academicJournals

Vol. 5(4), pp. 69-78, July, 2013
DOI 10.5897/JABSD2013.0201
ISSN 2141-2340 © 2013 Academic Journals
http://www.academicjournals.org/JABSD

Journal of Agricultural Biotechnology and Sustainable Development

Full Length Research Paper

Technological model for improving the management and yield of rainfed maize in Cohetzala-puebla-Mexico

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Accepted 31 May, 2013

This work presents a methodology for executing a technological intervention model that improves the management of maize and its yield per hectare. In order to meet the aforesaid goals, 60 maize growers were surveyed; the use of exotechnologies and endotechnologies was assessed through the calculation of the modern technology appropriation index (IATM, by its acronym in Spanish) and the rural technologies use degree (GETC, by its acronym in Spanish); and the growers were classified into low, medium and high efficiency categories in accordance with their IATM and GETC. The results showed that, the IATM was low and the GETC high; that growers used both types of technologies; and that there is not a direct relation between the IATM and the maize yield, although the yield and the GETC are in fact related. Finally, the maize growers were classified in accordance with their unitary yield and the most efficient maize management technological package used by the producers was identified. Such package is considered as the technological model, through which the low-efficiency and medium-efficiency growers can increase their yields to 91 and 24%, respectively.

Key words: Exotechnologies and endotechnologies, maize management, modern technology appropriation index (IATM) and rural technologies use degree (GETC).

INTRODUCTION

Maize is an essential crop for Mexico since the country grows 7.86 millions of maize hectares, which constitutes 35.8% of the total area that was grown in 2010 (Food, Agriculture and Fisheries Information Service, SIAP by its acronym in Spanish, 2011). Said crop is Mexicans' main food source; they annually consume between 120 to 130 Kg of maize per capita (Zahniser and William, 2004). A problem that affects the maize production in Mexico is its yield (3,210 Kg/ha), which is low in comparison to those of its commercial counterparts of the North American Free Trade Agreement: the United States (which yield is 9,450 Kg/ha) and Canada (which yield is 8,510 Kg/ha) (FAOSTAT, 2010). In the rainy areas the yield is much lower (2,210 Kg/ha), a ton below the national average (SIAP, 2011). In order to meet Mexico's internal maize demand, 9.2 million maize tons were imported at a price of almost 2,400 million Mexican pesos. Therefore, Mexico has a net trade (exportations-importations) equivalent to -9.1 million maize tons (SIAP, 2011). In Cohetzala the unitary yields are barely about 1,130 Kg/ha (SIAP, 2011)

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which are insufficient to ensure the family food security. The yield is a standard that results from the way in which the grower handles the croplands along with: a) the general production conditions that can be endogenous (weather, flora, fauna) and exogenous (agricultural promotion public programs and features regarding territory, as well as family unit) and that cannot be modified on short-term and medium-term basis; and b) the specific production conditions, which refer to the factors that are directly related to production (grower's land, capital, technology, knowledge and skills). The combination of the aforementioned resources explains the way in which the croplands are handled. In order to handle the croplands, growers perform several tasks (sowing, cultivation work, fertilization, control of plagues and diseases, etc.) that follows a successive order in the field and that are done by means of conventional (machinery, hybrids, agrochemicals) or traditional (local seeds, companion planting) production resources or by mixing either types of technologies.

Among the specific resources related to the handling of croplands, technology is the most important since it has been the most powerful boost for increasing the agricultural work and ground productivity. Technology is the result of the interaction among science, technique and culture and it represents the scientific knowledge application to production that is materialized in machines and devices or in the economic activity management and organization systems (Katz, 1999). The innovation in crops has to do with the incorporation of new technological elements for their handling. Said process in rainfed agriculture includes the use of technologies taken from the local context (exotechnologies) and environment (endotechnologies) in which the growers live Cáceres et al., 1997). The former have their origin in the Green Revolution and encouraged a radical innovation in crop management based on the use of agrochemicals. For its part, the use of endotecnologías involves a process of gradual improvement to strengthen the technological base predominantly in the management of maize (Galende, 2008).

