Article

Radical and progressive innovations in the management of maize in Calpan, Puebla-Mexico

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Abstract

The objective of the work was to evaluate the use of radical and progressive innovations used in the management of maize and its impact on yields per hectare. A questionnaire was applied to a sample of 110 maize producers in the municipality of Calpan, the application rate of radical innovations (IAIR), the degree of use of progressive innovations (GEIP) were calculated and they were typified to producers in low, medium and high, according to the IAIR and GEIP. The results indicate that the GEIP average was higher (60.1) than the IAIR (40.2), that there is a positive relationship between GEIP and yields, but not between the IAIR and yields. The variables that had a positive influence on the IAIR were schooling and the level of income, while for the GEIP were the number of members in the family and the age of the producer.

Keywords: management of maize, progressive and radical innovations.

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Introduction

Mexico is the ancestral home of maize its cultivation, started seven thousand years ago and its domestication allowed the nomadic groups to become sedentary thus becoming the sustenance of the Mesoamerican peoples (SAGARPA, 2015). Currently the consumption of maize in Mexico shows an increasing trend during the last three years.

The estimates of SAGARPA (2016), value a consumption level of 35.6 million tons during the agricultural year 2015, which represents an increase of 5.8% in relation to 2014. Of the total consumption of maize, it is estimated that 64% corresponds to white maize and 36% remaining to yellow maize (SAGARPA, 2016). For its part, the annual per capita consumption of maize, according to statistics from the Agri-Food and Fisheries Information Service (SIAP), is 276.9 kilograms (SIAP, 2016).

The problem is that Mexico is not self-sufficient in maize production and due to the increase in consumption, its import also shows a growing trend. During 2014, the highest volume of maize in history was imported, 10.3 million tons, a growth of 45.7% in relation to 2013 (FIRA, 2015). González (2016), adds that between January and May 2016 the import of white maize, the one destined for human consumption, grew 29.9% compared to the same period in 2015.

Rubio (2015), states that Mexico has a long history as a food dependent country, mainly in basic grains, which forces to buy white maize from other countries regardless of high grain prices. In view of this problem, multilateral organizations, the Food and Agriculture Organization of the United Nations (FAO), the Economic Commission for Latin America and the Caribbean (ECLAC) and the Inter-American Institute for Cooperation on Agriculture (IICA), called on the countries to strengthen their native agriculture, faced with the risk of food shortage and social and political world destabilization.

To strengthen local agriculture in Mexico it is necessary to increase the yields obtained per hectare which are related to the management of maize. Damián and Toledo (2016), indicate that in the management of this graminea there are two types of production conditions: a) general that can be climate, flora, fauna, etc. (endogenous) and government support programs for agriculture as well as the features of the family unit, etc. (exogenous), unmodifiable in the medium term; and b) concrete (sowing, soil preparation, sowing date, cultivation work, fertilization, density of plants, hybrids, agrochemicals, native seeds, use of manure, association and rotation of crops, etc.), referred to the factors of the production directly involved in the management of maize. The way in which these conditions (general and concrete) are combined during the productive cycle explains the way in which maize management is carried out.

Among the factors of production (land, labor and technology) that interact in the management of maize, the use of innovations stands out as these enhance the productivity of the other factors. In this regard, the Green Paper on Innovation of the European Commission (1995), points out that innovation is considered as a synonym to produce, assimilate and successfully exploit a novelty, in the economic and social spheres, in order to provide unprecedented solutions to the problems and thus allow us to respond to the needs of people and society.

For Jiménez and Rojo (2010), innovation is part of technology and therefore shares its methods with it, although it goes further, as the economic and social repercussions play an even greater role in innovations. That is, innovation is much more complex than technology. Because while technology is the transformation of knowledge into new products, processes or services, innovation goes a step further because it includes technology and involves the process of putting it to use, when a technology is not put into use it cannot be called innovation; therefore, the innovation process requires that the innovator has the capacity to use new knowledge to use available resources (unknown and past) in the production of improved goods and services (Fortuin, 2006).

In this work, innovation is conceived as the implementation of technology incorporated in techniques and tools that represent a positive change or improvement in a production process, which translates into better quality, efficiency and performance and that is also economically viable and socially acceptable.

