The income analysis considered the parameters described above and the sale price was determined according to the prevailing supply and demand conditions in the Chilapa and Iguala markets, considering the seasonality of the lemon in the state of Guerrero and the reported price variation at the Toluca Supply Center. Figure 1 shows the production percentage assigned by SIAP (2017) to each month for the state of Guerrero, where the highest production occurs from July to December and the lowest production from January to June.

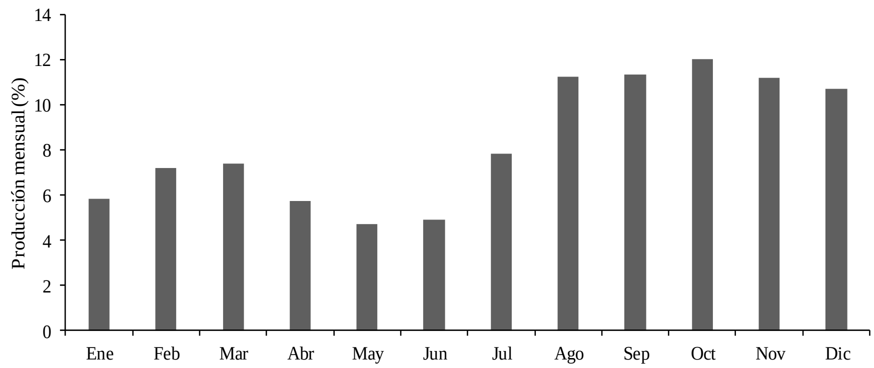

Figure 1. Seasonality of Mexican lemon production for the state of Guerrero. SIAP 2017.

Figure 2 shows the price variation of the last three years in the market closest to Guerrero and where this information is available; The best prices are obtained at the beginning of the year, when there is little supply of lemon and the lowest prices from May to July with a slight rebound in November-December 2017 (SIIM, 2019).

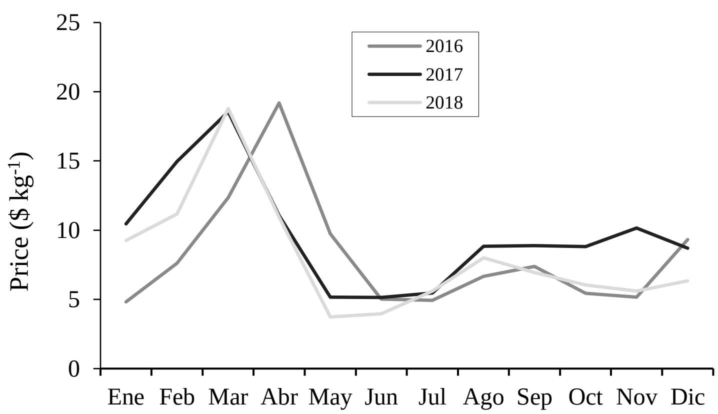

Figure 2. Price fluctuation in pesos per kg of lemon with seed without first quality classification. Toluca supply center. SIIM 2019.

Results and discussion

From the information obtained during the survey, it was determined that 23 Mexican lemon producers cultivate an average of 1 ha, with a variation between 0.25 to 2 ha. And only two producers have orchards in production, with the application of traditional technology, where the yield reported in surveys of 2 t ha^{-1} in the 2016-2017 production cycle was estimated, 83% lower than the state average (SIAP, 2017) At a production cost of $3 650 per ha, the fruit was harvested during May. They apply fertilizers (ammonium sulfate and diammonium phosphosphate) as a source of nitrogen and phosphorus to nourish the trees; they use herbicides (glyphosate) to control weeds; insecticides (imidacloprid) for pest control (black aphid (*Toxoptera citricida* Kirkaldy.), leaf miner (*Phyllocnistis citrella* Station), red spider (*Panonychus citri* McGregor), diaphorins (*Diaphorina citri* Kuwayama.) and whitefly (*Dialeurodes citrifolii* Morgan) and they do not control diseases (gomosis (*Phytopthora parasitica* Dastur) and anthracnose (*Colletotrichum acutatum* Simmonds), without a defined program, only following the recommendations made by the people who sell them the products, indiscriminately applying insecticides during the anthesis.

