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MANAGEMENT AND *IN SITU* CONSERVATION OF PLANT GENETIC RESOURCES IN INDIGENOUS LAND USE SYSTEMS OF THE HUASTECA POTOSINA

TESIS

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CONTENT

Abstract

Traditional land use systems managed by small-scale farmers, often indigenous in Mexico, are a reservoir of plant genetic resources and are considered a backbone for secure agricultural food production and *in situ* conservation.

The *Tének* farmers in the Huasteca Potosina region in Mexico manage highly diverse food biota in their agroecosystem complex that includes swidden maize fields locally known as *milpas*, agroforestry systems mainly dedicated to coffee and fruit tree production (*te'loms*), and home gardens.

The aim of this study was to describe and analyze the total, specific and intraspecific, diversity of food crops of the agroecosystem complex of the *Tének* and to learn how diversity parameters interrelate or co-vary. It considers the three main production systems of 33 farmers operating in three communities at different altitudes. The overall research question was: How is edible plant diversity in the different land use systems being simultaneously managed by *Tének* farmers characterized, interrelated and defined?

The study registered 149 botanical species from 108 genera that belong to 53 plant families. They were registered in the *milpas*, home gardens and *te'loms*, for a total of 347 between farmer recognized variants (FVar, 238) and farmer recognized species with no variants (FSpe, 109). FVar include 68.6% of the total farmer-recognized edible plant diversity, showing the dominance of intraspecific diversity in the agroecosystem complex. This highlights the need to document the richness of the managed world's crop genetic capital at the appropriate level.

This study leads to five overall main conclusions:

(1) The *Tének* in the Huasteca Potosina cultivate a high (and, so far, incomparable) diversity of different food crops at both inter- and intraspecific levels, with the medium altitude site showing the highest diversity;

(2) The three different production systems serve as a specific pool for plant genetic resources and there is low similarity between and within systems and localities, making it necessary to prioritize depending on conservation efforts and promotion of use;

(3) The FVar in the *milpa* serve as a significant indicator of the total FVar+FSpe in the agroecosystem complex, showing that diversity covaries within and between production systems;

(4) The identification of predictor variables for crop diversity is challenging; marginal conditions (distance, slope and rockiness) seem to play a significant role; and,

(5) The *Tének* people have a deep and specific knowledge about their edible plant diversity, which they classify using a practical classification system based on utility and which has a high correspondence with Linnaean taxonomy.

Based on results and these conclusions, the agroecosystem complex of the *Tének* in the Huasteca Potosina, in terms of richness, can be proposed here as an agrobiodiversity hotspot for edible plants in Mexico, and perhaps for the world. While it is being threatened by a variety of ongoing changes, such rich biodiversity deserves efforts to guarantee *in situ* conservation, both for the benefit of the farmers and their families and for the global community.

Key words: agroecosystem, home garden, *milpa*, *te’lom*, *Tének*

Resumen

Los sistemas tradicionales de uso de la tierra manejados por pequeños agricultores, a menudo indígenas, son un reservorio de recursos genéticos vegetales y se consideran un pilar en la seguridad de la producción agrícola de alimentos, así como para la conservación *in situ*. Los agricultores *Tének* en la Huasteca Potosina en México manejan una biota alimentaria altamente diversa en un complejo de agroecosistemas de uso de la tierra que comprende campos de maíz de tumba y quema conocidos como *milpas*, sistemas agroforestales principalmente dedicados a producción de café y árboles frutales (*te'loms*), y huertos caseros.

El propósito de este estudio fue caracterizar la totalidad de la diversidad, inter- e intra-específica, de cultivos alimentarios del complejo de agroecosistemas de los *Tének*, y aprender cómo los parámetros de la diversidad se interrelacionan o covarían considerando los tres principales sistemas de producción de 33 agricultores operando en tres comunidades a diferentes altitudes. La pregunta general de investigación fue: ¿Cómo está caracterizada y se interrelaciona y define la diversidad de plantas comestibles en los diferentes sistemas de uso de la tierra que manejan simultáneamente los agricultores *Tének*?

Este estudio registró 149 especies botánicas de 108 géneros y 53 familias de plantas en las milpas, huertos caseros y *te'loms*, por un total de 347, entre variantes reconocidas por los agricultores (FVar, 238) y especies reconocidas por los agricultores (FSpe, 109). Las FVar comprenden el 68.6% de la totalidad de la diversidad de plantas comestibles reconocidas por los agricultores, evidenciando la dominancia de la diversidad intra-específica en el complejo de agroecosistemas.

Esto destaca la necesidad de caracterizar al nivel adecuado la riqueza del capital mundial de genética de cultivos.

Los resultados de esta investigación llevan a cinco principales conclusiones:

(1) Los *Tének* en la Huasteca Potosina cultivan una alta--y hasta ahora incomparable--diversidad de diferentes cultivos alimentarios en niveles tanto inter- como intra-específicos, y el sitio de altitud intermedia muestra la más alta diversidad;

(2) Los tres diferentes sistemas de producción sirven como fuentes específicas de recursos genéticos vegetales y hay una baja similitud entre y dentro de los sistemas y las localidades, haciendo necesario su conservación y promoción de uso;

(3) Los FVar en la milpa sirven como indicador significativo de la totalidad de FVar+FSpe en el complejo de agroecosistemas, evidenciando que la diversidad covaría entre y dentro de los sistemas de producción;

(4) La identificación de variables predictores de la diversidad de cultivos es un reto, sin embargo, condiciones marginales (distancia al campo, pendiente y pedregosidad) parecen jugar un papel significativo; y,

(5) Los *Tének* tienen un conocimiento profundo y específico sobre su diversidad de plantas comestibles, las cuales clasifican usando un sistema práctico de clasificación basado en utilidad, y que tiene una alta correspondencia con la taxonomía Linneana.

