

## **Tlaxcala, research on native and improved corn: problems, fields of knowledge and new challenges**

Isrrael Vega Álvarez  
Diego Flores Sánchez<sup>§</sup>  
Miguel Jorge Escalona Maurice  
Fernando Castillo González  
Mercedes Aurelia Jiménez Velázquez

Postgraduate College-*Campus* Montecillo. Mexico-Texcoco Highway km 36.5, Montecillo, State of Mexico, Mexico. CP. 56230. (isrrael.vega@colpos.mx; mescalona@colpos.mx; fcastill@colpos.mx, mjimenez@colpos.mx).

<sup>§</sup>Corresponding author: dfs@colpos.mx.

### **Abstract**

Corn is the crop of greatest economic, social, cultural and political importance in Tlaxcala, in 2019 47.6% of the state agricultural area was sown. However, the problems related to its production, improvement and conservation are diverse, complex and progressive. Currently, the well-being of society is associated with the value that scientific knowledge adds to products and services, so the objective of the essay was to quantify and contrast some components of the published studies regarding corn in the state, to recognize their main trends. The documentary research was carried out through metasearch engines, bibliographic databases, library web portals, as well as specialized book and journal search engines. Two hundred forty-two documents published from 1951 to 2020 with a trend of progressive increase over time were recorded, of which 78.5% refer to native corn and 21.5% to improved materials. The fields of study with the highest frequency were technology, genetic improvement, social anthropology and productivity, which represent 51.2% of the total. Research has been conducted in the 60 municipalities of the state, most of it in Huamantla, Españita, Ixtacuixtla and Ixtenco. The institutions that have participated are 42, most of the documents were generated by COLPOS, INIFAP and BUAP. It seems that the published studies are not enough to explain all the factors and solve the problem. That is why it is imperative that researchers formulate a plan aimed at concrete results, which trigger changes in favor of farmers, population and environment.

**Keywords:** institutions, metasearch engines, networks.

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Corn was domesticated in Mexico in the Balsas River basin about 9 000 years ago (Matsuoka *et al.*, 2002; Ranere *et al.*, 2009). In the Puebla-Tlaxcala valley, human groups cultivated corn, beans and squash more than 3 000 years ago (Snow, 1976; Lesure *et al.*, 2006). In this way, the genetic diversity of corn has been generated by means of varietal complexes in the different agroecological conditions of the state. At present, the genetic wealth of corn is the set of populations managed by farmers, it is estimated that of the total production units that grow corn, 91% sow native materials (María *et al.*, 2019). In 2019, 111 682 ha of corn were sown, which represented 47.6% of the agricultural area of Tlaxcala; however, the area has decreased by 24% compared to 1980, where 147 450 ha were cultivated (SIAP, 2020).

The problems of production, improvement and conservation of corn in Tlaxcala are complex and diverse, the most documented is presented below. Soil erosion or loss began approximately 2 700 years ago during the pre-Hispanic Texoloc period, with the increase in population in the Puebla-Tlaxcala basin, which caused the intensification of agriculture and irrigation systems (Heine, 2003). Currently, Tlaxcala is the second state most affected by erosion, 92.9% of its area presents some degree, 16.8% is extreme, 16.3% strong, 15.6% mild and 44.9% moderate. The areas with exposure of the bedrock in more than 90% (extreme erosion) are in 1) Hueyotlipan-San Simeón-Apizaco; 2) from Nanacamilpa to Villa Mariano Matamoros; and 3) from Tlaxco to the border with Hidalgo, while the main areas with strong erosion are in, i) La Malinche; and ii) central corridor of the state from the north of Apizaco to the south of Tlaxcala and Santa Ana Chiautempan (Bolaños *et al.*, 2016). The rate of soil loss in the state ranges from 1 t ha<sup>-1</sup> year<sup>-1</sup> at sites classified with mild erosion to 478 t ha<sup>-1</sup> year<sup>-1</sup> at sites with very high erosion (Alvarado *et al.*, 2007).

