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PROFITABILITY OF CORN PRODUCTION IN AGROECOLOGICAL AND CONVENTIONAL SYSTEMS IN TWO COMMUNITIES OF TLAXCALA

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ABSTRACT

The objective of this study was to conduct a comparative study of profitability between glyphosate-free corn production in the agroecological lighthouse "Grupo Vicente Guerrero", Espańita, Tlaxcala and conventional Creole corn production in Huamantla, Tlaxcala. To calculate the profitability, a survey was applied to 20 producers who belong to the lighthouse and 20 to the *ejido* of Huamantla. The producers from Vicente Guerrero are characterized by their trajectory in agroecological agriculture and the promotion of alternative technologies; they manage corn as a poly-crop, associated with bean, squash and weeds, agro-ecosystem known as *milpa*. This management demands a greater number of people in the workforce to execute the tasks of farming, substituted in conventional management with the use of herbicides and other agrichemicals. In the calculation of profitability, the benefit cost B/C rate in Vicente Guerrero was 1.24, which is profitable for the producer; meanwhile, the opposite was seen in producers from Huamantla, with a B/C rate of 0.88, that is, negative, so this production is not profitable. The establishment of lighthouses ensures the agroecological management of corn which, in addition to being profitable, contributes to the decrease in risks and damages to the population's health.

Keywords: benefit-cost rate, production, production costs.

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INTRODUCTION

According to Gómez *et al.* (2018), the conventional agricultural model is based on a production system that depends on a high use of synthetic inputs, where monocrop predominates, which is justified as fundamental tool to attain greater efficiency in the productive process. However, this production system has shown serious sustainability problems and has caused the deterioration of natural resources. A grave problem is the use of harmful inputs not only for the environment but also for human health, such as the case of glyphosate. In Mexico, it has been identified that glyphosate is used in the cultivation of different species in the agricultural sector, among which its application in corn production stands out, with a 35% of the total national use, followed by the production of citrus trees with 14% approximately (CONACYT, 2020). In Mexico, on December 31st 2020, a Presidential Decree was published in the *Diario Oficial de la Federación*, which establishes that "the use, acquisition, distribution, promotion and import of glyphosate and agrichemicals that contain it as active ingredient must be gradually substituted by sustainable and culturally adequate alternatives, which allow

maintaining the production and are safe for human health, biocultural diversity of the country and the environment. In this sense, since the enforcement of the Decree and until January 31st 2024, a transition period is established to achieve the total substitution of glyphosate. Likewise, the agencies and entities of the Federal Public Administration are instructed, within the scope of their competencies and since the enforcement of the Decree, to abstain from acquiring, using, distributing, promoting and importing glyphosate or agrichemicals that contain it as active ingredient, within the framework of public programs or any other government activity. During this transition process, the entities of the federal public administration, should maintain a participation creating strategic alliances with research centers and universities in the search for actions that promote sustainable agriculture, using inputs or methods that are safe for human health, animal health and the environment" (DOF, 2020).

In the search for sustainable proposals that contribute to the gradual substitution of the use of glyphosate herbicides, to maintain the production and which are favorable for human health, the biocultural diversity and the environment in Mexico, a study was conducted on the profitability of production of glyphosate-free corn in the Agroecological Lighthouse "Grupo Vicente Guerrero", Tlaxcala. The production system in this place, corresponds to a rational management of natural resources, which considers biological diversity and without the use of products of chemical synthesis with the aim of obtaining healthy foods, and in addition, conserving and even improving soil fertility.

According to Infante (2015), an agroecological lighthouse is one of the centers where technical knowledge and agroecological processes are shared to guide the local producers towards sustainable systems.

Any project that provides demonstration, formation and training based on local practices can be known as an agroecological lighthouse. The technical, social and cultural proposal is sustained by the work with communities in the area where they are established and sustainable agroecological practices are implemented.

For Tlaxcala, the corn crop has great importance and cultural rootedness. Most of the production is in smallholdings and rainfed, although it depends on climatic aspects, and ranges between 100 and 120 thousand annual hectares. Meanwhile, the few producers that use irrigation have remained under 20 thousand (Massieu, 2017). According to Vega *et al*. (2022), corn is the crop of greatest economic, social, cultural and political importance in Tlaxcala, and in the year 2019 it was planted in 47% of the state agricultural area. However, the problems related to its production, improvement and conservation are diverse, complex and progressive, as Damián and Ramírez (2008) mentioned; the technological innovations generated are based on the use of agrichemicals and do not consider peasant technologies. This is why the use of synthetic agrichemicals is low among small-scale producers, and in addition, peasant technologies are more relevant in corn management than the recommended technologies based on the use of agrichemicals, since the deterioration of productive resources is accelerated and they contribute to global warming of the planet.