Con base en los resultados y las conclusiones, el complejo de agroecosistemas de los *Tének* en la Huasteca Potosina, en términos de riqueza, se puede proponer aquí como un punto clave (‘hotspot’) de la agrobiodiversidad de plantas comestibles en México, y tal vez del mundo. Siendo

amenazada por una variedad de cambios en curso, esa rica biodiversidad es merecedora de esfuerzos que garanticen su conservación *in situ*, tanto para el beneficio de los agricultores y sus familias como de la comunidad global.

Palabras claves: huertos, *milpa*, sistema agrícola, *te'lom*, *Tének*

INTRODUCTION

Agrobiodiversity and Current Trends

Biodiversity, together with the ecosystem services it provides, has gained worldwide importance as its relevance is being properly understood. Biodiversity at all its levels ranging from the variety of genes, species and ecosystems provides substantial functions to society. It provides material goods (food, fiber, timber, medicine), has protective functions (flood control, climate regulation, carbon sequestration and nutrient cycling) and provides recreational benefits (FAO 2019; Rands et al. 2010).

Biodiversity for food and agriculture or agrobiodiversity, a subset of biodiversity, includes all the biodiversity components that contribute directly or indirectly to agricultural and food production. It includes domesticated plants and animals and their wild relatives, forests and aquaculture systems, as well as associated biodiversity of cultivation systems such as microorganisms and pollinator species that sustain and maintain productivity and contribute to the stability and resilience of cultivation systems in general (FAO 2019).

The plant genetic resources that are used for food and agriculture include 80,000 edible plant species for humans. Worldwide, only 150 of the edible plant species are actively cultivated. Of these, 30 produce 95% of human calories and protein, also provided by meat, which finally is derived from forage and rangeland plants (FAO 1998; Füleky 2009). However, half of all the food consumed derives from only four plant species: rice (*Oryza sativa*), maize (*Zea mays*), wheat (*Triticum* spp.) and potato (*Solanum tuberosum*) (Janick 2001).

In view of rapid losses occurring globally, the conservation of biodiversity, including agricultural diversity is now considered urgent (e.g., CBD 2011; Girardello et al. 2019; Greve et al. 2013; Larsen et al. 2011; Naidoo et al. 2008). Main drivers of loss are climate change, international markets, consumer preferences and demography leading to land use change, pollution and overuse of external inputs, overharvesting and the proliferation of invasive species. The loss of genetic diversity is a severe concern as it is a valuable resource for genetic improvement. Local crop variants are especially adapted to specific abiotic and biotic conditions (Hanamaratti et al. 2008; Hellin et al. 2014) and there is a need for resistant varieties that are less vulnerable to adverse environmental effects such as droughts and heatwaves, which will occur more frequently due to climate change (Azeez et al. 2018; Raza et al. 2019). Moreover, the loss of local variants is intrinsically linked to the loss of human knowledge and linguistic and cultural diversity (Maffi 2002).

However, exact numbers and estimates on crop diversity loss are still missing and only a few are proven. Fowler and Mooney (1990) documented a decline in diversity of food crops in the U.S.A. comparing data from 1919 to 1983 that showed a loss of approximately 90% in varietal diversity of several vegetables and fruits. For Italy a decline of 75% in crop varieties was reported (Hammer et al. 2002). Estimations on the loss of genetic diversity exist for rice in Sri Lanka, Bangladesh and Indonesia, showing that high percentages of rice varieties are descendent from one maternal parent (75%, 62% and 74%, respectively) (Groombridge 1992). However, the famed “75% of crop genetic diversity that has been lost since the beginning of the last century” mentioned by

Nierenberg and Halweil (2005) and adopted by international organizations such as FAO[1] and IUCN[2] and others is also highly debated and considered a vague estimation because there is no valuable information on the origin of this number or the methods applied to prove it (e.g., Herforth et al. 2019; Montenegro de Wit 2015). Yet, to determine the status of agrobiodiversity remains difficult and depends on the spatial scale to be analyzed and some studies also report increases in crop diversity (Montenegro de Wit 2015; Renard et al. 2016). Still, the challenge remains to avoid crop diversity losses that are specific and contingent (Montenegro de Wit 2015).

Conservation Strategies

The conservation of crop diversity includes two main strategies: *Ex situ* conservation and *in situ* conservation. It is well-known that the combination of both strategies is the most effective way to maintain the plant genetic resources (e.g., Jarvis et al. 2000; Stolton et al. 2006). *Ex situ* conservation is the maintenance and collection of germplasm of agricultural crop variants outside of their place of origin. In 2012, Mexico inaugurated the national gene center with more than 373,200 accessions and 198,000 samples for *in vitro* conservation (SAGARPA 2014). Gene banks are important for the conservation of crop genetic diversity, especially to avoid loss of genetic diversity due to extreme environmental changes and catastrophes, but the costs of the *ex situ* approach are often very high. Problems with regeneration of the stored material makes *ex situ* storage often impracticable. Also, a relatively large number of species need to be propagated vegetatively or have recalcitrant seeds and cannot be stored in gene banks. However, one of the

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[1] http://www.fao.org/news/story/en/item/46803/icode/

[2] https://www.cbd.int/doc/pa/tools/Values%20of%20Protected%20Landscapes%20and%20Seascapes.pdf

mayor concerns is that *ex situ* conservation freezes the processes of natural adaptation and evolution (Altieri and Merrick 1987; FAO 2010).