The Oslo manual (2005) considers that innovations are divided into two types: radical innovations and progressive or incremental innovations. Jimenez and Rojo (2010), add that radical innovations represent great discontinuities in knowledge with the introduction of totally novel changes. While progressive innovations do not mean a sudden jump, but are produced by small changes or improvements on an invention or prior technological development.

The origin of the radical innovations applied in agriculture in Mexico, have been driven by the green revolution which, as indicated by Ceccon (2008), had the purpose of generating high rates of agricultural productivity in Mexico, based on a production of large scale and the use of high technology represented by technological packages. However, the green revolution did not contribute to its main objective, which was to end hunger or rural development. Agricultural production; through the expansion of irrigation, the use of synthetic fertilizers, the mechanization of agricultural work and applied genetics.

These increases brought about collateral effects in the environment, causing pollution in the atmosphere, soil, water and food (Rodríguez *et al*., 2014). On the other hand, the progressive innovations used in agriculture have been generated over the centuries by the producers, who year after year improve their techniques and practices in the management of crops. In fact, it was these progressive innovations that gave rise to agroecology, a science that allows the creation of alternative development models to the conventional agricultural model.

Rosset (2016) mentions that in Mexico, the organizations and social movements of rural populations, family farmers, peasants, indigenous peoples, rural women, rural and landless workers who participate in land occupations and others, increasingly use agroecology. FAO (2015), indicates that agroecology is continuously thriving, given the need to adapt to climate change and the crisis of natural resources, is an approach that will face the challenge of eliminating hunger and malnutrition in all its forms by increasing of the yields.

In this work the use of radical and progressive innovations used in the management of maize and its impact on yields per hectare was evaluated. To this end, a questionnaire was applied to a sample of 110 maize producers in the municipality of Calpan, the rate of application of radical innovations (IAIR), the degree of use of progressive innovations (GEIP) was calculated and typified to the producers in low, medium and high, according to the IAIR and GEIP.

Materials and methods

Geographical framework of the investigation

Calpan is located between parallels 19° 03' and 19° 09' North latitude and meridians 98° 23' and 98° 35' West longitude. It has an altitude above sea level of between 2 200 and 3 200 m and has an area of 67 km^2 (INEGI, 2015). The orography of the municipality is determined by its location with respect to the Sierra Nevada and the Neo-Volcanic axis, where the soil type is: Arenosol 38%; Phaeozem 26%; Cambisol 8%; Andosol 8%; Fluviso 7% and Leptosol 13%. In terms of hydrology, the municipality is located in the western high part of the Atoyac River basin, has intermittent and permanent streams from the foothills of the Iztaccihuatl (INEGI, 2010).

Most of the work areas are dedicated to rainfed agriculture. Maize represents the most important crop in the municipality, with a planted area of 2 256 ha, by 2015, 73% of the total area devoted to agriculture, obtaining yields of 2 701 kg ha^{-1} (SIAP, 2016).

Design and application of the questionnaire

To design the questionnaire, it was based on questions referring to the two conditions (general and concrete) that influence the management of maize.

Calculation of the sample

To determine the sample size, the simple random sampling formula was used (Cochran, 1982):

$$n= \frac{Z^2_{\alpha/2}\, S_n^2}{d^2 + Z^2_{\alpha/2}\, S_n^2} \qquad 1)$$

Where: n= sample size; N= 546 total families benefited from (PROAGRO Productivo) in the municipality; d= 0.14 (precision); $Z_{\alpha/2}$= 1.95 (reliability 95%); S_n^2= 0.25

Simple random sampling was applied with proportional distribution of the municipal sample according to the number of producers in the communities (334 San Andres Calpan, 146 San Lucas Atzala, 62 San Mateo Ozolco and 5 Pueblo Nuevo). The sample size was 110 families and were distributed as follows for San Andres Calpan 42, San Lucas Atzala 36, San Mateo Ozolco 27 and Pueblo Nuevo 5.