The area with good potential for corn production is only 58% of the total area sown, while the remaining 42% is classified between medium and low potential (Castillo and Fernández, 2007). The meteorological disasters with the greatest impact on the crop are droughts and frosts, which are frequent. The geographical position is the main factor that explains the incidence of frosts, in winter the cold air masses from the north arrive using the Sierra Madre Oriental and Occidental as corridor flanks until impacting with the Sierra Volcánica Transversal, where Tlaxcala is located. In addition, drought and frosts intensify in the so-called 'dry years', which are characterized by the absence of rains in April and high temperatures in May (Mendoza, 2012).

Altered precipitation and temperature patterns are the most obvious indicators of climate change, one of the main problems in rainfed agriculture, and have caused significant losses and low yields to corn producers in the state (Damian *et al.*, 2013). In a study carried out in 32 of the 60 municipalities of Tlaxcala, farmers identified that climate change has caused, a) delay in the start of the rainy season, before they began in May now until June; b) prolongation of the drought period, from May to July; and c) delay of the frost period, they currently start from September. Similarly, it was determined that drought is the most frequent disaster, indicated by 40% of farmers, followed by frosts (30%). The adaptation strategies used are: change in the date of sowing and selection of resistant seeds, used by 28%, in addition to the application of organic fertilizer (26%) (Orozco *et al.*, 2019).

Regarding the technology used by the farmers from Tlaxcala, the transfer of the technological package created by the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish) has a low adoption due to the following factors: the frequency

of training was low, only 8.3% of farmers were trained, the population is elderly with an average of 58.8 years, the level of schooling was 3.9 years, access to land is low with an average of 2.3 ha and access to irrigation is minimal 0.08 ha.

While traditional technology is used by a greater number of farmers, such as the sowing of native seed (92%), crop association (65%), crop rotation (66%), soil conservation techniques (64%) and manure fertilization (66%). On the other hand, the transfer of local agricultural knowledge is interrupted by migration, since 17% of the people who make up the family structure emigrate (Damián and Ramírez, 2008). In addition, 74% of the state's corn producers carry out other economic activities to complete family spending, also called pluriactivity. These conditions interrupt the transfer of knowledge and the good performance of agricultural work (Damián *et al.*, 2008, 2011).

On the other hand, it was found that the national agricultural policy has not contributed to the improvement of productivity, social welfare or the sustainability of the natural resources of the corn producers of Tlaxcala (Damián *et al.*, 2008). In state policy, the Secretariat of Agricultural Development (SEFOA, for its acronym in Spanish) promotes the use of hybrid corns that present risks of adaptation and leads to loss of agrobiodiversity (Lazos, 2014).

Regarding the INIFAP Experimental Site in Tlaxcala, which is the institution empowered to carry out agricultural research, they have not considered core factors of local agroecosystems, such as multiple crop products, germplasm adapted to local conditions, economic situation of farmers, and benefit-cost ratio, so the adoption of their technologies is low among small corn producers, being used by less than a third (Damian *et al.*, 2013). At the state legislative level, the 'Law for the Protection of Corn as Original Heritage, in Constant and Food Diversification, for the State of Tlaxcala' was approved in January 2011, which aims to declare landrace corn from Tlaxcala as the state's food heritage, promote the sustainable development of corn and promote the productivity, competitiveness and biodiversity of landrace corn, among others (Medina, 2016); however, no strategies for the development of the crop and the family economy have been built.

The problems present in corn production systems must be explained, quantified and solved through participatory comprehensive scientific research and medium- and long-term programming. To start, it is essential to examine the published studies, to know the available information and thus generate the solutions and develop the potentials of the crop. In the present work, the compilation and classification of studies conducted in Tlaxcala with native germplasm of the state and materials generated by conventional genetic improvement that could be used in its territory was made.