During the past decades *ex situ* conservation has been more strongly promoted, yet *in situ* conservation is gaining importance (e.g., Jarvis et al. 2000; Stolton et al. 2006; Vincent et al. 2013) and is the focus of this work. *In situ* conservation of plant genetic resources refers to their conservation in their natural and cultural environment, where specific traits regarding abiotic and biotic conditions but also cultural needs and preferences have been selected, promoted and conserved. Approximately 89 *in situ* projects and *in situ* conservation programs have been implemented in Mexico (Molina and Córdova 2006). However, more efforts are necessary to understand the distribution of crop diversity and to define priority areas of intervention to promote and conserve the agrobiodiversity *in situ*. This is especially important for Mexico due to its position as one of the centers of crop diversity and domestication (Mastretta-Yanes et al. 2019).

Traditional Land Use Systems and their Importance for *In Situ* Conservation in Mexico

Traditional land use systems are a reservoir of plant genetic resources and contribute to a secure agricultural food production (Altieri and Merrick 1987; Thrupp 2000), at the same time making farmers' livelihoods more resilient (BI 2019). They are mainly managed by small-scale farmers who interact with the environment based on gained experiences and knowledge throughout generations (Stolton et al. 2006). Those farmers usually do not have access to scientific information, external inputs, capital, credit and developed markets (Altieri and Merrick 1987). Traditional farmers often live in marginal areas and cultivate a wide range of different crops that contribute to the diversification of diets (Gübel 2019; Kremen et al. 2012). The efficient use of crop variants that cope with diverse and often adverse conditions is also a risk-minimizing strategy of farmers to assure food production (Stolton et al. 2006; Toledo et al. 2003).

Traditional land use systems often originate landraces and variants of important food crops or serve as a refuge for crop wild relatives from the natural surroundings (Engels et al. 2006; Galluzzi et al. 2010; Stolton et al. 2006; Thrupp 1998). They usually have a high plant diversity in time and space (Stolton et al. 2006; Toledo et al. 2003). Yet current tendencies to abandon agriculture and to emphasize the use of modern or commercial variants threaten the continuation of their role (e.g., Swaminathan 2000; Wale 2011). The widespread disappearance of landraces (Angioi et al. 2011; Camacho-Villa et al. 2005; Lehmann 1981; Negri 2007; Pautasso et al. 2013) results not only in a reduction of diversity at the genetic level but is also linked to a reduction of species diversity in general and ecosystem services (Biesmeijer et al. 2006; Chambers et al. 2007; Flynn et al. 2009).

Mexico belongs to one of the centers of origin and diversity of cultivated plants that includes some important food crops like maize (*Zea mays*), beans (*Phaseolus* spp.) and squashes (*Cucurbita* spp.) (Perales and Aguirre 2008; Vavilov 1935). Ethnobotanist have documented about 7000 utilized plants in Mexico of which more than 2000 are edible (Mapes and Basurto 2016).

The global importance of Mexico regarding the origin of cultivated plants is undeniable considering the fact that 16% of the 50 most important crops (excluding crops for fodder and forage production), in terms of the quantity of agricultural production, have been domesticated in this country (based on data from FAO 2010). It is remarkable that the plants domesticated in Mexico contribute to almost half of the food that is consumed by its inhabitants (Perales and

Aguirre 2008). Furthermore, Mexico is a center of diversity and domestication of minor crops, or neglected and underutilized cultivated plants, such as chayote (*Sechium edule*), Spanish plum (*Spondias purpurea*) and *tomatillo* or husk tomato (*Physalis philadelphica*) (Hernández-Bermejo and León 1994; Miller and Schaal 2005; Ruenes-Morales et al. 2010; Vavilov 1935).

Indigenous people in tropical Mexico tend to follow a multiuse strategy of the landscape that involves polyculture agricultural systems where a high number of edible plant diversity can be found. Those polyculture management systems contain species with different degrees of humanization as well as protected, tolerated and promoted species (Alcorn 1984; Perales and Aguirre 2008; Toledo et al. 2003).

Justification

Even though the value of traditional land use systems concerning the maintenance of genetic diversity is widely acknowledged by several authors (e.g., Agbogidi and Adolor 2013; Altieri and Merrick 1987; Gbedomon et al. 2017) studies normally do not include information on intraspecific diversity in order to provide substantial data to strengthen this argument and to precisely assess agrobiodiversity in traditional land use systems (Gbedomon et al. 2017). Most studies focus on the species level (e.g., Eilu et al. 2003; Toledo et al. 1994) or consider intraspecific richness if focused on one or more target crops (e.g., Blanco et al. 2013; Perales et al. 2003). Complete inventories are scarce even when they are necessary to determine where to focus conservation and research efforts are particularly important to characterize traditional land use systems in agrobiodiversity-rich areas. Thorough baseline data are needed to detect changes in the distribution patterns of intraspecific diversity under different agroecological conditions (de Carvahlo et al. 2016; Hammer et al. 1999).

Perhaps also associated with this lack of information, a wealth of crop diversity is underrepresented in gene banks and is neglected by agricultural science and breeding efforts (Hammer et al. 1999; Wambugu et al. 2018). Until now, research and development focus primarily on improving the productivity of a small number of existing crops that form the basis of a global food economy (FAO 2019; Shelef et al. 2017; Williams et al. 2018).

The *Tének* or Huastec farmers in the Huasteca Potosina region in Mexico manage highly diverse food biota in the agroecosystem complex that comprise swidden maize fields locally known as *milpas*, agroforestry systems mainly dedicated to coffee and fruit tree production (*te'loms*), and home gardens (Alcorn 1984). The high diversity in these systems certainly deserves a thorough inter- and intra-specific characterization of edible plant diversity, thus contributing to efforts aiming at a sustainable use and conservation of these plant genetic resources.