Likewise, Vega *et al*. (2022) pointed out that, in the state of Tlaxcala, the current problems in corn agroecosystems are diverse, complex and with cumulative effects in time; thus, the studies carried out on corns of the state do not seem to be enough to explain all the factors involved in these problems.

The objective of this study was to conduct a comparative study of the profitability of corn production under a glyphosate-free agroecological system and another under the conventional system with use of agrichemicals.

METHODOLOGY

This research was developed in the state of Tlaxcala, whose capital is Tlaxcala de Xicohténcatl, with an area of 4,060 km2; it has 60 municipalities and its extension represents 0.2% of the national territory. With a population of 1,342,977 inhabitants, it constitutes 1.1% of the entire country; 83% of the population of the state is considered urban and 17% rural. The education level is 9.8 years (almost the first year of high school) and its contribution to the National GDP in 2020 was 0.6%. It borders south, east and north with the state of Puebla, northwest with Hidalgo and west with Estado de México. The state is located at altitudes between 2,200 and 4,400 m, has temperate-humid climate, and a mean annual precipitation of 711 mm (Instituto Nacional de Estadística, Geografía e Informática [INEGI], 2022).

Two study sites were selected for this study:

1. Agroecological Lighthouse "Grupo Vicente Guerrero" in Tlaxcala. This site was chosen because corn production is free of glyphosate and other toxic agrichemicals. The community of Vicente Guerrero is located 40 kilometers from the city of Tlaxcala, northeast of the state, in the municipality of Españita (Carrillo and Ramírez, 2017). This group is characterized by its trajectory in agroecological agriculture and the promotion of alternative technologies; it is a peasant organization that drives sustainable development, with the purpose of consolidating alternatives to face poverty and environmental deterioration, to allow a better quality of life, primarily from the rural population. Its social objective is to promote, train and advise peasant organizations, communities, producers and institutions to achieve an ecologically sustainable development and a self-managing, more just, equitable society that is in harmony with nature. One of the main crops that are obtained in the lighthouse is corn. In the Agroecological Lighthouse, 20 producers that belonged to the lighthouse were selected, which represent 10% of the total who are registered (the Lighthouse has 100 producers, according to the representatives).
2. Creole corn producers in Huamantla and Tlaxcala. The municipality of Huamantla has an approximate territorial extension of 331.92 km^2, representing 8.7% of the state surface. It borders north with the municipalities of Xaloztoc, Terenate and Altzayanca; east with the municipalities of Altzayanca, Cuapiaxtla and the state of Puebla; south with the state of Puebla and the municipalities of Ixtenco, Zitlaltepec de Trinidad

Sánchez Santos and the state of Puebla; west with the municipalities of Teolocholco, San Francisco Tetlanohcan, San José Teacalco, Tzompantepec and Xaloztoc (INEGI, 2005).

The producers who are part of the study belong to the *ejido* of Huamantla; the selection criterion for the individuals, was that they had cultivated corn in the cycle prior to the study, that they were of legal age, and that they had the availability to answer a survey and participate in a course about corn management.

A directed survey was used, which was applied to both groups of producers; the use of surveys is used in different disciplines to perform exploratory studies, since it allows capturing abundant and basic information about the problem; it is also used to sustain hypotheses and guide the strategies to apply other data collection techniques. The structured or directed survey is used when there is not enough informative material about certain aspects that there is interest in researching, or when the information cannot be obtained through other techniques (Rojas, 2002).