The compilation of documents was done in metasearch engines: Redalyc, SciELO, CONRICYT, Dialnet, WWS, Elsevier and SpringerLink; bibliographic databases: Scopus, Sirius, Pascal and Francis, AGRIS, and AGRICOLA USDA; library web portals: SIDALC, COLPOS, UACH, BUAP, UATx, COLTLAX, UNAM, IPN, UAM and COLMEX, as well as specialized book and journal search engines. The objective was to examine some components of the published studies, such as years of publication and fields of knowledge classified by types of corn, geographical distribution, participating institutions and means of publication, to obtain the general perspective of the studies conducted to date, as well as to know the main trends and actors involved.

## Research on corn in Tlaxcala

In the current era, prosperity is associated with the value that scientific knowledge contributes to the generation or improvement of products and services. Research is a necessary activity to improve production processes, as well as the management, conservation and use of natural resources, food, education and other requirements (Maravert *et al.*, 2016). However, investment in research and development in Mexico has been precarious and with a downward trend, in the period from 2008 to 2017, only 0.42% of gross domestic product (GDP) was allocated on average, in contrast to an emerging country such as Brazil, 1.2% was allocated for the same period, while in the United States of America 2.74% (RICYT, 2018). In addition, in Mexico, public policy lacks the implementation of long-term research that addresses problems of regional interest, with certainty in financing, social relevance, transparency in the use of resources and accountability (Paredes and Loyola, 2006).

The scientific production in agricultural sciences of Mexico for the period of 1983-2002 was characterized based on bibliometric indicators from refereed papers. A linear growth trend was observed, with an average annual production of 787 papers, the states with the highest contribution were the Federal District, today Mexico City, with 30.77% of the total and the State of Mexico with 22.71%. For its part, Tlaxcala ranks among the last with 0.27%, along with Campeche (0.14%) and Hidalgo (0.11%) (Bravo-Vinaja and Sanz-Casado, 2008). The participation of each state can also be assessed by the number of researchers with membership in the National System of Researchers (SNI, for its acronym in Spanish), a program that recognizes the professional work in the generation of scientific knowledge and technology.

In the area of biotechnology and agricultural sciences, 4 409 researchers are registered nationwide. The geographical distribution of SNI researchers is similar to that of scientific production, in the first places the State of Mexico with 480 researchers that represent 10.89%, while in Mexico City, 342 that represent 7.76% and Tlaxcala among the last places with 24 (0.54%), followed by Colima with 19 (0.43%) and at the end Quintana Roo with 9 (0.2%) (CONACYT, 2020).

In the present bibliographic exploration, 242 documents on corn were recorded, published between 1951 and July 2020. Research and dissemination documents such as scientific papers, technical notes, descriptions of new varieties, books, bachelor's, master's and doctoral theses, conference proceedings, reports, as well as technical brochures were included. They were ordered by field of study and type of corn, Table 1 shows the classification, separating publications of native corn from improved corn, or that refer to both types in the same document.

The topic of technology is the most studied (17.4%) and studies on technology transfer with the green revolution type approach predominate (45.2%), followed by response and recommendation of fertilization doses (26.2%), peasant technology, crop association, cultural work and in recent years, technology of food made with native corns.

Studies in social anthropology represent 10.7% of the documents, of these, the topics addressed are: peasant economy (38.5%), peasant agricultural knowledge (30.8%) and new rurality (30.8%). The physical and chemical description class refers to the assessment of grain, plant and products made with corn, in which biochemical methods were applied (42.9%), morphological characterization by plant descriptors (33.3%) and determination of agronomic variables in 23.8%.

**Table 1. Studies by field of study and type of corn from Tlaxcala.**

Field of study	Native	Improved	Native with improved	Accumulated percentage
Technology	32	3	7	17.4
Genetic improvement	10	19	3	13.2
Anthropology	25	1	-	10.7
Productivity	17	3	5	10.3
Physical and chemical description	19	-	1	8.3
Agroecosystem	17	-	2	7.9
Pests and diseases	15	2	-	7
History	13	-	-	5.4
Climate change	10	-	1	4.5
Soils	8	-	-	3.3
Politics	6	2	-	3.3
Meteorological factors	5	1	-	2.5
Transgenics	5	-	1	2.5
Commercialization	3	2	1	2.5
Biocultural heritage	3	-	-	1.2
Total	184	38	20	100

Made with documentary research data from 1951 to 2020.

