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Remote monitoring of training and technology-transfer services in vanilla cultivation (*Vanilla planifolia* Jackson ex Andrews)

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ABSTRACT

Objective: to remotely monitor training and technology-transfer services (called "extensionism" in Mexico) using the Chapingo-AGROPEC Star© advisory and consultancy model to promote the development of vanilla small-scale agribusiness.

Design/Methodology/Approach: the study was implemented in Puebla and Veracruz, Mexico, with the participation of 81 producers and five advisors. The *ad hoc* designed digital platform AGROPEC Star© was used, which consists of assembled software tools for monitoring agribusiness management and advisory process. Advisors (agricultural extensionists) received training in both productive management, and the use of the software. Agricultural extensionists, in turn, provided technical assistance and training to the producers.

Results: data were collected from 40.68 hectares, with yields ranging from 50 to 300 kg ha^{-1}. The activities in technology-transfer included ground layering (51.85%), compost application (43.21%), pollination (38.27%), and weed control (37.04%).

Limitations/Implications of the study: in Mexico, vanilla is traditionally cultivated without technology, on small plots, where all the crop cultivation activities are done by the producers. Although productivity is low, it has potential.

Findings/Conclusions: digital monitoring with the advisory management platform enabled to verify those activities that agricultural extensionists and producers performed. Also, it allowed us the generation of indicators, and the identification of opportunities to improve vanilla crop productivity.

Keywords: advisory technicians, producers, agribusiness, training, technology-transfer services, agricultural extensionists.

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INTRODUCTION

Vanilla is a tropical terrestrial orchid with a climbing habit, which grows in the form of a vine. To produce its fruit, each flower must be individually pollinated. Due to the decline in the bee population that used to perform this task, producers are now responsible for manual pollination to obtain each fruit (a pod), so achieving production. Vanilla is a species that fetches a very high market value, with a current price of approximately 12 000 MXN pesos per kg of processed vanilla (Menchaca, 2018).

It is an aromatic product originating in Mexico and one of those with the highest demand in the soft drink and food industries. Between 2003 and 2016, vanilla production almost doubled, reaching a total of 512 tons (megagrams, Mg) in 2016. This was due to a 71.07% increase in the national average yield during that period. Of the 1059 hectares (ha) planted in 2016, 38.55% was managed mechanically, and 57.82% had technology applied to plant health. Of the 54.23% of the land planted with this crop, the cuttings were planted by producers with technical assistance; and 99% of production was established under rainfed conditions. Potential production for 2024 was estimated at 703 Mg, with an estimated export volume of 151 Mg (SAGARPA, 2017).

The cultivation and production of vanilla in the country have been historically linked to the Totonac indigenous region. For this reason, understanding and analysis of the behavior of this orchid would be incomplete without first establishing a profile of what this indigenous region still is (ASERCA, 2002). To do this, sociocultural and economic characteristics should be noted above all. In this region producers maintain plantations with little or no profitability, and in many cases the explanation lies in the producer's confidence that the price of green vanilla will increase, as occurred in 2004, when the price was $400 MXN per kg of green pod (Barrera-Rodríguez *et al.*, 2011).

Producers are distinctively characterized because they had small areas dedicated to vanilla cultivation, ranging from a quarter to a half hectare, with low yields of green vanilla. There are four different production systems. In acahual (traditional, on secondary succession wild populations, in disturbed areas), under the shade of pichoco (*Eritrina* sp.), orange tree (*Citrus sinensis* L. Osbeck), or shade cloth (at 50% light). Each of those shows a specific level of technical development, and use of traditional knowledge in crop management (Damirón, 2004).

In 2017, the national record of yield was 0.54 Mg per hectare (Mg ha^{-1}). Whereas it was 0.25 Mg ha^{-1} in the municipality of San José Acateno (Puebla), and 0.6 Mg ha^{-1} in Papantla (Veracruz) (SIAP, 2017). This variability is explained by the cyclical nature of production, which depends on crop renewal and management practices, as well as on physical and climate factors (precipitation, temperature, and humidity in that region). In addition to traditional production systems and some technical aspects such as the type of support used, whether or not there was premature fruit drop, poor nutrition, presence of pests and diseases. Finally, yield is affected by high production costs due to manual pollination (Elorza *et al.*, 2007; Coro, 2009).

A recent approach to production analysis is developed through information and communications technology, which facilitates the exchange of information, the monitoring and comprehensive evaluation of various processes, and the management of training, human resources, and materials, among other important aspects. Together, this represents a valuable tool for the process known as Agricultural extension, that is, the formal and operational procedure for extending knowledge and transferring technology in order to be understandable to farmers and producers (Hernández and Santillán, 2021; Mariscal *et al.*, 2023).