The production costs were obtained for the profitability analysis of the crop with the methodology of producers' panels (Red Mexicana de Investigación en Política Agroalimentaria [Agroprospecta], 2009, 2010; Ireta *et al.*, 2015), with groups of producers of similar characteristics at the technological level and surface destined to the crop. "The panels technique consists in gathering a group of producers through non-probabilistic sampling of expert selection" (Pimienta, 2000; Franco, 2018). In these panels, the estimation of production costs and incomes is carried out; the producers allow performing such estimation through consensus. Franco *et al.* (2018), mentioned that the producers' panels are an adaptation of the "Delphi" technique, used with the purpose of obtaining reliable and consensual responses from a group of "experts" (Dalkey and Helmer, 1962), which represent the relevant population to study (Domínguez and Gómez, 2013). It is recommended that producers have the same production system, technological level, with knowledge and information about technical parameters and production costs, recognized as opinion leaders to participate in the panels. According to Ireta *et al.* (2018), the methodology proposed by Agro-prospecta allows, through the consensus of participant farmers, to obtain the production costs for a specific agricultural cycle. Franco *et al.* (2018), points out that the results lack statistical significance; however, they are indicative of the situation of the production units with similar characteristics to the PRUs analyzed, located in the study zone. This methodology, is an alternative to the scarcely available resources to carry out research (Pimienta, 2000; Sagarnaga and Salas, 2014). In this study, two producers' panels were carried out in each locality with small-scale producers, each integrated by ten producers, by direct invitation, and the requirement was having cultivated corn in 2021. This methodology allows for producers meet in a specific date.

The concepts that were included for the calculation of the production costs, were soil preparation, seed, fertilizer, chemical products, workforce, and land rental. These include the average surface, of their own or rented, that they devote to the producers' crop; this

shows the cost structure that is average and representative of each stratum of producers. The calculation of profitability corresponds to the spring-summer cycle of 2021. The productivity and production costs were determined to quantify the profitability.

The costs included those of the inputs and the production means, such as seeds, fertilizers and workforce. General expenses were also included. Swenson and Haugen (2012) divided the costs into direct and indirect; the opportunity cost of the workforce which many times is familiar. To determine the profitability, the following algebraic expressions were used, based on economic theory (Krugman and Wells, 2006; Samuelson and Nordhaus, 2009): TC=PxX.; where TC = Total cost, Px= Price of the input or activity x, and X= Activity or input. The total income per hectare, is obtained by multiplying the yield of the crop by its market price. The algebraic expression is: TI= PyY; where TI= Total income ($ ha-1), Py=Market price of the crop and ($ t-1); Y= Crop yield (t ha^{-1}). Finally, the profitability is calculated with the following formula: Profitability= TI – TC. The profitability should be higher than zero for it to be considered positive.

RESULTS AND DISCUSSION

The farmers from the Agroecological Lighthouse that were surveyed manage rainfed corn as poly-crop, that is, associated with bean, squash and multiple weeds, agroecosystem known as *milpa.* The preparation of the land, is mechanized and the management of the productive process is agroecological.

The producers use inputs in crop management, such as: composting, vermicompost, leachate, bokashi, rock flours, beneficial microorganisms, green manure, plant extracts, and mineral products; this type of inputs are used in the production process of corn cultivation, where no chemical products are used.

Traditional producers from Huamantla plant rainfed native yellow corn. The land preparation is mechanized, as well as some agricultural tasks. It is known that the corn producer, does not have a technological package validated by any research institution such as INIFAP (*Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias*), where the correct doses are indicated per hectare for seed, fertilizers, pesticides and herbicides for the producing zone in the state, which is reflected in the production costs and influences the crop's profitability (Table 1). The farmer generates his technological package empirically and tends to the crop as he observes the plant development. He decides to apply inputs (fertilizers, agrichemicals, etc.) according to (or based on) his experience with the crop, observing and replicating what happens in the neighboring plots, whether the product or the results obtained convince him, or if there is good reference from a leading producer in the region; or else, following the generic indications provided by the technician-seller of the commercial house of the region's inputs.

Yields

Regarding the yields obtained, it was seen that in the Agroecological Lighthouse they were higher, compared to those obtained by producers in Huamantla. Meanwhile, the farmers

Table 1. Profitability of corn, prices from 2021.