For the assessment of genetic diversity, it is necessary to collect native corns and, on that basis, plan genetic improvement. The first exploration of extensive collection at the national level was carried out from 1943 to 1949 (Table 2), through a cooperative agriculture program between Mexico and the United States of America, the objective was to detect outstanding material to increase production and reduce imports (Casas and Martínez, 2009).

**Table 2. Collections of native corns in Tlaxcala and participating institutions.**

Period	Institution	No. of accessions
1943-1954	Office of Special Studies	60
1968-1979	National Institute of Agricultural Research (INIA)	479
1979-2009	National Commission for the Knowledge and Use of Biodiversity (CONABIO), INIFAP, UACH, UAAAN	254
2008	Antonio Narro Autonomous Agrarian University (UAAAN), funded by MONSANTO Company	-

Made with data from Wellhausen *et al.* (1951); CONABIO (2008); Ortiz and Muñoz (2016).

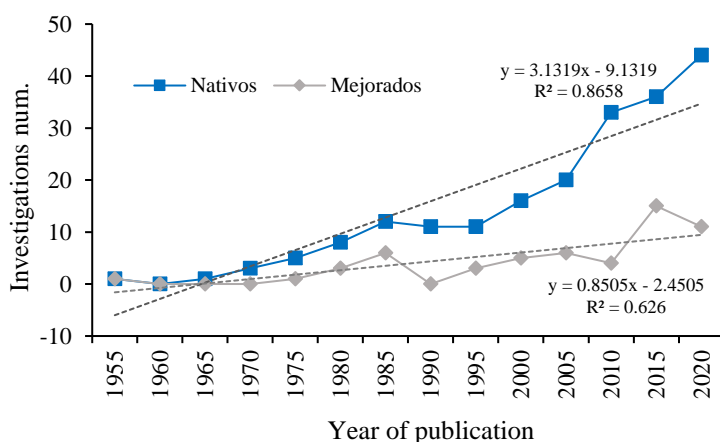
The National Institute of Agricultural Research, today INIFAP, made the second national collection, expanding the number of sampling sites, in Tlaxcala samples of 7 different races were obtained in 37 municipalities (CONABIO, 2008). Some were evaluated to select the most outstanding, the accessions Tlax 151 of white grain and intermediate cycle and Tlax 208 of early cycle and yellow grain stood out. Genetic improvement was carried out by means of the modified mass selection method, with which the improved rainfed varieties, Huamantla V-23 and Cuapiaxtla V-26A, were released (Carballo and Mendoza, 1981a, b).

A fraction of the important diversity among the native corns of high valleys are the pigmented ones, whose bioactive properties are considered nutraceutical. In Tlaxcala, the progress in the improvement of these corns is significant, from the evaluation of the content and productive potential of anthocyanins in native populations, to the determination of the agronomic potential of hybrids and synthetic varieties, among others. Currently, genetic improvement focuses primarily on generating, evaluating and transferring hybrids of intermediate and late cycle, with high yield potential for regions with a predominance of irrigation and mechanized agriculture. The limitation is that, in Tlaxcala, only 18 777 hectares sown with corn have irrigation (16.8%), while 92 905 ha are rainfed (83.2%) (SIAP, 2020). In addition, native corn seeds predominate in more than 91% of the corn area (María *et al.*, 2019).

### Territorial trends and timeline

Research in agricultural sciences is mostly carried out in industrialized countries, even so, with the budgetary restrictions in Latin America, relevant contributions are made. In a bibliometric study carried out to know the temporal (1995-2002) and spatial distribution of indexed papers in Latin America, an increase ranging from 9 in the first year to 92 in the last year was found, with Brazil being the country with the highest number with 244, followed by Mexico with 109 (Arenas *et al.*, 2004). In the present documentary research, there was also a trend of progressive increase, despite some years without publications between 1952 and 1993. The timeline is divided into two periods, in the first, from 1951 to 2002, an average of 2.6 investigations are estimated and in the second period, from 2003 to 2020, a notable increase to 8.9 publications per year was found.