Mexico's maize management is very diverse because growers do not have an equal access to the general and specific conditions related to the handling of maize; therefore, they do not achieve the same unitary yields. The identification of the technological package used by the high-efficency growers may be the basis for designing a technological intervention model for less efficient growers, regarding rainfed maize, that boosts the forces of production that are latent in the other specific resources related to maize management. This work proposes a methodology for designing a technological intervention model in order to improve rainfed maize management and yields. To meet said goals, the use of technologies is assessed and the high-efficiency maize growers, as well as the package they used for handling the maize are identified. The hypotheses of this methodology are:

i) That in a given territory, there are growers that differ from each other because the maize management and productivity standards among them are not the same,
ii) That there is a lack of public technologies designed for the conditions in which growers produce and live,
iii) That the knowledge, tools, skills, and concrete and abstract resources that have been used in maize management throughout millenniums are shared among growers (Kurtev et al., 2007). This methodology was validated by rainfed maize growers from Cohetzala, Puebla-Mexico.

MATERIALS AND METHODS

Research area

Cohetzala belongs to the Rural Development District of Izúcar de Matamoros, Puebla. Cohetzala is located in the southwestern part of Puebla and its geographical coordinates are: 19° 57'00'' and 20°05'18'' parallels, North latitude and 97' 24'36'' and 97° 34'54'' meridians, East longitude. Cohetzala is bounded to the North by the municipality Huehuetlán el Chico y Jolalpan, to the South by Xicotlán, Ixcamilpa de Guerrero and the State of Guerrero, and to the west by the State of Guerrero and Chiautla de Tapia (Figure 1). The weather in Cohetzala is very warm and it rains during the summer, with an average annual temperature and precipitation of 18°C and 450 mm, respectively. The main type of soil is regosol that is characterized by its poor evolution and sandy texture along with little pieces of rock similar to the original material from which said soil is originated. The territorial size of this municipality is equivalent to 344.44 km^2. It has 1356 inhabitants among of which 664 are men and 692 are women. The municipality's Gross Domestic Product has been the result of primary (61.4%), secondary (17.2%) and tertiary (16.9%) activities, the remaining 4.5% has to do with other activities (INEGI, 2011). In Cohetzala 1,308 ha, 95% rainfed and 5% irrigated, were cultivated. The main crop that is sown is maize, which covers 98.5% of the seeded area. The remaining percentage is sown with sorghum and peanuts (SIAP, 2011).

Research techniques

The methodology used in the research included three parts:

The carrying out of a survey and the determination of the sample size

The survey: A questionnaire was carried out in order to collect and systematize most of the information used in the research (Damián et al., 2004). Information collected includes demographic, economic, agricultural and livestock structure, all activities included in the management of maize and yield per hectare.

Sample size: The survey was conducted among a sample of growers that was calculated through simple random samples proportionally distributed in every locality in accordance with the number of growers. The sample system consisted of the 217 maize growers registered in the municipality's Program for Direct Assistance in Agriculture (PROCAMPO, by its acronym in Spanish). The sample size was calculated through Cochran's (1977) theorem, (Equation 1). The result was a sample of 60 growers with a precision of 40 Kg, a $Z_{\alpha/2}$ of 1.96, a α reliability of 0.05 and a standard deviation (SD) of 241.25 Kg.