Due to the importance of vanilla cultivation for the Mexican economy and the problems faced by producers in the Totonac region in vanilla management, the objective of the study was to monitor online the advisory and training process for technicians and producers, through the Chapingo AGROPEC Star© advisory and consulting platform, designed *ad hoc* to advise and manage vanilla small-scale agribusinesses.

MATERIALS AND METHODS

Monitoring and analysis were conducted with 81 vanilla producers from the municipalities of San José Acateno (Puebla), Hueytamalco (Puebla), and Papantla (Veracruz) from November 2015 to July 2016. Five agricultural extensionists participated, they were selected based on their professional training, experience in vanilla cultivation, and knowledge of the lands in the study area. These technology advisors received training in the use of the digital platform and in the cultivation techniques for vanilla production.

Online monitoring was implemented through the Chapingo-AGROPEC Star© advisory and consulting platform (Mariscal and Estrella, 2008; Estrella and Mariscal, 2020) which consisted of assembled tools of information technology and communication within a specialized digital platform, an original interface developed to provide this systematic services (Agropec Star©, 2000; Figure 1). The interface records the technical and cost management implemented during the vanilla production process; as well as, the training for agricultural extensionists and producers to provide subsequent monitoring. It also includes geolocation data, in Google Maps format, for the small-scale agribusiness participating.

The agricultural extensionists provided advice and training to producers to improve their capacities (capacity building) to implement technological innovations that would allow improving the productive development of a network in the value chain (Red

Figure 1. The Chapingo-AGROPEC Star© digital platform with a specialized interface for online monitoring of the agricultural extension effort in value chains. Select the specific network for vanilla cultivation (*Vanilla planifolia* Jackson ex Andrews) in the "Red Vainilla" option at the Main menu.

Vainilla). Scheduled activities were monitored in the field and online, as well as the diagnosis and performance of the small-scale agribusinesses, according to the production process in question. In this regard, emphasis is placed on the maximum usefulness of online monitoring, as it proved to be targeted, dynamic and cost-effective.

RESULTS AND DISCUSSION

The systematic and updated information records of this project can be consulted at https://www.agropecstar.com/proyectos/38# Query type, as a registered user, choose from the main menu, the option for Vanilla network ("Red Vainilla").

The inclusion of 81 small-scale agribusinesses was achieved, reaching a total of 40.68 ha dedicated to vanilla cultivation (Table 1). The average production area per producer was 0.50 ha, which coincides with the results of Damirón (2004) and Barrera *et al.* (2009), who indicated plot sizes of 0.25 to 0.5 ha for producers in the Totonacapan region, which includes several municipalities in the Mexican states of Puebla and Veracruz.

The geolocation coordinate pairs (UTM) that delimit the edges at the Cardinal directions of the area of influence of the evaluated small-scale agribusiness are (to the North) 20.29617 N, −97.26039 W; (to the South) 20.00720 N, −97.26213 W; (to the East) 20.09670 N, −97.17213 W; and (to the West) 20.16488 N, −97.42673 W. The specific coordinates of each agribusiness can be viewed on the cartography of the digital-monitoring system interface.

Ninety percent of producers are over 60 years old, with a maximum education level of three years in elementary school. Vanilla production is a secondary source of income; they do so solely out of tradition or because they inherited the land with the crop. Yields range from 50 to 300 kg of green pods per hectare. Fifty percent of producers are natives, from the Totonac Indigenous people.

Farmers do manually the flower fertilization for the orchid reproduction, from mid-February to the end of April. Furthermore, in many cases, replanting is not implemented, which is why the plant density per hectare is low. Sanitary control is scarce and sometimes nonexistent. Weed removal is done manually by the producer himself. Pest and disease control is not implemented. Leaf litter and decomposing wood are used as natural fertilizer, and commercial inorganic fertilizers are not applied.

Table 1. Small-scale agribusinesses and surface area (hectares, ha) evaluated by agricultural extensionists in the remote monitoring of Vanilla cultivation.

Extensionist's name	Agribusiness (No.)	Area (ha)
Alfredo Rodríguez Moreno	20	13.93
Eduardo Orlando Sánchez Días	20	10.04
Benjamín Torres Espejel	1	0.25
José Luis Pérez Hernández	20	7.81
Liliana Lucas Brito	20	8.65
Total	81	40.68

Training

Producers received training as workshops in five production disciplines. Marketing; Business Organizational Development; Soil Fertility; Pest and Disease Management; and Crop Management. These workshops were held at 27 events in different towns to facilitate the travel of participants. The workshops were attended not only by the 81 farmers participating in the study, but also by other producers interested in vanilla cultivation. As a result, a total of 313 attendees were gathered (Table 2). This represented almost four-folded (3.86 times) the expected attendance; it indicates the need to implement more training workshops, involving all producers in the region who are dedicated to (or interested in) vanilla production.