Folk names are often the first entry point for information on the diversity maintained on farmers' fields and are used for agrobiodiversity inventories (Jarvis et al. 2000; Otieno et al. 2015). A sound understanding of how people classify and label their crops helps to reduce the error rate of agrobiodiversity inventories and facilitates comparative analyses. Comprehensive studies about folk classification with focus on the *Tének* intraspecific food crop diversity have not been conducted, limiting the capacity to describe and understand the agrobiodiversity being managed and conserved by these traditional farmers.

Objectives

General Objective

To contribute to understanding agrobiodiversity and understanding it *in situ*, the aim of this study was to describe the total, specific and intraspecific diversity of food crops of the agroecosystem complex of the *Tének* and evidence its importance for *in situ* conservation.

Specific Objectives

1. Document the inter- and intraspecific diversity of edible plants and identify specific reservoirs of diversity of edible plants.
2. Understand how diversity changes and is correlated within and among the three land use systems, farmers and localities.
3. Describe the taxonomy of edible plants of the *Tének.*
4. Propose recommendations to guide conservation actions *in situ*.

The general research question was: How is edible plant diversity in the different land use systems, being simultaneously managed by *Tének* farmers, described, interrelated and defined?

Thesis Structure

The three communities studied, located on an altitudinal gradient, together with methodological and production system details are described in the methods sections of the next three chapters. These three chapters correspond to the three scientific articles that comprise the core of this thesis.

The edible plant diversity of the *milpa*, as the most salient and perhaps relevant system was the initial focus (Chpt. 1). This is followed by a comparative analysis for the three production systems: *milpa*, *te'lom* and home garden. General environmental and socioeconomic factors were included in order to gain understanding of which external factors influence food crop diversity at crop specific and intraspecific level for the three different land use systems (Chpt. 2). Additionally, the *Tének* folk classification of inter- and intraspecific food crop diversity was analyzed in detail to contribute towards a better understanding of agrobiodiversity as classified by *Tének* farmers (Chpt. 3). Finally, in Chpt. 4, main results are discussed leading to the general conclusions. Additionally, a co-authored paper on an analysis of the fruit agrobiodiversity considered by German-Mexican Olga Costa in her painting "La vendedora de frutas" is presented in an annex as a contribution to sharing the rich agrobiodiversity found in Mexico (Annex).

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CHAPTER I

Inter- and Intraspecific Edible Plant Diversity of the Tének *Milpa* Fields in Mexico

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Traditional land use systems are often rich in crop diversity. However, complete inter- and intraspecific data are scarce, limiting our understanding and underestimating the diversity of plant genetic reservoirs. This study attempted to characterize the total edible plant diversity of the *milpas*, or polyculture maize-based fields, managed by Tének communities in México. In 41 *milpas* belonging to 33 farmers in three localities at different altitudes, 191 edible plant types were inventoried, comprising 84 species that include 140 variants and 51 species with no variants. Diversity varies between and within localities. Only 8.4% of the diversity is shared among the localities and, on average, 61.2% of the total richness is managed by single farmers. The intermediate altitude has higher diversity, including 67.5% of the total richness. Crop population numbers are low and highly variable. To contribute to the interpretation and application of results, a proposed method to identify priority crops, sites, and farmers is presented. This study shows, once again, that indigenous farming communities are key actors for the use and conservation of crop genetic diversity. More detailed studies such as this may evidence much larger managed crop diversity than currently is acknowledged.

Los sistemas agrícolas tradicionales son a menudo ricos en diversidad de cultivos. Sin embargo, datos inter– e intra–específicos completos son escasos, limitando nuestro entendimiento y subestimando la diversidad de reservorios genéticos. Este estudio buscó caracterizar la diversidad total de las plantas comestibles en las milpas, policultivos basados en maíz, manejadas por comunidades Tének en México. En 41 milpas de 33 agricultores en tres localidades en diferentes altitudes, se inventariaron 191 tipos de plantas comestibles, comprendiendo 84 especies con 140 variantes y 51 especies sin variantes. La diversidad varía entre y dentro de las localidades. Solamente 8.4% de la diversidad es compartida entre las localidades y 61.2% de la riqueza es manejada por agricultores individuales. La altitud intermedia presenta la mayor diversidad, incluyendo 67.5% de la riqueza total. Los números poblacionales de los cultivos son bajos y altamente variables. Para contribuir a interpretar y aplicar los resultados, se presenta un método para identificar cultivos, sitios y agricultores prioritarios. Este estudio muestra, una vez más, que las comunidades agrícolas indígenas son actores clave para uso y conservación de la diversidad genética de cultivos. Más estudios detallados como este podrán evidenciar una diversidad de cultivos mucho mayor que lo que actualmente se reconoce.

Key Words: Agrobiodiversity, altitude, conservation, ethnobotany, Huasteca, richness.

Palabras Clave Agrobiodiversidad, altitud, conservación, etnobotánica, Huasteca, riqueza.

Introduction

Traditional farming systems are important reservoirs of agricultural diversity and valuable components for a secure agricultural food production (Altieri and Merrick 1987; Thrupp 2000). The

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Mesoamerican *milpas* are farming systems of mostly shifting cultivation primarily devoted to maize (Nigh and Diemont 2013). Besides their primary role in meeting farmers' needs by providing food and income generation, the *milpas* also function as dynamic sinks and sources of plant genetic resources. They harbor important landraces of maize (*Zea mays* L.), beans (*Phaseolus* spp.), and squashes (*Cucurbita* spp.) that have been domesticated and diversified in this region, as well as numerous associated crops and non-crops (Perales and Aguirre 2008; Toledo et al. 2003).