Radical Innovations Appropriation Index (IAIR)

To assess the use of radical innovations, the radical innovations appropriation index (IAIR) was calculated. To this end: a) the recommendations of the INIFAP (Table 1) were compared with the practices applied by the farmer; b) a nominal value was assigned to the management of 100 points and it was weighted according to the impact each component has on productivity: sowing date (10), variety (20), density of plants (15), fertilization dose (25), fertilizer application date (5), type (6) and herbicide dose (4), type (6) and insecticide dose (4) and disease control (5); and c) each weighted value was divided into two: the first quotient was for the use of the recommendation and the second for its proper management. The value of the IAIR varied between 0-100 units and for its calculation the following mathematical expression was used:

$$\text{IAIR}=\left[\sum_{i=1}^{k}(\text{pi})(\text{SPAi}/\text{PTAi}\right] \qquad 2)$$

Where: IAIR= rate of appropriation of radical innovations; k= number of components of the technological package recommended by INIFAP; p_i= weighting granted to the ith recommendation component; $\sum p_i = 100$; i= 1, 2, k; SPA_i = agricultural production system for the i-th recommendation component; i= 1, 2, k; PTA_i = agricultural technology package for the i-th recommendation component; i= 1, 2, k; (SPA_i/PTA_i)= proportion of technology used that can take values of zero, for the non-appropriation of the technology recommended by the INIFAP; one, for the appropriate use of technology and 0.5 for the inappropriate use of the technological component.

Table 1. Technological package recommended by INIFAP for the management of seasonal maize in the municipality of Calpan, Puebla-Mexico.

Technological component	Calpan
Planting date	March, April, May
Variety of seed	H-30, H-33, H-34, H-40, H-48, H-50 H-137, H-139, VS-22
Density of plants ha^{-1}	50 000
Fertilization formula	140-60-00 and 110-50-00
Name and dose of herbicide	Gesaprím 50 (1 kg), 500 FW (1.5 L), Hierbamina (1 L)
Name and dose of insecticide	Volaton 2.5% or Furadan 5% or Volaton 5% (25-12 kg) Folimat 1 000 dod (0.5 L); Parathion (1 L) methyl 50% or Malathion (1 L) dissolved in 200 L of water ha^{-1}.
Fungicides	There is no recommendation*

INIFAP (2009). *= the INIFAP considers that if the producer sows the varieties of seeds they recommend, they are resistant to pests and diseases.

Degree of employment of progressive innovations (GEIP)

To evaluate the use of progressive innovations, the GEIP was calculated which measures, on a scale from 0 to 100, the proportion in which the producers used the following agroecological practices or inputs: creole seed, association and rotation of crops, conservation techniques of soils and application of manure, giving each of them a value of 20 units. In this way, the nominal value of the GEIP was 100. The GEIP was obtained by applying equation 3 (Damián and Toledo, 2016).

$$GEIP= \sum_{i=1}^{k} (Vi) \quad 3)$$

Where: GEIP= degree of employment of progressive innovations; k= 5: number of technologies considered for the study; V_i= weight given to the i-th peasant technology depending on its use or not; The value was zero if the producer did not use the technology or 20 if he used it.

Typology of producers

The producers were grouped according to the value of units of the IAIR and the GEIP: low (0-33.3) medium (33.34-66.66) and high (greater than 66.66). The typology made it possible to identify general and specific characteristics and thus have a more integrated knowledge of the different producers.

Results and discussion

Evaluation of radical and progressive innovations

The management of seasonal maize in the municipality is based on the interaction and application of radical and progressive innovations. When evaluating the IAIR, only producers of low and medium appropriation were found (Table 2).

Table 2. Number of producers, (ha), yield (kg ha^{-1}), IATR averages, by type of producers in the municipality of Calpan, Puebla-Mexico.

Locations	Indicators	Low	Medium	Total/average
	Producers	26	84	110
Municipal total	IAIR	28.9	43.7	40.2
	Yield*	2561a	2403b	2440

Elaboration with data obtained from the survey, 2016. *= different letters in the means of performance (per row (a) or column (A)), it is interpreted that there is a statistically significant difference between the means (Student's t test, p< 0.05).

