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Article

Productivity of vanilla (*Vanilla planifolia* Jacks. ex Andrews) in Mexico from 2003 to 2014

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Abstract:

The production of vanilla (*Vanilla planifolia*) in Mexico has decreased as a result of a scarce application of technological packages adapted to the edaphoclimatic conditions of the crop. To test this hypothesis, an analysis of productivity was carried out from 2003 to 2014 at the international level, through means tests of Tukey, and at the national level with the model of decomposition of factors of production growth proposed by the Food and Agriculture Organization of the United Nations. Results showed that in the study period, Mexico did not increase its export of vanilla internationally due to the low sown area that was destined to the crop. In the national context for the period 2009-2014 compared to 2003-2008 there was an increase in production of 2.5 % in response to field yields (2.0 %). This was registered by 14 of the 52 municipalities involved, which presented a 1.6 % increase in the planted area and 1.8 % in the field, which contrasts with the drop in production (-0.1 %) of the remaining 38 municipalities, which came from a reduction in the cultivated area (-2.3 %). These results indicate that despite the good field yields obtained from 2009-2014, the country has not been able to increase its productivity at the international level, mainly due to the scarce surface planted and the lack of technology transfer to boost the development of the sector.

Key words: Productivity, crop yields, profitability, cultivation area, technology transference, *Vanilla planifolia* Jacks. ex Andrews.

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Introduction

The agricultural sector is a fundamental pillar in the economy and development of Mexico. However, it is becoming less competitive due to the growing import of food that limits the capacity of production and distribution in the national market (Ayala *et al*., 2011). The public policies that were undertaken since the 1980s have not promoted agricultural competitiveness in a sustainable manner; consequently, it has had to depend on purchases abroad (Gómez, 2008), which has created unfavorable conditions for some systems, particularly those of local production such as vanilla (Barrera *et al.,* 2011) of which Mexico is considered the center of origin (Lubinsky *et al.,* 2008). Despite this distinction, Salazar (2011) explains that low productivity at the national level is attributed to problems such as price instability, the effects of climate change and the scarce technological development faced by domestic producers, which prevents increase of the sown areas.

Historically, Mexico has ranked as the fifth producer of vanilla internationally with 4.97 %, after Indonesia (34.93 %), Madagascar (31.81 %), China (11.63 %) and Papua New Guinea (6.97 %); and before Uganda (2.90 %), Turkey (2.58 %), Tonga (2.08 %) and other countries such as Guadeloupe, Zimbabwe, Kenya, Malawi, Réunion, French Polynesia and Comoros that, as a group, represent 2.14 %. Regarding field yields (t ha^{-1}), Mexico (0.41) is only higher than China (0.60), ahead of Papua New Guinea (0.32), Indonesia (0.22) and Madagascar (0.04) which base their productivity on the extensive sown area that adds 94.36 % of the world total (FAOSTAT, 2017).

Commercial vanilla plantations in Mexico have an average life of 6 years; the first three are aimed to vegetative development and the other three to production (Kelso-Bucio *et al.,* 2012). At a national level, *Veracruz* is the main producer with

70 %, followed by *Oaxaca* and *Puebla*, which together contribute with around 29 % of the total production and, in smaller quantities, also by *San Luis Potosí*, *Hidalgo*, *Chiapas* and *Quintana Roo* (SIAP, 2017).

Most of the vanilla sold in the country is green, due to the low-tech production conditions and the poor organization of producers (FND, 2017). Whoever harvests the plant does not give it a fermentation and drying treatment that accentuates the flavor and aroma, and thereby limits its income; therefore, he cannot enter directly into the food, beverages, pharmacy, cosmetics, tobacco and handicrafts markets. Thus, the doors to international markets such as the United States of America, France, Germany and Japan, the main consumers of the world, are closed (Velázquez- Montes de Oca *et al.,* 2014).

The cultivation of vanilla is important because it has a social and economic impact on rural communities, as well as being part of the national culture and wealth (Salazar, 2011). Most of the producers that maintain the plantations do so with little or no profitability, and in many cases the explanation lies in the confidence that the value in green will increase. However, the fall in prices and the national market scheme that rewards the dealers more, has caused those who grow vanilla to migrate to other agricultural activities that ensure the sustenance of their families, thereby compromising the competitiveness of the sector (Jaramillo *et al.,* 2012).