Native corns are the most widely distributed and frequent in the state, and 78.5% of research works have been dedicated to them, while improved corns, mostly hybrids, are described in 21.5% of documents. Figure 1 shows the frequency of publications accumulated in periods of 5 years, of research on native and improved corns. In the native class, there is a constant increase, and two stages are identified, the first from 1951 to 1996 with an average of 2.1 studies for the years with publications, and the second from 1997 to 2019 with an increase to 6.3 publications per year. On the other hand, research on improved corns for the entire study period has remained with an average of two publications per year.



**Figure 1. Five-year frequency of studies by type of corn in Tlaxcala (1951-2020).**

The participation of institutions by geographical location had the following distribution: national institutions (84.4%), foreign institutions (8%) and state institutions (7.6%). The participation of foreign bodies was relevant from 1951 to 1970 because they conducted 66.6% of the works, the rest was from the National School of Agriculture (ENA, for its acronym in Spanish) today Chapingo Autonomous University (UACH, for its acronym in Spanish). The other periods where there is also foreign participation are from 1985 to 1987, with studies on agroecosystems and land use change, and from 1997 to 2003, with climate change and genetic contamination due to transgenics. On the other hand, in the period from 1971 to 1985, it stands out that most of the studies (72%) were carried out by COLPOS, the National Institute of Agricultural Research (INIA, for its acronym in Spanish) and UACH, various institutions joined in the following years.

Research on corn has been done in the 60 municipalities of Tlaxcala, some were part of the state sample and others the study site. The largest number of studies is reported in Huamantla, 44 of native corns and 27 of improved corns. The least frequent are Acuamanala de Hidalgo, San Juan Huactzinco and Santa Catarina Ayometla, each with 15 native and one improved.

It should be noted that not all the research works found refer to any specific municipality, some describe regions, several refer to the entire state and others do not specify sampling sites. Huamantla is the municipality with the greatest variety of topics of study, of the classification in 15 fields, 13 are studied, the most frequent are on productivity (12), genetic improvement (11) and agroecosystems (8).

It is followed in importance by three municipalities in which 11 fields of knowledge are studied, in Españita, social anthropology has been addressed more frequently, with nine investigations, Ixtacuixtla de Mariano Matamoros on genetic improvement (9) and Ixtenco that also stands out for its studies in social anthropology (10).