The low use of these radical innovations is explained because they prioritize the edapho-climatic factors and elude, that the general and concrete conditions of maize management are different among the producers (Damián and Toledo, 2016). The results show that there is no relationship between the degree of application of radical innovations and performance (r= -0.086, p= 0.369). Even the producers of low appropriation obtained higher unit yields than the average ones, finding significant differences between the yields, even though they applied 14.8 more units of the technological package.

This coincides with that reported by Damián *et al*. (2007); Osorio *et al*. (2012), that when evaluating the use of technology appropriation, it was found that farmers adopted the technology, but this did not have a positive effect on the increase of maize yields.

For its part, Table 3 mentions that the GEIP average is higher (60.1) than the IAIR (40.2). Likewise, it is evident that in the use of progressive innovations there is a direct relationship between the GEIP and yields (r= 0.263, p= 0.011), with significant differences between yields of the types of producers. The highest yields are due to the fact that progressive innovations promote agroecological interactions which improve the productivity of the scarce resources used to manage maize (Mendoza, 2004, Altieri and Nicholls, 2012).

Table 3. Number of producers (ha), yield (kg ha^{-1}), GEIP averages, by type of producers in the municipality of Calpan, Puebla-Mexico.

Locations	Indicators	Low	medium	High	Total/average
Municipal total	Producers	12	58	40	110
	GEIP	20	53.7	81.5	60.1
	Yield*	2004a	2322b	2745c	2440

Elaboration with data obtained from the survey, 2016. *= different letters in the means of performance (per row (a) or column (A)), it is interpreted that there is a statistically significant difference between the means (Student's t test, $p< 0.05$).

Variables related to the appropriation of radical innovations and yields

In Tables 4 and 5 it was observed that in Calpan the variables that had a positive correlation with the IAIR were the level of schooling and the income of the producer (r= 0.235 p= 0.014; r= 0.259 p= 0.013, respectively).

Table 4. Schooling, number of producers, (ha), yield (kg ha^{-1}), IAIR averages, by type of producers in the municipality of Calpan, Puebla-Mexico.

Location	Scholarship	Number of producers		Yield (kg ha^{-1})	IAIR
Municipal total	0-4	46	42%	2482	35
	5-8	40	36%	2443	43
	9 >	24	22%	2360	47

Elaboration with data obtained from the survey, 2016.

Table 5. Annual income level, number of producers, (ha), yield (kg ha^{-1}), IAIR averages, by type of producers in the municipality of Calpan, Puebla-Mexico.

Location	Income level ($*)	No. of producers		Yield (kg ha^{-1})	IAIR
Municipal total	10 000-24 000	31	28%	2 569	38
	24 001-38 001	55	50%	2 460	41
	38 002-52 002	24	22%	2 229	42

Elaboration with data obtained from the survey, 2016. *= Mexican national currency.

The greater schooling is related to a greater receptivity to the advice provided by the agrochemical merchants in the municipality. Morales *et al*. (2012), indicate that the level of education is positively associated with the use of radical innovations.

Regarding income, this greater appropriation is due to the fact that radical innovations have a high cost and can only be accessed by higher income producers. In this regard, Bernardino (2013), indicates that level of income positively influences the use of radical innovations.

Variables related to the appropriation of progressive innovations and yields

According to the figures shown in Tables 6 and 7, the variables that correlated positively with the GEIP were the number of members per family (r= 0.229, *p*= 0.016) and the age of the producer (r= 0.273, *p*= 0.019).

Table 6. Members in the family, number of producers, (ha), yield (kg ha^{-1}), GEIP averages, by type of producers in the municipality of Calpan, Puebla-Mexico.

Location	Members in the family	Number of families		Yield (kg ha^{-1})	GEIP
Municipal total	1-4	23	21%	2267	54
	5-7	54	49%	2405	59
	8 >	33	30%	2619	67

Elaboration with data obtained from the survey, 2016.

The first case is due to the fact that in the municipality of Calpan a traditional smallholder agriculture is practiced, where certain agricultural activities (cultivation work), requires a greater amount of labor force. Magdaleno *et al*. (2014), confirm that a greater number of children represents a greater labor force to carry out agricultural activities, contributing with their work force in various tasks in the field.