Activity	Agroecological Lighthouse Vicente Guerrero	Huamantla Tlaxcala
Land preparation ($) (1)	$2,366.70	$3,980.00
Agricultural tasks ($) (A+B+C+D) (2)	$9,180.70	$3,556.00
Weed management ($) (A)	$5,400.70	-
Nutritional management ($) (B)	$2,030.00	-
Pest and disease management ($) (C)	$1,750.00	$1,606.00
Other activities (e.g. Application of herbicides or weeding) ($) (D)	$0.00	$1,950.00
Inputs ($) (3)	$4,900.50	$4,814.00
Harvest ($) (4)	$1,930.00	$1,890.00
Total cost ($/ha) (5=1+2+3+4))	$18,377.90	$14,240.00
Yield (t ha^{-1}) (6)	3.50	2.50
Price ($/t) (7)	$6,500.00	$5,000.00
Input per ha ($) (8=6*7)	$22,750.00	$12,500.00
Utility per ha ($) (9 = 8-5))	$4,372.10	-$1,740.00
Cost ($/t) (10= 5/6)	$5,250.83	$5,696.00
Utility per t ($/t) (11=7-10)	$1,249.17	-$696.00
Benefit/Cost Rate (12=7/10)	$1.24	$0.88

Source: prepared by the authors, based on field information during 2021.

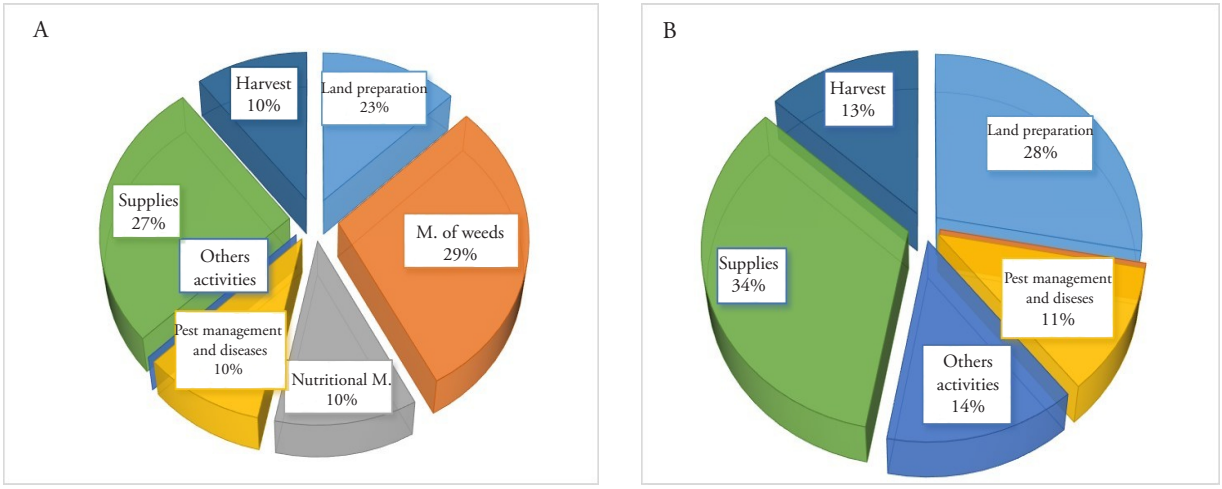
with the agroecological scheme obtained an average of 3.5 t ha^{-1}, higher even than the national and state average, in addition to the production of bean and squash obtained; for farmers with conventional system, the average yield was 2.5 t ha^{-1}, lower than the state average of 2.72 t ha^{-1} and the national one of 3.34 t ha^{-1} (Sistema de Información Agroalimentaria y Pesquera [SIAP], 2021). The low yield, is consequence of the lack of a technological package adapted to the climate conditions of Huamantla, which has a direct impact on the productivity of the crop.

Production costs

Table 1 shows the comparison of the profitability of the corn crop for the two sites and the two production systems studied.

For the farmers of the Agroecological Lighthouse, the costs are different in every aspect, but the highest one is from other activities (50%) which includes weed management (manual control or with implements such as hoe or machete), nutritional management (application of compost or elaboration of their own manure, such as leachate), and pest and disease management (use of minerals and biological control). These cultivation tasks, are substituted in the conventional management with the use of herbicides and other agrichemicals (Figure 1A).

For the proposal of practices directed to the substitution of herbicides, the knowledge that farmers have accumulated from the participation of researchers in the region is used, some of them even used by farmers as food. Much of the profitability is explained by differences in price and yield, which has nothing to do with agroecological practices, although it does



Source: prepared by the authors for this study.