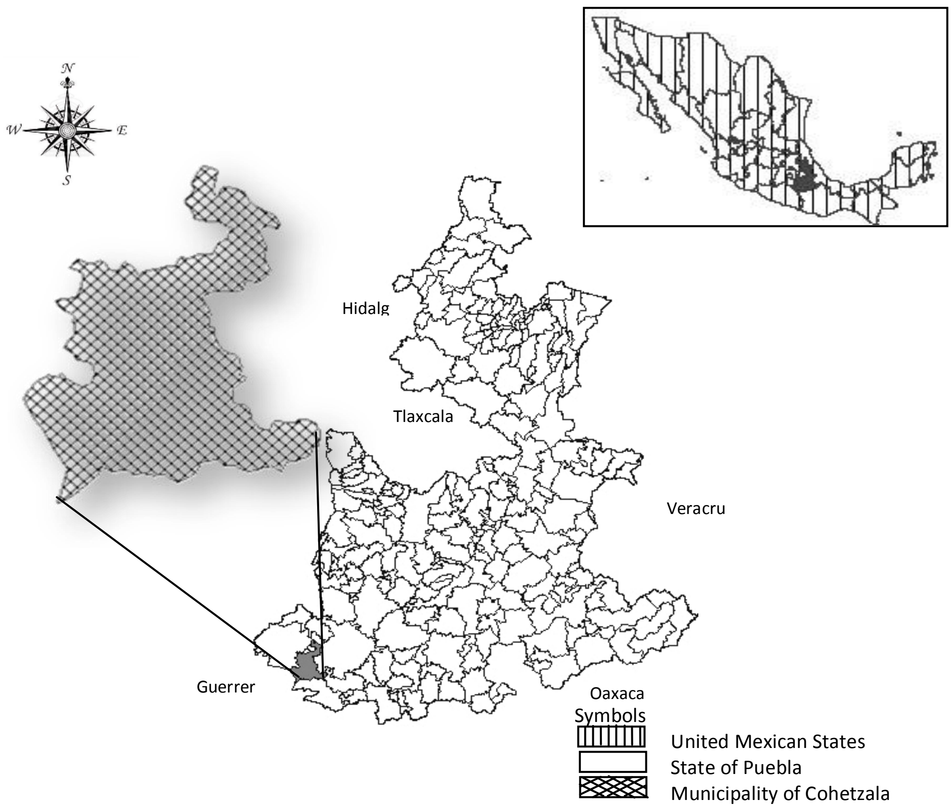

Figure 1. Geographical illustration of the municipality Cohetzala-Puebla. Source: This document is based on the information of the Basic Statistics Project, National Institute for Statistics and Geography (INEGI, by its acronym in Spanish) 2005.

$$n = \frac{N Z^2_{\alpha/2} S^2}{Nd^2 + Z^2_{\alpha/2} S^2} \quad (1)$$

Where: n = Sample size. N = 217 producers, D = Accuracy: 40 kg, Zα / 2 = 1.96 = table value standard normal distribution considering α = 0.05 (reliability = 95%), S = standard deviation of 241 kg estimated yield preliminary data.

The resulting sample was 60 farmers. The selection of the sampling units (producers) was random one by one and without replacement.

Ownership index modern technology (IATM) and GETC calculation and growers' classification according to the IATM and GETC

IATM calculation: In order to calculate the use of the exotechnologies created by the INIFAP, the INIFAP's recommendations were compared with the practices applied in the field each respondent producer; assigned a nominal value of 100 points PT and weighted according to the impact of each component productivity: planting date (10), range (20), plant density (15), fertilization (25), date of application of fertilizer (5), type (6) and dose of herbicide (4), type (6) and dose of insecticide (4) and combating diseases (5), and divided each weighted value between two: the first quotient devolved to the use of the recommendation and the second to its proper management. The value of IATR varied between zero and 100. The IATM was calculated through the theorem proposed by Damián et al. (2007). For calculating (IATM) are applied to Equation 2.

$$IATM = \sum_{i=1}^{k} [(p_i)(SPA_i/PTA_i)] \quad (2)$$

Where, IATM is ownership Index modern technology, k = 10: Number of components of the technology package recommended by INIFAP, Pi is Weightings given to the i-th component of the recommendation, Σ pi = 100, i = 1,2, ... k. SPAi: agricultural production system for the i-th component of the recommendation, i = 1,2, ... k, PTAi: Agricultural Technology package for the i-th component of the recommendation, i = 1,2, ... k, (SPAi / PTAi): Proportion of the technology used, compared with the recommended technology.