Still, there are insufficient data about the overall richness being conserved and managed on farmers' fields. Most studies focus on the species level (e.g., Eilu et al. 2003; Toledo et al. 1994) or consider intraspecific richness if focused on one or more target crops (e.g., Blanco et al. 2013; Perales et al. 2003). Complete inventories are scarce even when these are necessary to determine where to focus conservation and research efforts and are particularly important to characterize traditional land use systems in agrobiodiversity-rich areas. Thorough baseline data are needed to detect changes in the distribution patterns of intraspecific diversity under different agroecological conditions (de Carvalho et al. 2016; Hammer et al. 1999).

A variety of crops is underrepresented in gene banks and neglected by agricultural science and breeding efforts (Hammer et al. 1999; Wambugu et al. 2018). Until now, research and development focus primarily on improving the productivity of a small number of existing crops that form the basis of a global food economy, which results in the loss of agrobiodiversity and greater susceptibility to biotic and abiotic stressors (FAO 2019; Shelef et al. 2017; Williams et al. 2018). Highlighting the relevance of crop species and variants in farmers' fields promotes more resilient agricultural systems and the use and conservation of local food crop diversity (Thrupp 2000; Williams et al. 2018).

There are several studies about the Mayan *milpas* in southern Mexico (e.g., Mateos–Macas et al. 2016; Teran and Rasmussen 1995), but the crop diversity among other indigenous cultures is less studied. This research was conducted on the *milpas* of the Tének (or Huastec), an indigenous people of Mayan origin living in the humid and sub-humid tropical zone of northeastern Mexico known as the Huasteca. The Huasteca is a multi-ethnic and multi-linguistic region in which different indigenous peoples share a set of practices, ideas, and life styles (Alcorn 1984). The Tének live in portions of the Huasteca that belong to the federal states of Veracruz, Hidalgo and San Luis Potosí. For this study only Tének farming communities of San Luis Potosí (Huasteca Potosina) were considered.

The *milpas* or polyculture maize fields of the Tének are still managed traditionally. Farmers apply shifting agricultural techniques and cultivate numerous different food crops in the same field. The Huasteca Potosina is characterized by environmental heterogeneity and cultural diversity (Alcorn 1984), which are factors that promote crop diversity (Brush 1995). This leads us to hypothesize that the *milpas* of the Tének in the Huasteca Potosina are important genetic reservoirs that are cultivated and managed in situ.

The aim of this article is to describe the complete edible plant diversity and intraspecific richness of this Tének farming system and to establish baseline data. Since altitude is a significant factor in the distribution of plant genetic resources (Brush and Perales 2007), the study comprised three localities distributed along an altitudinal gradient.

Additionally, to further interpret and apply insights gained, a method is proposed to prioritize crops, sites, and farmers and is presented as an example for the research area. This exercise may contribute to guiding and enhancing efficacy of future activities, such as payments for agrobiodiversity conservation services (e.g., Krishna et al. 2013; Narloch et al. 2011), or other goals based on the use and conservation of crop diversity. To prioritize is a challenging task, especially in heterogeneous landscapes that are highly variable in species composition and managed by subsistence farmers, yet practical approaches are required.

One suggestion in these cases is to define the target crops that are representative of a particular region and widely accepted by farmers. Focusing on them will be in harmony with the local production strategies (Brush 2000). A next step is to define a focus area or localities with the desired crop diversity as priority sites. This approach has been applied recently on a wider geographical scale (Pacicco et al. 2018) and in the case of crop wild relatives (Contreras–Toledo et al. 2019). Further, it is necessary to identity farmers to collaborate with (Brush 2000), particularly in cases where work with the whole community is impractical.

Methods

STUDY AREA AND SITE SELECTION

The study area is the Huasteca Potosina, an 11,409-km^2 area located in the southeastern part of the federal state of San Luis Potosí in Mexico (Fig. 1) with a population of 746,719 (INEGI 2010). The landscape is highly heterogeneous, dominated by different land use mosaics and varying geophysical and hydrological conditions at a relatively small scale. Four main ethnic groups, the Tének, Nahuas, Xi'iuyet, and Mestizos, inhabit this region. In this study, the focus is placed on the Tének, who inhabit this region and have managed and shaped the ecosystem for more than 3000 years (Alcorn 1984).

To select the research localities, four important open-air local markets were visited during two preliminary explorations into the research area. Fifty-five Tének merchants were surveyed about the origin of their products. Based on that, a list of preselected Tének localities was established. Given the detail of this study, three of these localities were selected (Fig. 1, Table 1) according to several criteria, including the persistence of local language, an orientation towards subsistence agriculture and altitude.

DATA COLLECTION

Key Informant Selection, Survey, and Plant Inventory

To select the farmers included in this study, a purposive sampling method of key informants in combination with the snowball sampling method was applied (Tongco 2007). Two of the main selection criteria were that the informants were small-scale traditional Tének farmers and mainly produce for self-consumption. Since the study was part of a larger research project, all farmers included also manage agroforestry systems and home gardens. In total, 33 farmers were selected (10 in LowAlt, 12 in MedAlt, and 11 in HigAlt).

The research was undertaken respecting the ISE code of ethics. In adherence to the ISE guidelines, an educated prior informed consent to the research activities was established with the local community authorities and all key informants who participated in this study did so freely. In each locality, the purpose of this study was presented to the community members. Workshops were organized to communicate the progress and results of the work.

Structured interviews were conducted with each farmer to obtain general information about his/her household and *milpa* management. From February 2016 to May 2018, 13 1- to 3-week-long field visits were made and 41 *milpa*s belonging to the 33 farmers were inventoried, covering a total area of 15.9 ha. When farmers manage more than one *milpa*, results were grouped for that farmer. The area of each *milpa* was measured, and data were taken of altitude (using GPS), rockiness, and slope gradient. These data were complemented with information from Google Earth.