Figure 1. A: Corn production costs in the Agroecological Lighthouse. B: Corn production costs in Huamantla, Tlaxcala.

with the type of product, which is considered to be agroecological and allows offering it at a higher price. The production under organic methods is also developed to take advantage of the environmental and socioeconomic conditions that are favorable for the activity and provide a sustainable alternative to the production systems of small-scale producers, cooperative members, *ejidatarios* and *comuneros* (DOF, 2006).

The agroecological management of corn production, requires a larger workforce, approximately 32 to 38 day laborers, and in some cases the workforce is family-based; however, due to the accelerated field-city migration the workforce available in the rural sphere has drastically reduced, conflict which communities of this type face.

According to the Corn Product System-Tlaxcala (2009), the workforce is scarce and difficult to obtain. Facing the seasonal nature of field employment, the young population prefers to be employed in the nearby factories or to migrate to the United States. This situation, makes it hard to find occasional day laborers, and the most frequently available are those of advanced age, since they are no longer employed in the factories, nor have clear possibilities for work in other countries. From this, they only work a few hours and make sure that food and transport are provided as part of their conditions.

Under this scenario, Jaramillo *et al.* (2018) indicated that the diversification of activities of small-scale farmers and peasants, has always been a basic survival strategy, developed through the combination of agricultural and non-agricultural activities that can be developed within or outside the production units. This situation is seen in the study region, since producers carry out other economic activities at the same time as agriculture, with which they may attain incomes while the corn harvest is obtained.

For the case of producers in Huamantla, Tlaxcala, they use on average 16 workdays, and they destine a higher percentage to the purchase of inputs such as fertilizers, pesticides

and herbicides. There is no control in nutritional and weed management, since they base their production scheme in the use and application of chemical inputs and without technical accompaniment. The application of herbicides or chemical inputs is considered in other activities. It was seen that the lack of knowledge of producers about production technologies and, as consequence, the ill use of implements and application of incorrect doses of inputs results in an increase of production costs. For Damián *et al*. (2008), the excessive use of fertilizer in the state is a key factor derived from the predominant type of soils: cambisols, which are scarcely developed and similar to the original material, so their productivity is low.

Profitability

In the Agroecological Lighthouse, a positive utility was obtained; the farmers presented economic profit in corn production, in addition to bean and squash production, which is obtained in the productive process and serves for auto-consumption. On the other hand, the Huamantla producers had losses per ton in their production, which means that conventional production of Creole corn using chemical inputs is not profitable in the study site.

Agroecological producers, mentioned a higher price compared to producers with conventional management. The better yields and prices in the Agroecological Lighthouse allow for their production to be profitable. According to the estimations performed with the data provided by the producers, the benefit-cost (B/C) rate was 1.24 in the community of Vicente Guerrero, which means that for each peso invested, 24 cents are being earned, indicating that the activity of growing corn is profitable for the producer. In addition, edible weeds can be found. This value is even lower than what was reported by Mancilla *et al*. (2020), who found values of 8.22 (B/C) under agroecological management and 3.83 under conventional growing.

To attain positive profitability values, in traditional or alternative systems, it is necessary for the practices to include technical accompaniment, as well as them being part of the system through cultivation cycles; that is, that they allow the establishment and conditioning of the plots year after year throughout many production cycles, as is reflected in the work by Mancilla *et al*. (2020), who evaluated a period of 5 years. Meanwhile, in this study, one agricultural cycle was assessed, although with the condition that the agroecological cultivation systems evaluated here have carried out these practices for many agricultural cycles. The experiences in *milpa* management are successful, since a production free of agrichemicals is obtained and the production of other crops such as bean and squash are strengthened, which allows recognizing that agroecological technologies are better for families, the environment, and favor food sovereignty. The *milpa* is a traditional Mesoamerican poly-crop that includes corn, squash and bean (Ebel *et al*., 2017); it is characterized by a synergy between these three crops that favors their yield together and generates resilience in the presence of external disturbances. Damián *et al*. (2010) mention that poly-crops, associated or multiple crops, maximize agroecological interactions, since the grouping of plants with different energetic efficiency, growth habits and root structures

use solar energy, nutrients and water more efficiently (Altieri and Nicholls, 2007). With an agroecological production of corn, farmers' work is revalued, since they elaborate their own inputs with resources from the localities, the domestic production of native seeds is promoted, the agricultural and rural economy is reactivated, and the community's social cohesion is fostered. The corn-bean-squash association also boosts the water-soil-plant-environment relationship, since bean fixates atmospheric nitrogen that is used by corn, and squash, with its wide foliage and crawling habit, protects the soil from erosion and prevents weed growth and water evaporation (Damián *et al*., 2012).