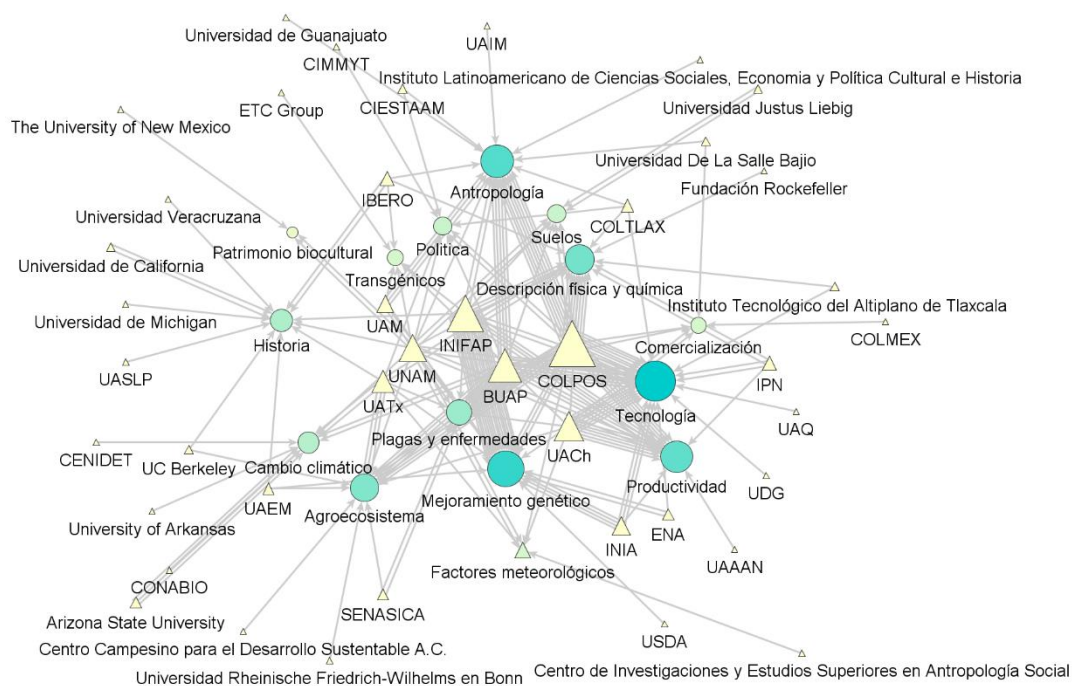
While the municipalities with the least diversity are Acuamanala de Miguel Hidalgo, Mazatecochco de José María Morelos, San Juan Huactzinco, Santa Apolonia Teacalco, Santa Catarina Ayometla and Tetlatlahuca, with five themes in each place. On the other hand, the fields of knowledge with coverage in all jurisdictions of Tlaxcala were technology with an average of 5.4 studies per municipality, anthropology with an average of 5.5 and climate change with an average of 3.7 studies per municipality. The topics of less coverage were politics, soils and meteorological factors with two municipalities and commercialization with three.

### **Research institutions and their publications**

In Tlaxcala, there are higher education institutions that carry out research, those dedicated to biotechnology and agricultural sciences with researchers registered in the SNI, in order of importance, are: the Center for Research in Applied Biotechnology of the National Polytechnic Institute, CIBA-IPN-Tlaxcala, the Autonomous University of Tlaxcala (UATx, for its acronym in Spanish), the Polytechnic University of Tlaxcala, the Technological Institute of the Altiplano of Tlaxcala and the National Autonomous University of Mexico (UNAM, for its acronym in Spanish) Institute of Biology, Tlaxcala campus. Also, because in the state corn is grown predominantly under conditions of traditional peasant agriculture, research in social sciences is relevant, the participating institutions are the Autonomous University of Tlaxcala, the College of Tlaxcala (COLTLAX), the Polytechnic Institute of Apizaco and UNAM (CONACYT, 2020).

Similarly, a Law on Science and Technology was enacted in Tlaxcala, which dictates in its second article that the state government, municipalities, dependent institutions and organizations of the public, social and private sectors will be the ones who guarantee, boost and promote science and technology for the benefit of the population. This law contemplates the creation of a State System of Science, Technology and Innovation and the formation of an Institute of Science and Technology of the State of Tlaxcala (H. Congreso del Estado, 2003), although it seems that these institutions have not yet been implemented, they are already part of the planning of the state structure.

The institutions that have conducted research on corn in Tlaxcala are 42, which forms an extensive universe and expands the range of orientations and topics so that the 15 fields classified in the present essay are covered. To examine the relationships between research institutions and fields of knowledge, network analysis was applied, using the Visone 2.16 software (Brandes and Wagner, 2004) and is presented in the diagram of Figure 2.