These workshops were conducted in response to the problems identified in the diagnostic assessment. Emphasis was placed on capacity building among producers and the need to adopt the proposed technology to improve production processes (Figure 2). Current production systems are characterized by a low level of technological development. Overall, this is due to the use of traditional crop management, where vanilla cultivars are established in wild plant populations of secondary succession called "acahuales." In these populations, planting densities are estimated to be low, as it is the area covered. Host plants (phorophytes) vary and are selected based on the tree species already present on the site, in particular farmers use non-introduced trees (*i.e.*, native species).

In general, there is no pest and disease control program, and when it is implemented, it is not done at the right time. Because of this, the incidence of diseased vanilla plants is high, so that in many cases only 10% of the plants produce flowers. Production does not occur until the fourth year and not in the third as it should. Furthermore, productivity is low and the plants are not very vigorous; most of the time, a plant produces only once and tends to die, which coincides with what was reported by ASERCA (2002), Barrera *et al.* (2009), and Rocha *et al.* (2018).

Evidence of technology transfer

As a result of agriculture extension services, training, and capacity building provided to producers, coupled with participants' interest in improving the vanilla production process, several technologies were indeed transferred, including ground layering (42 producers), compost application (35 producers), pollination (31 farms), and weed control (30 producers).

Table 2. Training workshops provided to participating farmers and other producers interested in vanilla cultivation.

Workhsop	Events (No.)	Attendees (No.)
Crop management	6	64
Pest and disease management	7	81
Soil fertility	5	71
Commercialization	4	42
Organizational development of enterprises	5	55
TOTAL	27	313

Figure 2. Workshops provided to producers. A: vanilla marketing strategies; B: soil fertility, preparation of Bocashi organic fertilizer; C: pest and disease control, preparation of bioinsecticides and biofungicides; D: manual pollination; E: general crop management; F: pest and disease monitoring; and G: compost application.

Other activities adopted to a lesser extent were production estimation, flowering record, pruning, and irrigation, which also had an impact on the existing traditional production system (Table 3).

Labors and activities that were implemented, as well as the transferred innovations based on this study, favored the following aspects in vanilla cultivation.

Reactivation of the vanilla production process. Vanilla production continued despite the adverse conditions present over time. Producers never abandoned the system; rather, knowledge extension and technology transfer efforts encouraged producers to

Table 3. Technologies transferred and implemented by the vanilla producers evaluated in this study.

Tasks	Producers recording the task	
	(No.)	(%)
Layering vines	42	51.85
Applying compost manually	35	43.21
Manual pollination	31	38.27
Manual weed control	30	37.04
Guiding vines	28	34.57
Making planting basins	25	30.86
Manual pesticide application	20	24.59
Manual harvesting	17	20.99
Pest monitoring	16	19.75
Manual herbicide application	14	17.28
Plant losses	12	14.81
Estimating harvest	11	13.58
Measuring flowering	6	7.41
Irrigation	6	7.41
Pruning	5	6.17
Pruning support tree	4	4.94
Manual shade regulation	3	3.70
Planting	2	2.47
Sanitizing support tree	1	1.23
De-capping	1	1.23
Manual fertilizer application	1	1.23
Replacing support tree	1	1.23
Plant sanitation	1	1.23
Removing diseased fruits	1	1.23

reactivate production on each of the host trees they rely on to establish a vanilla plant. Producers' interest persists, even though vanilla cultivation is not their primary source of income.

Acquisition and establishment of cuttings. An average of 25 vanilla plants was established per producer using their own resources, without the support of any government program or agency, thereby increasing planting density.

Preparation and use of organic fertilizer. This practice was implemented and Bocashi fertilizer was produced. It was applied to a portion of each producer's plantation. For Bocashi preparation available resources were used and materials from the same plot or location, such as banana stems, composted sawdust, decomposing tree branches and trunks, and other materials.

Preparation of bioinsecticides and biofungicides. Bordeaux mixture and sulfocalcium mixture were prepared as alternative products to prevent major vanilla pests and diseases.

Irrigation. Some producers already had irrigation systems for other crops; therefore, they were suggested to irrigate their vanilla crop to improve its yield. Irrigation was successfully applied by 7.41% of producers, primarily in the municipality of Papantla, Veracruz.

Organizational principles. The foundations were established for collective work to begin. In the case of producers in Puebla, for the possibility of joining the legally constituted group "Vanilla Producers of San José Acateno SPR de RL," which would allow them to share the benefits of a consolidated group.