Vanilla competitiveness analysis has been addressed by several authors. Jaramillo *et al.* (2012) estimated the profitability and competitiveness of two vanilla beneficiation systems through the matrix of policy analysis. Barrera *et al.* (2011), on the other hand, analyzed the profitability and competitiveness of two systems of vanilla production from a macroeconomic perspective. These studies focus on comparisons between production processes and their results show a competitive behavior for a given process. However, they do not examine competitiveness in the context of production growth. In this regard, Cruz *et al.* (2013) consider that the competitiveness of an agricultural product can change positively by varying the yields per hectare, the area planted and the structure of land use; they assure that the effects of these variables are not final explanations of the growth of the sector,

but they do constitute a link in the search for the causes and variables that condition the competitiveness of the product.

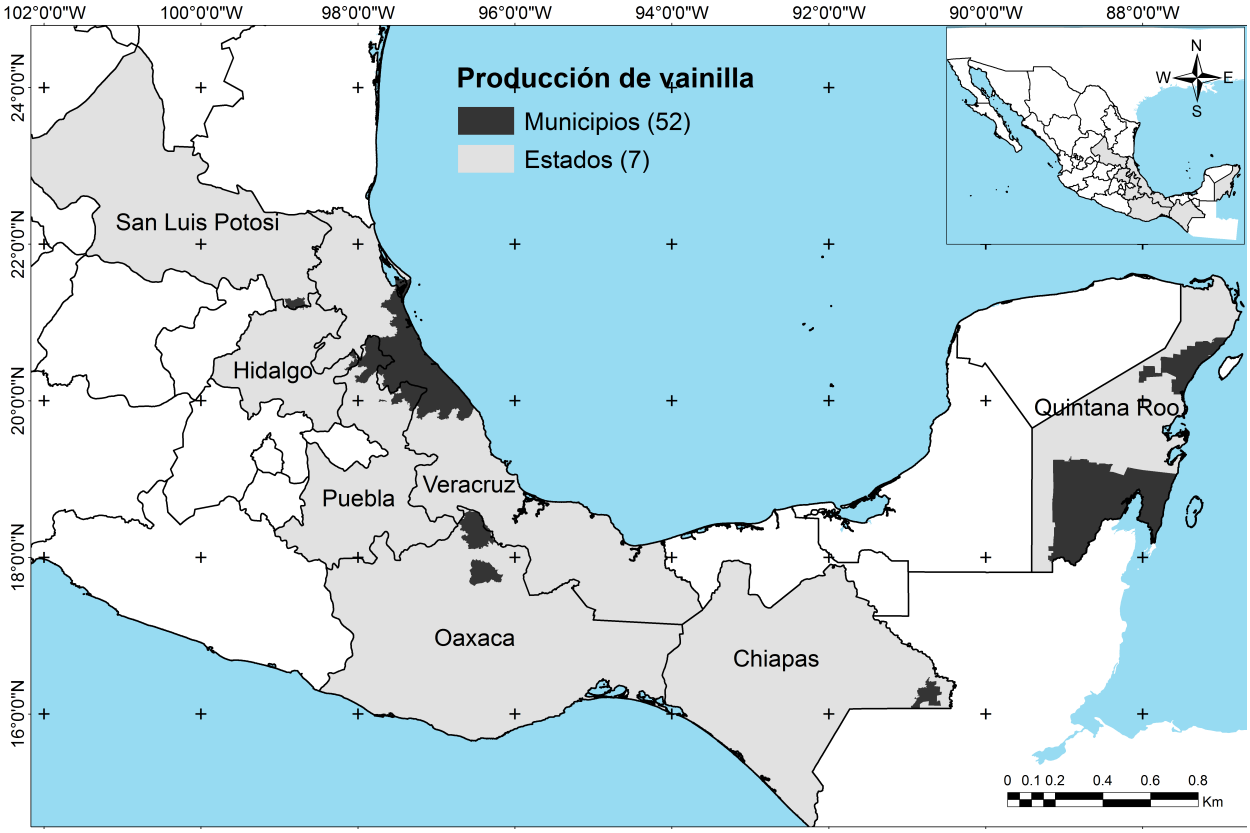
According to Gómez (1994), the analysis of agricultural production helps to understand the competitiveness of the crop in question, because it refers to the interaction of the area sown with the yields in the field. On the planted surface the tasks of preparation of the soil and sowing are manifested, and in the yields the current modalities in the application of the production techniques and the management practices used.