According to Equation 2, the value of IATM ranged from zero, when not using any of the recommendations of the technology package INIFAP, 100 when used correctly all the recommendations of the technology package.

Rural technologies use degree (GETC) calculation: The GETC is measured on a 0 to 100 scale, which represents the level at which growers used endotechnologies in maize management. The GETC was calculated through the following production resources and agricultural methods: local seeds, companion planting, crop rotation, and soil and manure conservation techniques, all of which were assigned 20 units. The GETC was calculated through the theorem proposed by Damián et al., (2011). For calculating (GETC) are applied to Equation 3.

$$GETC = \sum_{i=1} vi \quad (3)$$

Where, GETC is Employment Grade Peasant Technologies. k = 5: Number of rural technologies considered for the study. vi: The value assigned to the it peasant technology according to their use or not by the producer. The value was zero if the producer did not use the technology or 20 if used.

According to the above, a producer does not employ any technology GETC farmer obtained a scratch, if used one of the five technologies GETC was 20, if used two technologies the STRP was 40, and so on. When a producer used the five technologies listed obtained a GETC 100.

Growers classification: Growers were classified into three categories according to the IATM and GETC values; a) low-efficiency (0-33.33), b) medium-efficiency (33.34-66.66) and c) high-efficiency (>66.66).

Technological intervention model design

High-efficiency maize growers' identification: In order to identify the high-efficiency maize growers, the difference between the grower's highest and lowest unitary yields was calculated. Said difference was divided into three and the quotient that resulted from such operation was added to the lowest yields in order to establish three types of growers according to the yields they achieved: low-efficiency, medium-efficiency and high-efficiency growers.

Grower's technological package identification: It was identified and characterized to producing high yields, and technology package used in the management of corn, because it is the model proposed in the technological intervention.

RESULTS AND DISCUSSION

Exotechnologies, maize, management and yields

Several institutions that were created throughout history are in charge of Mexico's exotechnologies creation and dissemination. The most important ones are the Office of Special Studies (OEE by its acronym in Spanish, 1943); the Agricultural Research Institute (IIA by its acronym in Spanish, 1947); the National Agricultural Research Institute (INIA by its acronym in Spanish, 1960), which resulted from the fusion of the OEE and the IIA; and the National Institute for Forestry, Agriculture, and Livestock Research (INIFAP by its acronym in Spanish, 1985), which resulted from the fusion of the INIA and the national institutes for forestry and fisheries research. Nowadays the INIFAP is the institution that meets the demand of the producers and agroindustrial chains in fisheries research (INIFAP, 2003). The technological package recommended by the INIFAP for Cohetzala is presented in Table 1 which dominated the use of agrochemicals, genetic hybrids and synthetic materials.

The IATM calculation showed: that there are low-efficiency (22%) and medium-efficiency (78%) growers because, on average, only 40.6 units of the INIFAP's innovations were used; that there is not a significant relation between the use of said technologies and their performance ($n = 77$, $r = -0.0908$, $p = 0.4324$); and that there is not a significant statistical difference between the arithmetic means of growers with a low and medium technology appropriation level ($t = 0.1102$, $p = 0.9126$), though those with a medium level used another 16.2 units of the recommended modern innovations Table 2. The low use of exotechnologies is explained by the fact that, the INIFAP:

i) Supposes that only the soil and weather factors are related to maize management and evades the fact that the grower's access to the general and specific conditions for maize management is directly related to such management,
ii) Proposes a technological package based on technologies, methods and agricultural resources that most of the growers have not used until now. Besides, the high costof said package does not enable a grower that earns an annual average wage of 3,700 Pesos to afford it (Escalante, 2006),
iii) Believes that, growers are unable to produce technologies and evades the fact that rural innovations have been used in maize management since many millenniums ago.