Producers do not apply fungicides and if contact and systemic pesticides to control pests detected in orchards and do not control diseases. The rest of the farmers have certified Mexican lemon plants in vegetative growth. All respondents belong to a producer organization called El Copalito, SPR de RL de CV.

The degree of adoption of innovations observed was 88%, which meant that of the seven innovations proposed to producers, only two (using a certified plant and training pruning) knew them fully, learned how to use them, applied them in their garden, it has been useful and will continue to be applied. Table 3 shows that in balanced chemical fertilization the degree of adoption was 95%, so only few producers have not benefited them.

Table 3. Degree of adoption of the agronomic innovations implemented in Mexican lemon in the town of Tlalcozotitlan, Copalillo.

Agronomic innovation	Score obtained from the five basic questions			Adoption degree (%)
	Average	Maximum	Minimum	
Use of certified plant	20	20	18	100
Training pruning and rejuvenation	7	7	5	100
Pruning for healing and fruiting	11	13	9	85
Balanced chemical fertilization	19	20	14	95
Induction to flowering	13	20	9	65
Pest management	6	7	5	86
Disease management	11	13	10	85
Total				88

Survey applied to 30 producers.

Pest management, disease management and production and sanitary pruning, with 86, 85 and 85% degree of adoption respectively, some producers did not learn to apply it and see little benefit. In induction to flowering, with a low average rating of 13 points out of the 20 maximums and 65% degree of adoption, it is necessary to reinforce this agronomic innovation, so that most producers apply it in their garden and see the benefit of harvesting lemon out of season, where demand is higher and income increases for families in poverty.

The yield result for the two types of garden management during the two cycles is shown in Table 4, where producer 'B' started the harvest in November to December in 2017 and continued from January to December 2018, with accumulated production of 7.37 t ha^{-1}, with gross annual income of $97 725.00. While the producer-promoter 'A', the harvest was carried out from February to June 2018, it continued in November to December and January 2019, with accumulated production of 11.55 t ha^{-1} and with gross annual income of $134 640.00.

Table 4. Analysis of the gross annual income for the producer-promoter 'A' and producer 'B' with handling of Mexican lemon in the school-plots of Tlalcozotitlan, Copalillo.

Year	Month	Price (monthly t^{-1})	Integrated management of Mexican lemon 'A'		Integrated management of modified Mexican lemon 'B'	
			monthly production (t)	monthly income	monthly production (t)	monthly income
2017	November	$14 285.71	0	$0.00	0.63	$9 000.00
	December	$14 285.71	0	$0.00	0.7	$10 000.00
2018	January	$17 142.86	0	$0.00	0.84	$14 400.00
	February	$17 142.86	0.28	$4 800.00	0.98	$16 800.00
	March	$17 142.86	1.96	$33 600.00	1.05	$18 000.00
	April	$14 285.71	2.52	$36 000.00	1.05	$15 000.00
	may	$7 142.86	2.66	$19 000.00	1.05	$7 500.00
	June	$5 714.29	0.35	$2 000.00	0.16	$900.00
	July	$5 714.29	0	$0.00	0.16	$900.00
	August	$4 285.71	0	$0.00	0.16	$675.00
	September	$4 285.71	0	$0.00	0.14	$600.00
	October	$5 714.29	0	$0.00	0.14	$800.00
	November	$10 000.00	0.21	$2 100.00	0.16	$1 575.00
	December	$10 000.00	1.89	$18 900.00	0.16	$1 575.00
2019	January	$10 857.14	1.68	$18 240.00	0	$0.00
Annual yield			11.55		7.37	
Gross annual income				$134640.00		$97 725.00

Prices in national currency.

Regarding fruit yield, in an area where the climate is semi-arid (BS1hw), the level was slightly lower (11.55 t ha^{-1}), compared to the state yield (11.99 t ha^{-1}), with the main area of production in sub-humid warm climate (Aw1), where there are better conditions during the year for production. However, the degree of deterioration of the plantations due to the lack of adequate care in their development. However, it was important to observe the response to production during the winter and the lower incidence of pests and diseases of these plantations and the possibility of increasing the yield and consequently a better B/C ratio.