In this context, the objectives of this study consisted in analyzing the productivity of green vanilla in Mexico from the national and international production from 2003 to 2014 to identify the factor (area sown or yield in the field) that conditions the growth and to know the situation the sector faces.

Materials and Methods

The study area

Vanilla (*Vanilla planifolia* Jacks. ex Andrews) is an orchid native to the rainforests of southeastern Mexico and Central America (Bello *et al*., 2015). Due to the characteristics of the crop, it grows in subtropical, warm and humid climates, at altitudes below 600 m, although plants have been found up to 1 100 m, with temperatures from 20 °C to 32 °C, average annual rainfall between 2 000 at 3 000 mm; for optimum growth it requires 50 % shade, and up to 70 % in dry seasons to conserve soil and air moisture. It grows in land with excellent drainage, rich in humus and pH from 6 to 7 (Hernández, 2011). In Mexico, the production of vanilla has been recorded in 52 municipalities (Figure 1), which are located in the states of *Chiapas* (1), *Hidalgo* (1), *Oaxaca* (7), *Puebla* (11), *Quintana Roo* (3), *San Luis Potosí* (2) and *Veracruz* (27) (SIAP, 2017).



Producción de vainilla = Vanilla production; *Municipios* = Municipalities; *Estados* = States

Figure 1. Location of vanilla-producing municipalities (*Vanilla planifolia* Jack. ex Andrews) in Mexico from 2003 to 2014.

International productivity of the vanilla sector

From the Food and Agriculture Organization of the United Nations (FAO) data were obtained on production (t), planted area (ha) and field yields (t ha^{-1}) of the main vanilla producing countries for the 2003-2014 period (FAOSTAT, 2017). Through an analysis of variance and Tukey's means tests, significant differences were established for each of the variables by country, and by means of the application of the methodology proposed by Santillán *et al.* (2014), the type of production system (intensive or extensive) was determined.

National productivity of the vanilla sector

From the Agricultural and Fisheries Information System (SIAP, 2017) variables were obtained: yield in the field (t ha^{-1}), area sown (ha) and production (t) of the municipalities that registered continuous operations from 2003 to 2014. Such period was divided into two stages: the first from 2003 to 2008 and the second from 2009 to 2014, as the renewal cycles of the plantations last around six years (Kelso-Bucio *et al.,* 2012).

To analyze the productivity of vanilla we used the decomposition model of growth factors of production (Gómez, 1994), the model has been used effectively in different investigations (Cruz *et al*., 2013, Santillán *et al*., 2014; Schwentesius and Sangerman, 2014) and precisely determines the influence of the yields in the field and the sown area, as well as their interaction in the growth of production in a base period (2003-2008) with respect to a final period (2009-2014).

The sown area, the yield in the field and the interaction (area planted - yield in field) in percentage, were plotted to calculate the growth of the vanilla production at the municipal level, if it is extensive or intensive and which of the factors explains said growth. The municipalities were classified according to the typology established by Santillán *et al.* (2014), in which different combinations are made to know those in which production increases and in which it decreases.

Finally, to identify some of the factors that explain the changes in the planted area and the field performance at the municipal level, specialists in the production of vanilla from the *Universidad Autónoma Chapingo* (Autonomous University of Chapingo) and the *Colegio de Postgraduados* (Graduate Studies College) were interviewed, as well as producers and representatives of the *Comité Sistema Producto de Puebla y Veracruz* (Product System Committee of Puebla and Veracruz). The interview guide considered phytosanitary, climatic, social and market aspects.