Given that the aforesaid hypotheses have no grounds, this technological package is not suitable for the context in which growers live and produce; therefore, they only use and adapt some of the INIFAP's recommendations.

Endotechnologies and maize management

The traditional maize management is commonly held under adverse soil, weather and economic conditions. Maize management has been sponsored by country people, academics, and scientific and non-governmental organizations. It has its roots in the empirical knowledge that growers have applied to agriculture (CBD, 2000). However, when said knowledge prevails in maize management, most of the politicians and technicians consider it is inefficient because they believe that scientific knowledge is more important and that other kinds of knowledge do not meet the validity or rigor that western science requires for the development of technologies (De Sousa, 2006).

The lack of acknowledgement regarding rural innovations has no grounds. The research shows that growers use modern and rural innovations in maize management and that the latter innovations are the most used.

The GETC calculation showed that the GETC is, on average, 41.6 units higher than the IATM and that, there are significant statistical differences between the yield averages of the growers with a medium and high GETC ($t = 2.8103$, $p = 0.0064$), as well as a significant relation ($n = 77$, $r = 0.4621$, $p < 0.0001$) between the GETC and the yields (Table 3).

The highest productivity of endotechnologies has to do with the use of agricultural methods that are more suitable and intensive regarding the conditions in which

Table 1. Technological package developed by the National Institute for Forestry, Agriculture, and Livestock Research (INIFAP, by its acronym in Spanish) for the management of maize in the municipality of Cohetzala, Puebla, Mexico.

Technology	RDD for Izúcar de matamoros
Sowing date	March-May
Type of seed	H-137, H-139, H-34, H-30, H-33, H-40, H-48, H-50, H-311, H-516, H-515, VS-536, H-507, H-509, V-524, VS-529, and VS-22
Plant density per hectare	50-60 thousand plants
Fertilization formula	120-60-00; 100-50-00; 180-80-60
Fertilization date	The formula is used in the sowing and second plowing process
Herbicide name and dose per hectare	Gesaprim 50 (1 Kg); 500 FW (1.5 L); Gesaprim 50 (1 Kg) and Hierbamina (1 L); Gesaprim50 (1 Kg); flowableGesaprim (1 L) and Basagran 480 (0.5 L); Marvel (1 L); GesaprimCombi (1 Kg); Fitoamina 2.4 D (1 L), Hierbamina 2.4 D (1 L); Esteron 2.4 D (1 L)
Insecticide name and dose per hectare	Volaton 2.5% (25 Kg); Volaton 5% (12Kg); Furadan 5% (12 Kg); Folimat 1000 (0.5 L); Methyl parathion 50% (1 L); Malathion (1 L); Sevin 80 (1 Kg); Volaton 5% G (12 Kg); Methyl parathion (1 L); Sevin 80% P H (1 Kg); Malathion 1000 E (1 L); Diazinon 25% (1 L)

Source: INIFAP (2009).

Table 2. Number of producers, modern technology appropriation index (IATM, by its acronym in Spanish) and yield (Kg ha^{-1}) per type of growers from Cohetzala-Puebla-Mexico.

Indicator	Low		Medium		High		Municipality's average	
	Number	%	Number	%	Number	%	Number	%
Producers	42	70	18	30	0	0	60	100
IATM	22.1		37.3		0		26.7	
Yield	745		748		0		746	

Source: This chart is based on the information collected through the research survey (2009).

Table 3. Number of producers, Rural Technologies Use Degree (GETC, by its acronym in Spanish) and yield (Kg ha^{-1}) per type of growers from Cohetzala-Puebla-Mexico.

Indicator	Low		Medium		High		Municipality's average	
	Number	%	Number	%	Number	%	Number	%
Producers	0	0	35	58	25	42	60	100
GETC	0		57.7		83.2		68.3	
Yield	0		695		816		746	

Source: this chart is based on the information collected through the research survey, 2009.

maize growers work because they involve interactions that generate the production forces included in the maize management resources. Among the said methods, the most important ones are:

i) Water and soil conservation, since it prevents the loss of water and nutrients,

ii) Companion planting, since it combines several elements of the agro-ecosystem (crops, soils, plants, animals) and generates synergies that boost the performance of natural resources (solar energy, air, nitrogen, carbon), all of which are free. For instance,

Table 4. Types of growers and yield (Kg ha^{-1}) levels in Cohetzala-Puebla-Mexico.