There are other innovations that could not be transferred or implemented because the study period was short. Among those are the establishment of "mother orchards" to generate high genetic quality germplasm, plantation renewal, increased planting densities, application of commercial fertilizers, use of modern production systems (such as shade cloth). Also, construction of facilities to process the product, intensive production systems using orange trees as host plants, and ongoing technical advice. Some authors such as Hernández (2014), Vargas and Gámez (2014), Rocha *et al.* (2018) and Santillán *et al.* (2018) conducted evaluations of these technologies in vanilla cultivation and reported encouraging results focused on improving the production process, increasing the number of plants per hectare, comprehensive crop management, pest and disease control, plantation renewal, and producers' organization.

Chapingo-AGROPEC Star© digital agricultural innovation platform was transferred as technology. The adoption of the digital innovation platform by the agricultural extensionists enabled remote, updated and online monitoring of the agricultural extension and technology assimilation processes.

It was found that most producers who restart this activity do so with little or no profitability, since they hope for an improvement in the price of green vanilla, which is the most common way this product is sold (Jaramillo *et al.*, 2012; FND, 2017). Thus, increasing yields per hectare, planted area, and improving structure in land-use can positively change the competitiveness of vanilla as an agricultural product.

The effects of these variables are not definitive explanations for the sector's growth, but they do constitute a link in the search for the causes and variables that determine the competitiveness of this production system. Since it is in the planted area where soil preparation and planting efforts are noticed, which in turn impact yields. As well as do innovations in the implementation of production techniques, and the effects of better management practices (Cruz *et al.*, 2013; Santillán *et al.*, 2018).

Production costs

Due to the physiological cycle of vanilla cultivation, production and harvest stages occur only once a year; harvest is done in December. Unfortunately, the period covered by this research did not coincide with the harvest season, then, it was not possible to account for any changes in productivity factors and profitability for the production cycle evaluated. However, with 49.38% of the producers studied, we got records of the production costs summed up to July 31, 2016. It was observed that 90% of them had a cost per hectare between $1060 and $1900 MXN, and only 5% recorded expenses exceeding $2320 MXN (Table 4).

Table 4. Ranking of expenditures observed in producers who recorded this indicator.

Stratum ($, MXN)	Agribusinesses	
	No.	(%)
Less than 1,060	15	37.50
Between 1,060 and 1,480	16	40.00
Between 1,480 and 1,900	5	12.50
Between 1,900 and 2,320	2	5.00
More than 2,320	2	5.00
Total	40	100.00

These costs, which are not for the complete production cycle, are very low compared to those reported by other authors. As reference, Vargas and Gámez (2014) reported production costs of vanilla up to $25 000 MXN in the traditional system (“acahual”). Barrera-Rodríguez *et al.* (2011) mentioned a cost of $23 MXN kg^{-1} of vanilla produced in a system with orange trees as host plants, which means a cost per hectare of $23 000 MXN with an average yield of 912 (kg ha^{-1}) which is obtained under this production system.

Santillán *et al.* (2018) indicated that vanilla crop yields are extremely variable, because they depend on the age of the plant, planting density, cultivation method (traditional or technical), source of moisture (rainfed or irrigation), soil characteristics, climate of the planting site, and crop management by the producer. However, according to the review by Rodríguez *et al.* (2023), the most efficient producers are those who begin to take into account the income derived from the crop and, those are the ones that produce vanilla with citrus as hosts, and under shade cloth.

Consequently, a remote monitoring platform contributes to technology transfer activities and capacity building in production systems. In the case of this study, it was pertinent to improve vanilla cultivation in at least some of the summarized aspects. Moreover, we consider vitally important to plan, incentivize, and rescue vanilla cultivation in Mexico through the design and implementation of public agrifood policies. Vanilla is a product native to our country that could become profitable enough for improving producers' household incomes. Otherwise, Mexican vanilla production could decline rapidly in the medium term (Luis *et al.*, 2020).

CONCLUSIONS

Through the Chapingo-AGROPEC Star© interface, online monitoring of the agricultural extension process was achieved for small-scale agribusiness producing vanilla. It was verified that vanilla is grown traditionally on small plots, and all the crop management is done by the producers and their family. In spite of the technological practices transferred and the use of innovation in production monitoring and records to improve crop management, farm lands productivity is still low.

Because there is potential to increase production, it is recommended that producers be provided with advice and training to improve technical crop management and increase production efficiency. The recommendation is to continue recording information of the production process through the specialized digital interface, as there are areas of opportunity that, with proper attention, can improve the productivity and profitability of Mexican vanilla cultivation.

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