Results and Discussion

International productivity of the vanilla sector

According to Tukey's means test, Indonesia and Madagascar, the main vanilla producing countries in the world, base their production on an extensive system, which compensates for the low yields in the field. The success of Indonesia and Madagascar is based on the comparative advantages associated with favorable natural factors. It is driven by the low opportunity cost of internal production factors such as labor, land and capital (Hernández *et al.,* 2010). However, they cannot be considered competitive, because according to Porter (1991) a competitive advantage is based on the ability to transform labor, land and capital into differentiated goods and services, which increases efficiency in order to increase profit. Gómez (1994) postulates that intensive systems tend to be more competitive by making production techniques and management practices more efficient, which according to Ormerod (1997) stimulates economies of scale and improves competitiveness.

On the other hand, Mexico presented the second best yields in the field, but its production is reduced by the low area sown for cultivation (Table 1). Barrera *et al*. (2011), Jaramillo *et al.* (2012 and 2013) agree that the problem of competitiveness of the national vanilla sector is more a problem of differentiation, since most of the vanilla sold in the country is green, which reduces direct purchase prices to the producer, and causes an abandonment of the sector, which explains the reduction in the area sown. They also agree that although yields in the field are acceptable, there is a wide margin for improvement that, together with an increase in the harvested area and a marketing scheme with niche markets, would substantially improve international productivity.

Table 1. Significant differences by Tukey in the production factors of the main vanilla producing countries for the 2003-2014 period.

Country	Surface area (ha, %)	Yield (t ha^{-1})	Production (t, %)	System
Madagascar	65 222 (77.01) a	0.04 d	2555.8 (31.81) a	Extensive
Indonesia	12 964 (15.31) b	0.22 c	2806.6 (34.93) a	Extensive
China	1 905 (2.25) c	0.60 a	934.4 (11.63) b	Intensive
Papua Nueva Guinea	1 725 (2.04) c	0.32 bc	559.7 (6.97) b	Intensive
Mexico	965 (1.14) d	0.41 b	399.5 (4.97) c	Intensive
Others[1]	191 (2.25)	0.31	77.9 (9.69)	
Total	84 691 (100)		8035 (100)	
R^2	0.89	0.61	0.78	

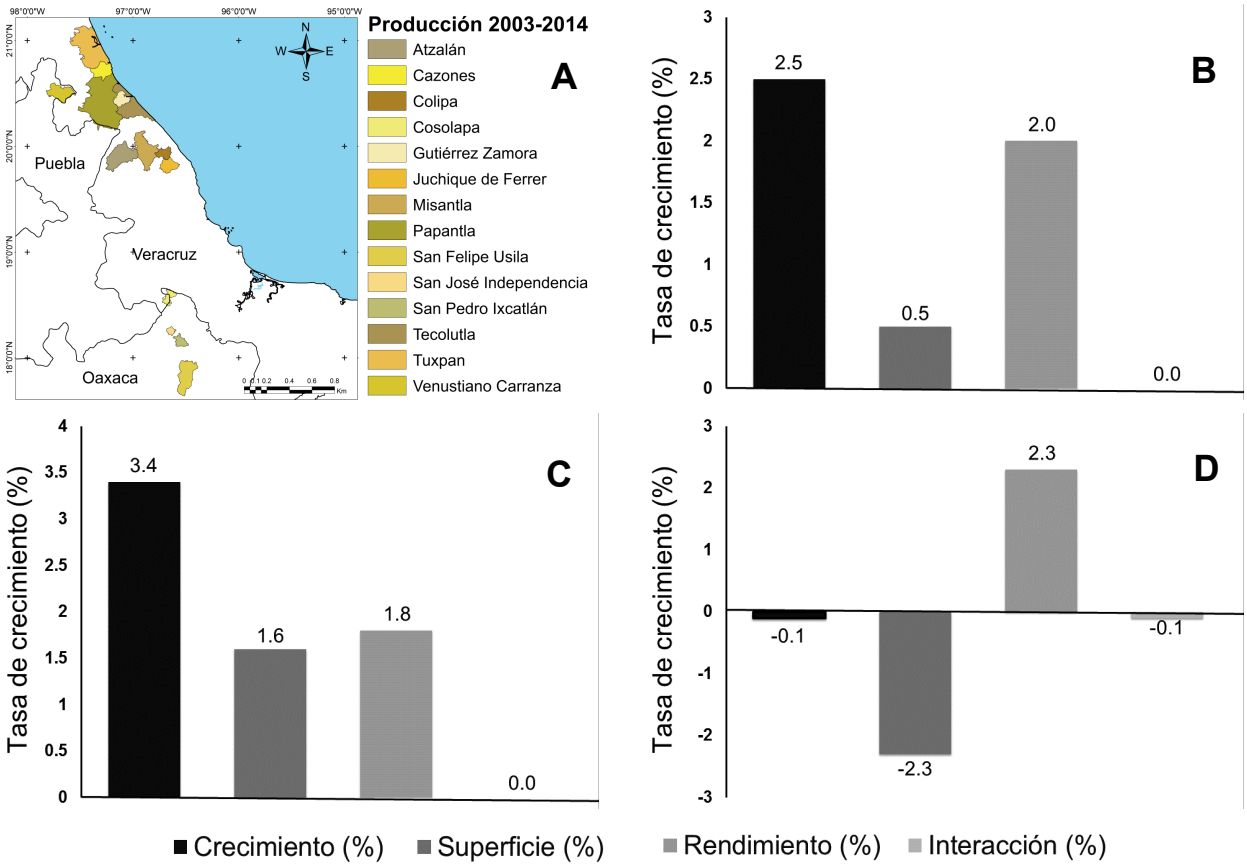
Means with the same letter per column are not statístically different (α = 0.05).