Types of growers	Yield level	Number of growers	%
Low	400-600	14	23
Medium	601-800	27	45
High	> 800	19	32

Source: This chart is based on the information collected through the research survey (2009).

Table 5. Innovations used in maize management per type of growers from Cohetzala-Puebla-Mexico.

Innovations	Low		Medium		High		Municipality's average	
	No.	%	No.	%	No.	%	No.	%
Total of hectares sown with maize	29.5	21	61	44	47	34	137.5	100
Soil conservation (ha)	4	14	22	36	11	23	37	27
Sowing date (June)	19.5	66	29.5	48	20	43	69.0	50
Sowing date (July)	10	34	31.5	52	27	57	68.5	50
Sowing of local seed	29.5	100	58	95	47	100	134.5	98
Plants density per hectare	51282		53034		50781		51911	
Companion planting	27.5	93	61	100	47	100	135.5	99
Companion planting with leguminous plants	24.5	83	39.5	65	47	100	111	81
Crop rotation	8	27	26.5	46	21	45	55.5	41
Manure application (kg/ha)	1434		1677		1775		1645	
Fertilized hectares	24.5	83	57	93	47	100	128.5	93
Herbicides use	8.5	29	11	18	7	15	26.5	19
Insecticides use	0	0	5.5	9	9	19	14.5	11

Source: This chart is based on the information collected through the research survey (2009).

through plants grouping (maize-leguminous plants-pumpkins) with a diverse energetic efficiency and root systems, the solar energy, nutrients and water are more efficiently used and the relation among soil, plants, fauna and environment is improved because leguminous plants concentrate atmospheric nitrogen, from which maize benefits, and promote the flora and fauna biodiversity by creating food chains that regulate the plagues development (Altieri, 1991),

iii) Crop rotation, since it reduces the problems regarding plagues, diseases and edaphic erosion and increases the available nitrogen level in soil (Ball et al., 2005),

iv) The relation between agriculture and cattle raising, since it produces manure that improves the soil structure, texture and physical, chemical, and biological fertility; increases the water aeration, penetration and retention; improves the development of microorganisms that are benign for plants; and concentrates carbon (Fenton et al., 2011).

Technological intervention model design

High-efficiency maize grower's identification

Among the classification of the types of growers in accordance with their productivity (Table 4), the medium-efficiency growers outnumber the other types of producers to which a third part of the high-efficiency maize growers belong. If yield is the result of the way in which maize is handled, the following challenge is to identify and characterize the technological pattern used by the high-efficiency maize growers.

Technological package of efficient producers

The technological package used by growers in maize management confirms the importance of rural innovations (Table 5). By comparing this package with the one of INIFAP, several undeniable differences are identified. The most important ones are described as follows:

1) The sowing dates recommended by the INIFAP are suitable for Puebla's high plateau, but not for the warm-dry areas such as Cohetzala, which has a rainy season that normally starts at the end of June or at the beginning of July,

2) The INIFAP recommended to sow hybrids; however, the vast majority of the maize growers sowed local seeds because they are better for the elaboration of tortillas; they constantly adapt to the local agroecosystems that were affected by recurrent natural disasters; they constitute the basis of cattle reproduction, since through