**Figure 2. Network of institutions and field of study on research in corn from Tlaxcala 1951-2020.**

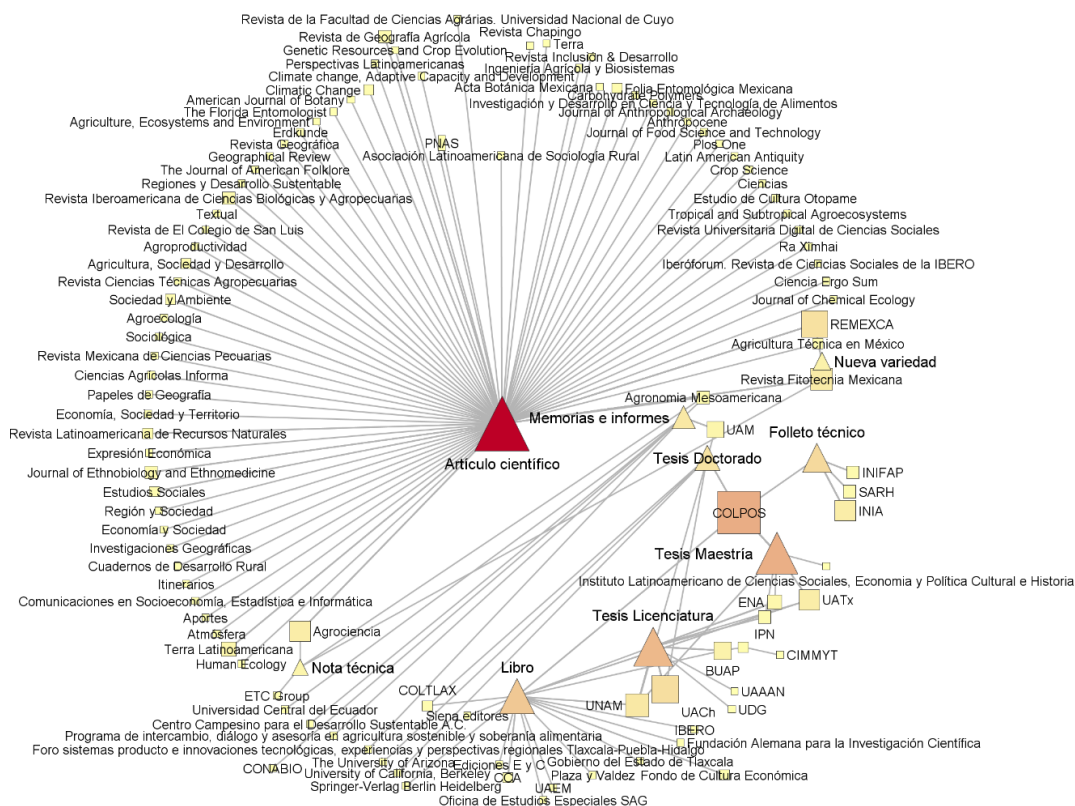
The size of the nodes represents the network attribute degree, which is interpreted as the number of nodes to which it is directly connected. In the network, the collaboration of COLPOPOS is notable, which participates in 52 of the studies in 11 fields of knowledge, its greatest number of links are in the fields of technology, social anthropology and physical and chemical description. INIFAP is the second institution with the highest number of connections, with 31, participates in nine fields of knowledge and stands out in genetic improvement, productivity and physical and chemical description.

The participation of state institutions is of low frequency, therefore, it can be an opportunity for their future studies to be directed to essential issues, which contribute to solve the problems related to the production, improvement and conservation of corns in the state. The UATx is the one with



the largest number of relationships, and participates in eight fields of knowledge, the most outstanding are agroecosystem, climate change and physical and chemical description. COLTLAX is next in importance, its contribution is in anthropology, physical and chemical description, politics and technology.

The publication of new knowledge contributes to improving the management of agroecosystems, it is very important that the information is clear, accurate and available to those interested, to streamline research processes and thus solve new challenges. Figure 3 shows the classes of documents found and their relationship with the organizations that have published them.



**Figure 3. Network of classes of corn research papers in Tlaxcala and organizations that published them.**

In the network, the size of nodes represents the attribute degree, and the color the indegree, which is the number of referred relationships. It was observed that the scientific paper format is the most used, it represented 43.7% of the documents, is the most effective for its access on the web, is also peer-reviewed and the data exposure is concise. The papers collected are published in 70 different journals, most of them of national origin and some of them from abroad. The papers are written in the following languages: Spanish (74%), English (23.1%), in both languages (1.9%) and in German (1%). The journals with the highest number of papers are the Revista Mexicana de Ciencias Agrícolas (REMEXCA), Agrociencia-CP, Revista Fitotecnica Mexicana-UACH and Terra Latinoamericana.