For corn producers in Huamantla, sowing this crop is done conventionally under rainfed conditions, and the preparation of the land and the harvest are mechanized. Inputs such as fertilizers, herbicides and pesticides are used; however, their application is based on their experience or from the generic indications provided by the technician-seller of the commercial house of inputs in the region. As was mentioned before, they do not know of a package recommended by INIFAP, for example. According to Damián and Ramírez (2008), the adequate use of technology translates into a higher yield per hectare, although corn production depends on the climatic conditions, which makes it vulnerable.

The producers carry out purchases of inputs individually, as well as the sale of the harvest, because they do not belong to any productive organization. Regarding training, 24% of the native corn producers from Huamantla attend training and dissemination events of production technologies for native corn in the region, which are organized by the Ejido Commissariate from San Luis Huamantla. The benefit/cost (B/C) rate was 0.88, which means that for each peso invested 12 cents are being lost, indicating that native corn growing under conventional conditions is not profitable for the producer in Tlaxcala. However, despite the low profitability of the crop, the producers continue sowing corn because of traditions, since 60% of the production is destined to auto-consumption because it is a basic food.

Among the main problems of the crop, there are high costs of production, caused by the inadequate use of inputs, from the purchase of seeds, fertilizers, and in some cases, herbicides and pesticides; likewise, the production is rainfed, and in some cases, the producers use varieties or hybrids that require irrigation. It is important for the producer to understand and have access to technological packages of commercial production, which consider the planting densities per hectare, the fertilization doses, and the optimal recommendations for application according to the phenological stage of the crop, which together will foster the decrease in production costs and improve the productivity, primarily for that which is destined to commercialization.

The lack of knowledge already mentioned of Huamantla producers, of the adequate technological packages to cultivate native corn, has the consequence of applying incorrect doses of inputs, such as seed or fertilizer, increasing the production costs and the deterioration of the crop yield and, as consequence, affecting the profitability. According to Ayala *et al.* (2013), it is essential for producers to reduce their production costs per ton, which can be achieved with the adoption of technology by the producers.

Damián and Ramírez (2008) point out that peasant technologies are more relevant in corn management than the technologies recommended by INIFAP or other institutions, which are characterized because they have been created with research models imported from developed countries, due to the low impact they have in the increase of productivity among producers in the state of Tlaxcala, and because they are based exclusively, on the use of agrichemicals, accelerating the deterioration of productive resources and contributing to the planet's global warming.

In this case agroecological technologies, showed higher yields per hectare, because they boost agronomic interactions, promote agriculture-livestock production synergy, and are more efficient in the use of natural resources. Damián *et al*. (2010) mention that in corn management in the state of Tlaxcala, the use of peasant technologies is essential, which under the conditions of the farmers studies, were more productive than the technologies based on the use of modern inputs that accelerate the deterioration of human and natural resources. It has been shown that peasant technology has generated a harmonious relationship between man and nature through time, and for this reason they induce agronomic interactions which improve the productivity of the scarce resources used by corn producers.

CONCLUSIONS

The use of products that are alternative to conventional production, such as organic manures, is reflected in the cost reduction from purchasing them, as well as the decrease in activities. A lower cost could be reflected in the benefit/cost (B/C) rate of 1.24.

To attain positive profitability values, it is necessary for the practices to include technical accompaniment, as well as them being part of the system throughout cultivation cycles; that is, they allow the establishment and outfitting of the plots year after year, through various production cycles.

The production under agroecological schemes, requires greater workforce and demands more effort in work, compared to conventional production.

For the case of Huamantla farmers, the profitability is negative; the absence of a relationship between corn producers and research institutions, in addition to the lack of knowledge of technological packages to cultivate corn in the state of Tlaxcala, has as consequence of the incorrect application and excessive use of inputs such as seed or fertilizer, which causes the increase in production costs and the deterioration of the crop's profitability, although it is corn that is destined for auto-consumption. The benefit-cost rate indicated losses for the producer. Based on this, to contribute to the increase in yield per hectare and attempt to conserve traditions in the techniques for corn production, it is necessary to design a strategy that contributes to the dissemination of technological packages apt for each native corn-producing region, which will favor the profitability of corn.

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