The inventoried *milpas* consisted of annual crops, as well as trees and shrubs. Commonly, the plants were heterogeneously distributed; thus, a stratified random sample approach was applied.

After an explorative walk together with the farmer through each *milpa*, the field was subdivided into different units according to the main crops and the relevé sampling method was applied. In each unit, depending on its size and heterogeneity, three to 11 initial 1-m^2 nested sample plots were randomly selected (Zarin et al. 1999). The final size of each sample plot was determined according to the species–area relation (Mueller–Dombois and Ellenberg 1974) and varied between 2 and 16 m^2. Individuals of all edible plant species and variants, defined below, were counted. Trees and shrubs were sparsely distributed and therefore not included in the sample plots and were all counted separately.

Information About Inter- and Intraspecific Diversity

Farmers identified (recognized) all plant types in their fields. To corroborate identification, a formal taxonomic procedure was applied to species while the final identification of variants within the species was a process conducted mainly with farmers. Additionally, some seeds of variants were grown in pots at the university campus to obtain complete samples (flower, seeds, leaves, stems) and confirm their taxonomic identification.

Voucher specimens of each species were collected and prepared for their taxonomical identification by taxonomists at the SLPM herbarium (http://slpm.uaslp.mx/). Taxonomic keys and descriptions (e.g., Lira–Saade 1995) were used as well as online taxonomic data (e.g., Tropicos–Flora Mesoamericana, https://www.tropicos.org/Project/FM). Additionally, a photographic record of the fruits, seeds, and leaves of species and variants was

Fig. 1. Location of the research area in the federal state of San Luis Potosí, Mexico, and of the three research localities: Poytzen (Tancanhuitz municipality), Jol Mom, and Unión de Guadalupe (Aquismón municipality).

taken in the field to complement the information of the vouchers of each species.

Intraspecific diversity is based on farmer-recognized variants, which refer to all the edible plants in this study that have one or more specific traits that farmers do distinguish from other variants within each species and usually provide a local name for them. This is in accordance with previous works detailing that farmers recognize their crop varieties according to different phenotypical traits, their adaptation to different environments, management practices, different taste, and uses (Jarvis et al. 2000). The usefulness of local names to identify and quantify the intraspecific diversity is often debated. The phenotypical characters used by farmers to describe their crop variants are usually, but not necessarily, linked to their genetic makeup. Thus, certainty about the genetic distinctiveness is not provided in this work. A detailed discussion and examples are provided by Sadiki et al. (2007), indicating that folk variety names are often the first entry point to gather information and are useful in

Table 1. Characteristics of the research localities Poytzen at low altitude (LowAlt), Jol Mom at medium altitude (MedAlt), and Unión de Guadalupe at high altitude (HigAlt).

Information	Data type	LowAlt	MedAlt	HigAlt
Location	North latitude	21° 40′ 17.24″	21° 32′ 33.33″	21° 36′ 38.68″
	West longitude	98° 59′ 14.67″	99° 03′ 04.86″	99° 06′ 47.98″
General[a]	Number of inhabitants	452	721	267
	Number of family units	104	189	70
Social[a]	Indigenous speakers (≥ 3 years old)	378	631	171
	Monolingual speakers (≥ 3 years old)	13	160	3
	Level of marginalization	High	Very high	High
Environmental	Altitudinal range of the *milpas* (m.a.s.l.)	59–67	525–733	865–1247
	Mean annual temperature (°C)[b]	26.0	23.0	21.5
	Mean annual precipitation (mm)[b]	1630	2370	1950
	Potential natural vegetation[c]	Tropical deciduous forest and tropical rain forest	Tropical rain forest and cloud forest	Oak pine forest and cloud forest

[a] INEGI (2010)
[b] Fernández–Eguiarte et al. (2018)—extrapolated data sets
[c] Alcorn (1984)

providing a complete overview of local crop diversity.

To avoid over- and under-estimation of the intraspecific richness due to any inconsistency of local names, personalized interviews with the farmers about the variants from their *milpa* were conducted. Of the 33 farmers that were experts at identifying and describing the local crops, 7 were consulted frequently. Two participatory workshops were held at each locality to collectively discuss and identify the edible plants of the *milpas* using photographic material and plant and seed samples.

Local markets were visited to broaden the understanding of the naming and traits of different crop variants in the region. In general, a conservative approach was followed to identify variants. Variants from different localities with the same name and no clearly distinctive traits mentioned by the farmers are considered as the same variant.

Henceforth, the acronym "FVar" refers to farmer-recognized variants and "FSpe" to farmer-recognized species with no documented variants—although Tének farmers do not necessarily make a clear distinction between variants and species and this terminology is in accordance with scientific terminology. The farmers' edible plant diversity is expressed as "FVar+FSpe."

DATA ANALYSIS

Diversity of FVar+FSpe and, separately, of FVar from each *milpa* for each locality was calculated by using the Shannon–Wiener Diversity index (H', Magurran 1991) as:

$$H'_{FVar+FSpe} = -\Sigma p_i \cdot \ln(p_i) \qquad (1)$$

where $pi = \frac{ni}{N}$

ni = number of individuals of the ith FVar+FSpe;

N = total number of individuals

and

$$H'_{FVar} = -\Sigma p_i \cdot \ln(p_i) \qquad (2)$$

where $pi = \frac{ni}{N}$

ni = number of individuals of the ith FVar;

N = total number of individuals.