Regarding income, this greater appropriation is due to the fact that radical innovations have a high cost and can only be accessed by higher income producers. In this regard, Bernardino (2013), indicates that level of income positively influences the use of radical innovations.

For its part, the positive relationship between the age of the producer and GEIP can explain why producers over 63 years of age maintain management habits that have been nourished by knowledge, experience, knowledge and peasant practices, which were taught by their ancestors, which allows them to achieve higher yields (Table 7).

Table 7. Age, number of producers, (ha), yield (kg ha^{-1}), GEIP averages, by type of producers from the municipality of Calpan, Puebla-Mexico.

Location	Age	Number of producers		Yield (kg ha^{-1})	GEIP
Total Municipal	31-46	35	32%	2160	51
	47-62	35	32%	2377	58
	> 63	40	36%	2742	71

Elaboration with data obtained from the survey, 2016.

Authors such as Koohafkan (2010); Toledo (2013), point out that the peasant knowledge used in the management of applied resources in agricultural production is a fundamental characteristic of the elderly population and is based on experience and practice, conditions that maximize the synergies between resources.

In this study, the higher productivity of older maize farmers (>63) is due to the fact that they managed the maize in the following way.

They selected the creole seed immediately after the harvest considering: the ears of greater size and quality, that the ear was thin, selecting the part of the middle of the ear from which they obtain the grains that they will use in the next planting. The farmers select the maize seed from the barn after the harvest, considering the size of the ear, size of ear and shape of the seed.

They carried out the sowing in the months of March-April, probably this influenced in a greater use of light hours what derived in a greater yield. Cirilo (2015), mentions that early plantings present the maximum production potential, since they take advantage of solar radiation levels.

They used an average of 2 196 kg ha^{-1} of manure, which is an essential component of maize management since it improves the structure of the soil and thereby increases the water retention capacity and the availability of nutrients for plants (López *et al*., 2001).

They associated the cultivation of maize with legumes beans (*Phaseolus vulgaris* L.) and fava bean (*Vicia faba* L.) in 92%, while younger producers associated maize-legumes on average 45%. The associations boost soil productivity, since they limit the problems of pests and diseases; as well as legumes capture nitrogen one of the essential nutrients for the development of plants (Damian and Toledo, 2016).

They carried out crop rotation, a technique that allows them to break the biological cycle of pests and improve soil properties. Among the main rotations found among these producers is the bean and leguminous bean which, as already mentioned, is essential for the capture of atmospheric nitrogen.

They carried out soil and water conservation practices, terraces and boards, which allowed them to preserve these inputs, as well as nutrients and their recycling, which are essential to improve the productive capacities of agricultural land. In addition, these practices guarantee greater biodiversity of plants, which regulates the proliferation of pests and diseases.

They planted a higher density of plants (70 513), which is probably associated with the use of higher quality creole seed, manure and the third labor that only they applied. Krall *et al*. (1997), state that high yields are associated by a greater number of plants, which together make efficient use of water and nutrients.

The complementarities and interactions that occur between progressive innovations are those that trigger the highest yields. As indicated by Vallejo *et al*. (2011), farmers have learned to grow their grain in small plots located at different altitudes and in different microenvironments, to rotate their crops to break disease cycles and maintain healthy soils, planting a wide variety of crops, carry out tillage practices and select seeds that tolerate particular micro niches.

Conclusions

In order to evaluate the use of radical and progressive innovations used in the management of maize, the IAIR and the GEIP were calculated, resulting in adequate instruments to measure the degree of appropriation of innovations. This allowed to classify the producers in low, medium and high, which in turn helped to understand the general and particular characteristics of the different producers.

The results indicate that in the management of maize, radical and progressive innovations interact with a predominance of the latter; that there is a positive relationship between GEIP and yields, but not between the IAIR and yields.

On the other hand, the variables that had a positive influence on the IAIR were schooling and the level of income, while for the GEIP, the variables with a positive correlation were the number of members in the family and the age of the producer.

Progressive innovations proved to be effective and efficient in raising maize yields; however, despite the predominance and evident efficiency, which they possess, the proposal of radical innovations driven by the green revolution does not include them.

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