them a higher amount of high-quality forage is produced; their yield remains at the same level through time; and their handling requires a lower investment,
3) Fertilizers were the most used production resources due to Cohetzala's type of soil (regosol), which is characterized by its incipient development and low fertility,
4) Herbicides are another type of agrochemicals used by growers, it replaces manpower. The exclusion of the subsistence producers from the public policies has led to the emigration and retirement of growers that, subsequently, reduce their readiness to work; hence growers are forced to use herbicides. Among the total of members that formed part of the growers' families (328 individuals), 47% emigrated. Besides, the growers' average age was 55.5 years,
5) Insecticides were the less used agrochemicals. Some studies carried out by Herrera et al., (2005) suggest that the diversity and richness of arthropods is higher in polyculture than in monoculture. Said condition originates food chains in the plot of land that, subsequently, produce a biological equilibrium through which the damage caused by plagues can be prevented. It stands out that a fifth part of the high-efficiency maize growers used folidol in order to kill the leafcutter ant plague, which is one of the most harmful plagues that exist in this region,
6) There are three activities (soil conservation, companion planting, and crop rotation), as well as two production sources (local seed and manure) that are not included in INIFAP's technological package, though all of them have been used by maize growers throughout history. Besides, it can be clearly seen that the technological packages used by all the different types of growers are similar, though the high-efficiency growers use endotechnologies more frequently. Said technologies have to do with progressive innovations that result from several long-term processes in which growers generate, select, adopt, adapt and disseminate the technologies, techniques, methods and agricultural production resources that are more suitable for the conditions in which they produce and live.

The awareness of the differences in maize management and their origin, which has to do with the dissimilar access to resources among growers, is essential in order to explain the causes of the diverse productivity that determines the classification of growers.

Characteristics of efficient producers and their technology package

Table 6 showed that, all the different types of maize growers aim to achieve similar life conditions. Nevertheless, the high-efficiency growers are characterized by the fact that:

1) Have a lower average age; hence they are able to perform a higher amount of work, given that the maize rural management is intensive,
2) Earn lower wages and receive fewer remittances. It stands out that remittances constitute, on average, almost the half of the income earned by producers. Therefore, migration has become one of the main survival strategies of the subsistence growers,
3) Are more receptive to technical consultancy,
4) Have diversified their primary sector activities regarding crop management while less efficient maize growers perform tasks of the secondary and tertiary sector, which bear little relation to crop management. Performing several tasks among the different sectors is considered as a way of increasing the family's income (De Janvry and Sadoulet, 2004; Reardon et al., 2004) and as a direct cause of the reduction in the agricultural income (Ansee and Laurent, 2007). The performance of several activities has caused a technological regression among the growers, which is reflected in the maize management lack of specialization and neglect. According to Smith (1982), the most important progress regarding the productive means of work and the flair, skills and good sense through which it is performed has to do with the continuity of work division. It stands out that those who only performed activities related to maize management are the most long-lived producers; they have an average age of 66 years, which is the main obstacle for them in relation to the performance of tasks.
5) Hold a larger and higher quality agricultural area, since the ground is both flat and inclined,
6) Have less access to the agricultural machinery and more access to the yoke. Both means concentrate 35% of the cattle; hence the agriculture-cattle raising relation is preserved.

When Chart 6 figures are explained from another point of view, the social importance regarding the low-efficiency maize growers' use of the technological intervention model is highlighted.

1) All the maize growers deal with food poverty, since their monthly average income per capita is equivalent to 707 Mexican pesos. A lower sum of money is not enough to afford the basic food basket (National Council for the Evaluation of Social Development Policy, CONEVAL by its acronym in Spanish, 2011). The dependence of the producers' families on remittances and the recurrent economic crisis that have affected the United States of America (USA) stress the urgent need to increase productivity. IDB's (2009) figures show that, 37% of migrants reduced the amount of remittances in the first semester of 2009 in comparison to 2008,
2) Maize growers are classified as smallholders due to the size of the land they own; they sow areas of less than 5 ha (Artís, 1997).

Table 6. Socioeconomic features and production means availability according to the yield of growers from Cohetzala-Puebla-Mexico.