For mean diversity and richness data, the Shapiro–Wilk test was used to test normal distribution. In case of normal distribution, a one-way ANOVA was performed, followed by the Tukey's HSD post hoc test to determine the differences between the groups. In accordance with the methodology applied (Deng et al. 2012), for non-normal distribution, the Kruskal–Wallis test was used followed by the Dunn's multiple comparison test with Bonferroni corrected P values. The linear bivariate relation between the number of species and FVar+FSpe in the *milpas* was analyzed using Pearson's correlation.

The importance value (IV; McCune et al. 2002) of each FVar or FSpe in each of the three different localities was calculated as:

$$\mathrm{IV} = \frac{\mathrm{RD} + \mathrm{RF}}{2} \qquad (3)$$

where

$$\textit{Relative density}\ (\mathrm{RD}) = \frac{\textit{Indiv. i}}{\mathrm{Sum}\ \textit{of total indiv.}} \cdot 100 \qquad (4)$$

and

$$\textit{Relative frequency}\ (\mathrm{RF}) = \frac{\textit{Number of milpas in which FVar or FSpe occurs}}{\mathrm{Sum}\ \textit{of}\ \mathrm{all}\ \textit{milpas}} \cdot 100 \qquad (5)$$

Most calculations and analyses were made using the PAST 3.20 and Sigma Plot V. 14.0 programs.

A two-way indicator species analysis (TWINSPAN) was conducted with presence–absence data of FVar or FSpe in order to classify clusters of *milpas* according to indicator species (Hill 1979). PC–Ord–6 was used for the TWINSPAN.

PROPOSAL TO IDENTIFY PRIORITY CROPS, SITES, AND FARMERS FOR INTERPRETATION AND APPLICATION

The proposed method that facilitates prioritization is presented here as an example for the research area. It consists of the following steps, of which the criteria can be modified according to specific conditions:

(a) Select the priority crop species and their variants that are representative and/or highly important for a particular region.

Although several criteria can be used to select priority crops, like choosing to conserve all diversity or the rare one, here it was considered that selecting crop species with high importance value is more in harmony with farmers' choices. This criterion may be important when starting work with limited resources.

The tenth highest importance values from the FVar or FSpe of each locality were averaged to establish a reference point, which resulted in 18.2. The IVs for each FSpe and FVar in the three localities were added, and those with a summed IV value larger than 18.2 were selected as priority crops (Fig. 2; Appendix 1, Electronic Supplementary Material [ESM]). For the cases of FVar, the species to which that FVar belongs to, together with all its other variants, was selected as a priority crop species. The rationale behind adding up the three IVs for each FVar or FSpe is that in this manner, cases are selected where an IV was relatively high in only one locality and null in the other two. Using the average IV for the three localities would preclude their selection. This obeys to giving importance to relevant FVar or FSpe even if they are present in only one locality. Adding up does not disregard FVar or FSpe with low IVs but which are found in more than one locality.

(b) Select the priority site.

The priority site was selected according to the distribution of diversity and richness of priority crops among the three localities. In this exercise, the locality with the most priority FVar+FSpe is chosen as the priority site. Complementary criteria used to reinforce site selection are the distribution of all FVar and FSpe and of unique FVar and FSpe in a locality.

(c) Select priority farmers.

In order to identify priority farmers, data about the richness of priority FVar+FSpe at a farmer's level within the chosen priority site were used. Farmers that already cultivate a large number of priority FVar and FSpe are selected. Complementarily, farmers that cultivate unique FVar and FSpe that are not cultivated by others can also be considered in order to encompass the largest possible sample of priority FVar and FSpe.

Results

GENERAL DESCRIPTION OF THE *MILPA* SITES AND FARMER HOUSEHOLDS

Of the 33 selected farmers, 88% use fire for land preparation and sow at the beginning of the rainy season, between May and June. Throughout the year, farmers sow and harvest diverse crops in separated areas of their *milpa* or in combination with other crops. Farmers cultivate the same field for an average period of 2.47 years (SD 0.95 years) ranging from 1 to 5 years. The average fallow period is 3.44 years (SD 1.87 years) ranging from 0 to 6.5 years. The use of external inputs is relatively low. On an irregular basis, only 15% of farmers apply organic fertilizers, 24% use herbicides, and 15% use pest control substances of organic or synthetic origin.

The altitude of inventoried *milpas* ranges from 59 to 1247 m (Table 1). The *milpas* in the medium altitude (MedAlt) and high altitude (HigAlt) are characterized by remarkable slope gradients ranging from 3.2° to 43.0°. A further characteristic of the *milpas* in the two higher altitudes is the high presence of limestone rocks, with ca. 50% average rockiness, and the use of the soil that accumulates in crevices between the rocks for cultivation. At each site, more than 50% of farmers evaluate the soil quality in their *milpas* as "good." The average distance of the *milpas* from the house is 0.88 km (SD 0.68 km), ranging from 0.3 to 2.5 km. The *milpas* are rather small with an average of 0.34 ha (SD 0.30 ha) in LowAlt, 0.55 ha (SD 0.35 ha) in MedAlt, and 0.47 ha (SD 0.31 ha) in HigAlt.

The average farmers' age is 52.0 years (SD 14.6 years) and every *milpa* contributes to the nourishment and production of income to an average number of 4.3 (SD 2.6) family members ranging from 1 to 13. The average farmers' experience managing their *milpa* is 30.8 years (SD 15.6 years), ranging from 1 to 69 years. As a main constraint, 42.0% of farmers identified yield loss due to the presence of animals feeding on their crops (e.g., opossum [*Didelphis marsupialis* L.] and white-nosed coati [*Nasua narica* L.]). Most of the farmers (76%) are not supported through governmental programs or by other subsidies.