[1]Includes Guadalupe, Zimbabwe, Kenya, Réunion, Malawi, French Polynesia, Comoras, Tonga, Turkey and Uganda.

National productivity of the vanilla sector

In order to determine the factors that prevent an increase in the area planted at the national level, which has a positive impact on international productivity, the factor decomposition model of production growth at the municipal level was applied (Gómez, 1994). It was found that from 2003 to 2014, 52 municipalities cultivated vanilla nationwide, of which only 14 had constant production throughout the period, located in the states of *Puebla* (1), *Veracruz* (9) and *Oaxaca* (4) (Figure 2A). In the national context from 2009 to 2014 there was a sector growth of 2.5 % compared to 2003-2008, as a result of an increase in field yields (2.0 %) and area sown (0.5 %) (Figure 2B). However, this growth is registered only by 14 out of the 52 vanilla producing municipalities. For them, in the same periods of analysis, there is a 3.4 %

rise in production in response to a 1.6 % increment in the planted area and 1.8 % in field yields (Figure 2C), which contrasts with the fall in production (-0.1%) of the remaining 38 municipalities, as a consequence of a reduction in the planted area (-2.3%) (Figure 2D). Barrera *et al.* (2011) assigned this effect to the cyclical nature of the crop, management practices, physical and climatic aspects, but above all to two factors: the lack of enough economic resources and of knowledge about production technology by the producer.



Producción = Production; *Tasa de crecimiento* = Growth rate; *Crecimiento*= Growth; *Superficie* = Surface area; *Rendimiento* = Yield; *Interacción* = Interaction

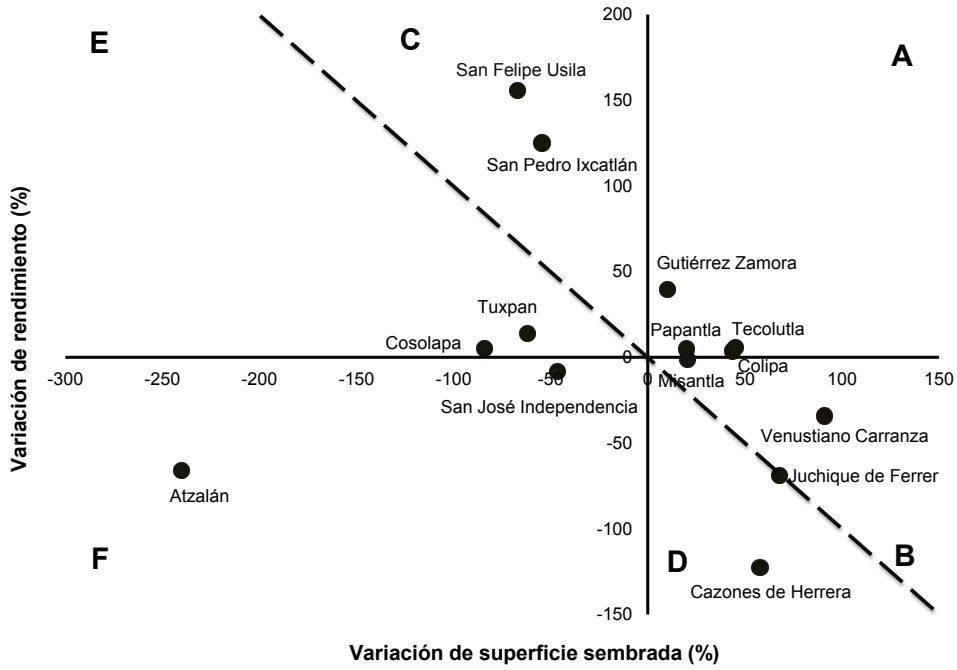
Figure 2. Growth of vanilla production in Mexico in the 2009-2014 period compared to 2003-2008.