The diagnosis detected that the producers did not harvest lemon in winter. The proposed management allowed producers to harvest 74% of the production from November to April, during the lowest supply of fruit in the state and reach the best sales prices from January to March, with an average value of $17.4 kg^{-1}, while the lowest prices were from May to October at $5.48 on average.

In the economic evaluation of the two technologies, the factor of labor involved in harvesting and crop management activities was not taken into account, because the higher the demand for this resource increases and the cost of production increases, preventing more objective analysis, in addition to the fact that the workforce is provided by the family unit and has its own land for production.

In this scenario, producers with traditional technology in the 2016-2017 cycle had a gross income of $14 285.71 ha^{-1}, with a B/C coefficient of 3.91 and a production cost of $3 650.00 (Table 5). While producer-promoter 'A' in the 2017-2019 cycle applying MIL technology, his gross income was $134 640.00 ha^{-1}, with a B/C coefficient of 7.95 and production cost of $16 927.70 and producer 'B' that the MIL-M modified its gross income was $97 725.00 per ha, with B/C of 6.93 and production cost of $14 106.35 ha^{-1}.

Table 5. Financial analysis of integrated management (MIL), modified integrated management (MIL-M) and traditional technology (MT) in the production of Mexican lemon. Tlalcozotitlan, Copalillo, Guerrero.

Package	Yield (t ha^{-1})	Production cost per hectare^{z}	Harvest sale (value in $)	Ratio B/C^{y}
MIL 'A' (cycles 2017-2019)	11.55	$16 927.70	$134 640.00	7.95
MIL-M 'B' (cycles 2017-2018)	7.37	$14 106.35	$97 725.00	6.93
Traditional (cycles 2016-2017)	2	$3 650.00	$14 285.71	3.91

^{Z}= includes input costs for nutrition, weed management, pest and disease management; ^{Y}B/C ratio= sales product/cost of production.

MIL technology applied in a timely manner was more profitable than the producer's technology. Despite the fact that the cost of the production process per hectare with the MIL system was $16 927.70 pesos, while the low cost of production with traditional technology is 78% less than the proposed technology. Both producers applied integrated management (MIL); however, only producer 'B' modified it, by not performing sanitation and production pruning. The results of two years of harvest suggest that in the semi-arid climate conditions of Tlalcozotitlan, Copalillo, tree pruning plays an important role in obtaining greater yield.

However, this requirement is not yet well studied in Mexican lemon, but preliminary observations seem to indicate that pruning is necessary to keep the streets of the orchard open (Medina-Urrutia *et al*., 2004). So also in Pakistan Ahmad *et al*. (2006), studied the effect of pruning on the yield and quality of Kinnow tangerines, concluded that pruning helps to control the size of the tree and is also the best method to obtain the maximum yield, quality and orange-red color of tangerine fruits.

The recommendation of integrated management is based on the economic benefit, increased production, availability in the market and ease of application. This allows peasant families in Tlalcozotitlan to increase income and reduce poverty levels, this situation is consistent with what was reported by Ramírez *et al*. (2013), who demonstrated that production systems aimed at perennial crops, except for the case of coffee, allow rural inhabitants to improve their living standards by reducing the level of marginalization.

Also, Ruiz *et al*. (2012) showed that the adoption and adaptation or rejection of the components of the milpa technology interspersed in fruit trees, determined an increase in the yield of corn and obtaining economic income for the Mixe peasant family in Oaxaca, contributing to the development of producer capacities, evidencing that the results do not determine that the conception of this innovation is total by the producers, that finally they decide to innovate and/or reject, based on the experience obtained and by the sociocultural and economic structure of the farmer.

Conclusions

The innovations with the highest degree of adoption were the use of a certified plant, training, production and sanitary pruning, balanced fertilization, as well as pest and disease management. Flowering induction was more difficult to adopt.

The MIL technological package proposed and developed by INIFAP, for the municipality of Copalillo in the town of Tlalcozotitlan, has the potential to boost the sector and increase its income, making its activity more profitable.

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