Indicator	Low		Medium		High		Municipality's average	
	No.	%	No.	%	No.	%	No.	%
Average age	54.8		57.8		52.6		55.5	
Number of family members	70	21	160	49	98	30	328	100
Number of migrants per family	28	40	81	51	45	46	154	47
Average remittances per month ($, Mexican currency)	230		258		217		238	
Monthly average expenses per capita ($, Mexican currency)	510		519		505		512	
Technically advised growers	1	7	2	7	2	11	5	8
Primary multiactive producers*	6	43	18	67	18	95	42	70
Secondary multiactive producers*	4	29	4	15	1	5	9	15
Maize growers**	4	28	5	18	0	0	9	15
Flat hectares	6	20	4.5	7	17	36	27.5	20
Slightly inclined hectares	15.5	53	52.5	86	24	51	92	67
Considerably inclined hectares	8	27	4	7	6	13	18	13
Self-owned tractor per grower	2	14	3	11	1	5	6	10
Leased tractor per grower	1	7	0	0	0	0	1	2
Self-owned yoke per grower	10	71	19	70	16	84	45	75
Leased yoke per grower	1	7	5	19	2	11	8	13
Large size livestock (heads of livestock)	63	19	166	50	106	32	335	100
Small size livestock (heads of livestock average)	148	15	492	49	366	36	1006	100

Source: this chart is based on the information collected through the research survey, 2009. *Producers that grew maize and performed other economic tasks in the primary sector, ** Producers that exclusively grew maize.

Table 7. Yield (kg ha-1) and output (Kg) as potential producers yields per hectare of Cohetzala-Puebla-Mexico.

Indicator	Low		Middle		High		Total /average	
	No.	%	No.	%	No.	%	No.	%
Actual return (RR)	486		751		930		746	
Yield potential (RP)	930		930		930		930	
RP-RR	444	91	179	24	0	0	184	25
Prod Vol Real (VPR)	14,250		46,150		43,720		104,120	
Prod Vol Potential (VPP)	27,285		57,172		43,720		128,177	
VPP-VPR	13,035	91	11,022	24	0	0	24,057	23
No. Members / Family	70		160		98		328	
VPPCR	204		288		446		317	
VPPCP	390		357		446		391	
VPPCP-VPPCR	186	91	69	24	0	0	73	23

Source: Own survey data, 2009. Volume VPPCR = real per capita production, VPPCP = Volume of output per potential.

Other results of the survey showed that, all the maize growers are subsistence growers, given that they eat the maize they grow. Only 11 growers (18%) of Cohetzala produce maize surpluses that they sell in local and/or regional markets.

Relevance of technological intervention model and yields

The results found (Table 7) showed that, if the pattern is transferred Cohetzala technology of high yielding corn growers to low and middle income grow, on average, 91 and 24%, respectively. Similarly, the production volume and the volume of output per capita would increase by the same percentage.

Advantages of the technological package used by high-efficiency maize growers

If high-efficiency maize growers' technological pattern is applied by the low-efficiency and medium-efficiency growers, their yields will increase to 91 and 24%, respectively. As said, if surplus is consumed, each member of the producer's family will have an annual maize surplus of 81 Kg. Besides, these agricultural systems provide environmental services by mitigating the greenhouse gases emissions, reducing the impacts of natural disasters, preserving biodiversity, and protecting the water and soil resources (Espinoza et al., 1999). These agricultural systems also function as sinks of CO_2 (Etchevers et al., 2001), which is the main gas that causes global warming.

Conclusions

The research results showed that, the use of exotechnologies is much lower in comparison to endotechnologies and that there is a direct relation between the use of said technologies and the yields per hectare. The results also show that the unitary yields can be increased, on average, at a 50% if the high-efficiency maize growers' technological package is used.

ACKNOWLEDGEMENTS

To the FOMIX-CONACYT (Mixed Funds of the National Council on Science and Technology) and the Government of the State of Puebla for financing this research, which was conducted during the postdoctoral training of the first author regarding the Master's degree in Regional Rural Development Sciences of the Universidad AutónomaChapingo.

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