The growth of the vanilla production at national level was presented by an increase of the yields in the field, which counteracts the reduction of the sown area. Hernández (2011) states that vanilla yields have a positive trend but are still considered low and associated with a lack of technological innovation; this fact prevents increasing its production internationally. FND (2017) points out that the yields of vanilla have fallen around 0.35 t ha^{-1} and agrees that the use of higher technology and improved processes would increase yields. The aforementioned author calculated that with traditional technology, 0.33 t ha^{-1} is produced and with technological innovation it is possible to obtain up to 1.55 t ha^{-1}. In this regard, SAGARPA (2011) and FIRA (2012) granted support to the agricultural sector for the transfer of technology, technical assistance, training and technological development, with the aim of improving the productivity of the field of cattle raising.

From 2003 to 2014, 63 % of national production was based on 14 municipalities that registered continuous operations (SIAP, 2017). Table 2 shows the productivity of these municipalities from 2009-2014 compared to 2003-2008 and their importance in the national context; Four municipalities (*Gutiérrez Zamora, Papantla, Tecolutla* and *Colipa* in *Veracruz*) have increased their sown area and field yield (Type A). *Misantla* and *Juchique de Ferrer* (*Veracruz*), and *Venustiano Carranza* (*Puebla*) have adopted an extensive model (Type B); *San Felipe Usila* and *San Pedro Ixcatlán* (*Oaxaca*) an intensive model (Type C). However, the most drastic scenarios are located in *Atzalán, Cazones de Herrera* and *Tuxpan (*Veracruz), and *San José Independencia* and *Cosolapa* (*Oaxaca*) where productivity has declined (Type D, E and F). Figure 3 illustrates, above the dotted diagonal, the municipalities that had growth in production, and below those that showed a reduction in production for the period 2009-2014 compared to 2003-2008.

Table 2. Tipology of municipalities according to the growth or reduction of vanilla production from 2009-2014 in regard to 2003-2008.

Tipology	Production	Sown Superficie area	Yield in the field	Number of municipalities	Contribution (%)			Yield in the field (t ha^{-1})
					Municipalities	Sown area	Production	
A	Increases	Increases	Increases	4	7.69	38.18	37.44	0.47
B		Increases	Disminishes	3	5.77	5.87	7.89	0.56
C		Disminishes	Increases	2	3.85	4.81	6.18	0.60
D	Disminishes	Increases	Disminishes	1	1.92	10.51	5.05	0.20
E		Disminishes	Increases	2	3.85	7.08	5.71	0.37
F		Disminishes	Disminishes	2	3.85	1.49	0.97	0.28
Others				38	73.07	32.06	36.76	0.41
Total				52	100.00	100.00	100.00	



Variación de la superficie sembrada = Variation of the shown area; *Variación del rendimiento* = Yield variation

Figure 3. Typology of municipalities based on growth axes in sown area and yields in the field.

From 38.18 % of the planted area, 37.44 % of the production is obtained, which is concentrated in four of 52 municipalities. When considering those that have lost productivity and those that have been inconstant in their production, 48.49 % of the national production is at risk.