Master's theses are the next most frequent, they represent 13.9% of the documents, prepared and published by six different organizations. In the present study, journals were taken as publication entities in the case of papers and new varieties, publishers in the case of books and universities or institutes for theses. The UACH is the one with the highest number of bachelor's theses (45%), while COLPOS has the highest number in master's (70%) and in doctoral theses (50%). The books found were 23, some dedicated entirely to the subject and others with contributions of chapters. There are 17 publishers and institutions that publish them, which constitutes an important effort for the study and characterization of corns in Tlaxcala.

At the state level, the UATx has the largest number of publications (12), including books, bachelor's and master's theses, scientific papers among the most recent. It is followed by COLTLAX with three papers and a doctoral thesis on the defense of native corn in the state, and the Technological Institute of the Altiplano of Tlaxcala is in the third place, with two papers on technology of foods made with corn.

## Recommendations

Figure 3 shows that the distribution of documents is very extensive, which is an inconvenience for those who intend to consult them. It is suggested to organize the information in an electronic system of free access to national researchers, which records all the works related not only to corn, but to all the crops considered important for the state, each one referred to the geographical space where it was carried out, in the geoinformation portal format.

The institutions of Tlaxcala should be in charge of designing and coordinating a master plan of research on the crop, so important for the state. Among the most urgent issues are soils and fertility, which, as observed, are among those of less frequency and are important due to the strong erosion in extended areas and its persistent form (Heine, 2003; Bolaños *et al.*, 2016). The state agricultural policy is another of the main issues to be addressed since it has been little studied, as observed in the network, and is of great relevance for the state government to have the information to act efficiently in the resolution of the problem.

Likewise, it is considered that climate change should have greater attention, to know the specific effects on agroecosystems at the regional level and thus have efficient technical recommendations for mitigation and reduction of impact. The formation of improved free-pollinated varieties should be an alternative for the improvement of native corn populations, as hybrids are limited to only a few areas and the technological packages they use are very expensive, and inaccessible to most farmers.

## Conclusions

In the state of Tlaxcala, the current problems of corn agroecosystems are diverse, complex and with important accumulations over time, so the studies research carried out on corn of the state do not seem to be enough to explain all the factors and solve the problem. Erosion in the territory is remarkable, even so, the field of knowledge 'soils' is one of the least studied, as well as 'public

policy', which is fundamental to understand and improve the relationship of the state with farmers, an entity that should be one of the main actors in the promotion of sustainable corn production, since it is the most important crop for feeding the population and the one with the largest area sown.

The review shows that 'technology' is the most studied field of knowledge, but at the same time the innovations promoted have had little adoption by farmers. In contrast, 'climate change' is a little addressed issue, but it is one of the main factors that cause low yields and crop loss.

It seems that the studies have been conducted in the first place based on the capacities and resources of the institutions and the focus on the current problems has been left in second place. The trends identified in the set of studies collected were: constant increase over time in the number of studies conducted, with a significant increase in 2003. Native corns are the ones with the largest number of studies, fields of study, institutions and geographical coverage, although these contributions have not been sufficient to cover the accumulated demands.

The territorial coverage of the studies is extensive, studies have been carried out in all the municipalities of Tlaxcala, although in some only as part of the sampling. Ixtacuixtla and Huamantla stand out for being among the ones with the largest number of studies, in these, research on genetic improvement and productivity predominate. Likewise, there are high frequencies of studies in Españita and Ixtenco, these sites stand out for their activity of peasant organization, here the most frequent topic was social anthropology. The number of participating agricultural and social science research institutions is large and is a factor that has enriched the diversity of fields of study. On the other hand, the participation of Tlaxcala's research institutions has been precarious.

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