The production of vanilla increased in 9 of the 14 municipalities analyzed and the yield in the field is the factor that mostly influenced this tendency. From 2011, institutions such as SAGARPA and FIRA, implemented the application of technological packages to the cultivation of vanilla, which generated more knowledge in the management of the crop; this fact explains the increase in yields at the national level (Hernández, 2011). However, the country has not been able to compete internationally. FAOSTAT (2017) reports that Mexico obtains higher yields than those of Indonesia and Madagascar, but that it has not been able to increase its sown area and thus, its production. Although support programs have already been created, it is necessary to train producers in crop management and design strategic programs to increase the sown area. With the productive increase that results, it is expected it is expected to improve the competitiveness of the vanilla sector (Hernández, 2011; Jaramillo *et al.,* 2012).

Finally, when interviewing specialists in the production of vanilla from the *Universidad Autónoma Chapingo* and the *Colegio de Postgraduados*, as well as producers and representatives of the *Comité del Sistema Producto de Puebla y Veracruz*, it was possible to establish some of the factors that explain the changes in the sown surface and yield in field by type of municipalities (Table 3).

Table 3. Factors that explain the increase (+) and decrease (-) of planted area and yield in the field by type of municipalities with continuous production from 2003 to 2014.

Type	Municipality	State	Sown surface	Yield in the field
A	*Gutiérrez Zamora* *Papantla* *Tecolutla* *Colipa*	*Veracruz* *Veracruz* *Veracruz* *Veracruz*	Reconversion of citrus, maize and cattle areas to vanilla cultivation areas (+)	Use of high productivity technologies (+)
B	*Misantla* *Juchique de Ferrer* *Venustiano Carranza*	*Veracruz* *Veracruz* *Puebla*	Reconversion of citrus and maize areas to vanilla cultivation areas (+)	Use of traditional technologies in rainfed conditions(-)
C	*San Felipe Usila* *San Pedro Ixcatlan*	*Oaxaca* *Oaxaca*	Abandonment of plantations because of phytosanitary problems (-)	Plantations renewal (+)
D	*Cazones de Herrera*	*Veracruz*	Reconversion of maize areas to vanilla cultivation areas (+)	Lack of specialized workforce on pollination and making of organic fertilizers (-)
E	*Tuxpan* *Cosolapa*	*Veracruz* *Oaxaca*	Abandonment of plantations because of climatic factors phytosanitary problems (-)	Use of high productivity technologies (+)
F	*San José Independencia* *Atzalan*	*Oaxaca* *Veracruz*	Abandonment of plantations because of phytosanitary problems (-)	High production costs from inapropriate management of the crop (-)

Although in Mexico there are conditions that could encourage the production of vanilla, such as good land, guardians, plants, productive experience and quality control, climate, running water and organic matter, we also have low prices, market unstable (price variation, lack of buyers, etc.), climatic changes of prolonged drought, pests and diseases, lack of specialized and permanent technical assistance, infrastructure, equipment and work tools, financing and promotion of the establishment of plantations. To this should be added the insecurity in some of the production areas as occurs in the *Totonacapan* region, the main producing area nationwide. The causes mentioned are present in 38 of the 58 producing municipalities, and unfortunately, it is difficult to reverse them in the future.

Conclusions

The analysis of the production of the Mexican vainillero sector, decomposed by the factors of surface planted and yield in field, shows that the national productivity has not been able to increase and be competitive at international level, due to the reduction of the sown surface. The good yields in the field that Mexico presented during the period of interest are insufficient to reverse this situation. In 14 of 52 producing municipalities 63.24 % of the vanilla production is concentrated; the remaining 38 municipalities have reduced their sown areas. Under this scenario it is necessary that the producers know the tasks that must be done during and after the harvest, to ensure a higher production. The strengthening of the vanilla sector in Mexico can be achieved if there is access to packages that allow greater knowledge about sowing and technical assistance in cultivation.

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Conflict of interest

The authors declare no conflict of interest.

Contribution by author

Alberto Santillán Fernández: conceptualization and design of the study, statistical analysis and writing of the final manuscript; Alejandra Salas Zúñiga: elaboration of cartographic maps through GIS, review of data and analysis of information, writing of the original manuscript; Nehemías Vásquez Bautista: review and monitoring of results.