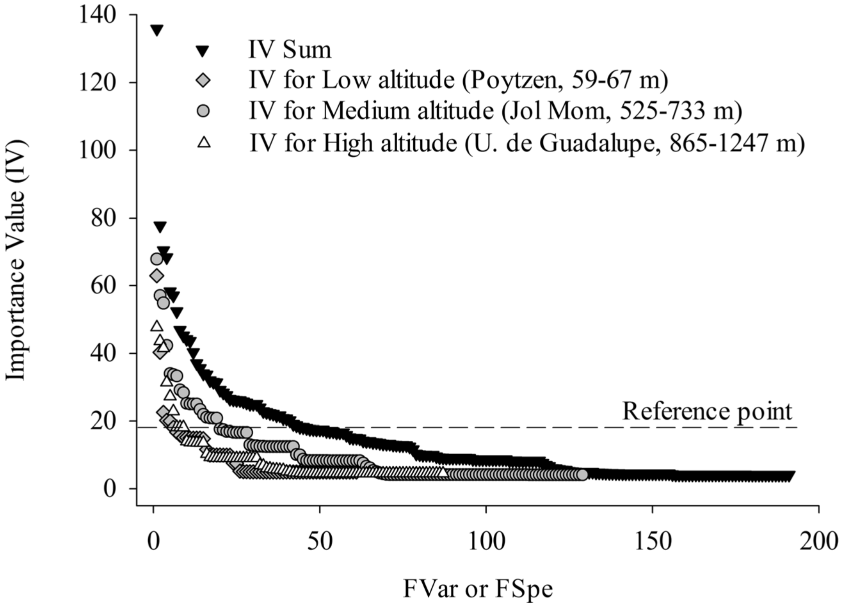

Fig. 2. Importance value rank–curve of the FVar or FSpe of *milpas* in the three research localities. FVar = farmer-recognized variants, FSpe = farmer-recognized species with no documented variants.

Richness and Diversity

In total, 191 FVar+FSpe that belong to 36 plant families, 66 genera, and 84 species were registered (Appendix 1, ESM). The edible plant diversity consists of 51 species with no variants (FSpe) and 140 farmer-recognized variants (FVar), including 16 commercial varieties and four wild ancestors of cultivated plants. The number of FVar+FSpe for each *milpa* ranged from 2 to 49 in the three localities with an average of 16.4 (SE 4.6). The richness and diversity as determined by the Shannon–Wiener index were significantly higher for the MedAlt locality (Table 2).

The species with the highest intraspecific richness are *Cucurbita moschata* Duchesne (19 FVar), *Phaseolus vulgaris* L. (18 FVar), *Phaseolus coccineus* L. (11 FVar), and *Zea mays* L. (11 FVar) (Table 2 of Appendix 2, ESM). Intraspecific richness is unequally distributed among the three research localities. For example, in the MedAlt, most *C. moschata* variants can be found (95%), meanwhile *P. vulgaris* and *P. coccineus* variants are almost exclusively distributed in HigAlt. An almost equal number of *Z. mays* variants can be found in each of the three localities. Data also show that the number of variants at the community level notably exceeds the number of variants at farmer level.

The number of individuals per variant of these species varies considerably between and within species (Table 2 of Appendix 2, ESM). For example, the average number of individuals per maize variant is 44,358 with a very high SD of 49,491, while for *C. moschata*, the average is 25 and the SD = 22. Additionally, for all FVar+FSpe, the average number of individuals per FVar or FSpe is 4070 and the SD = 16,278. For 29.3% of the FVar+FSpe, the average number of individuals per FVar or FSpe is ≤ 10.

The importance value rank–curve shows that only a few FVar and FSpe reached high scores, while most have a low IV in the three different research localities (Fig. 2). Scores vary between the localities and some of the large values represent high importance within only one locality. The FVar that achieved the highest summed IV is the *Z. mays* variant “maíz criollo, amarillo, breve” with a score of 135.85; followed by the *Capsicum annuum* L. variant “chile pico de pájaro” with 77.76; the *P. vulgaris* variant “frijol negro de guía” with 70.41; and a second *Z. mays* variant “maíz criollo, blanco, breve” with 68.37. Importance values for

TABLE 2. RICHNESS AND DIVERSITY OF THE FVAR+FSPE AND FVAR IN THE THREE RESEARCH LOCALITIES.

	Low altitude			Medium altitude			High altitude		
	Diversity index	SD	Range	Diversity index	SD	Range	Diversity index	SD	Range
Richness FVar+FSpe	10.0^{a**}	6.0	5–25	26.0^{b}	11.8	10–49	13.5^{a}	8.6	2–27
FVar	7.4^{a**}	4.0	4–18	19.4^{b}	8.8	10–36	11.2^{a}	7.2	2–26
H′ FVar+FSpe	0.78^{a**}	0.34	0.10–1.17	1.52^{b}	0.50	0.40–2.19	0.81^{a}	0.48	0.06–1.65
FVar	0.71^{a*}	0.36	0.05–1.08	1.19^{b}	0.49	0.16–1.90	0.79^{a}	0.48	0.02–1.56

Means within a row followed by a different letter are significantly different from each other (**$P < 0.01$; *$P < 0.05$)
FVar+FSpe farmer-recognized edible plant diversity, *FVar* farmer-recognized variants, *H′* Shannon–Wiener Diversity Index

each FVar and FSpe are shown for each locality in Appendix 1, ESM.

Diversity and Richness at Farmer Level

As shown for line A in Fig. 3, there is a highly significant ($P < 0.01$) positive correlation between the number of species and FVar+FSpe grown in each of the *milpa*s ($R = 0.95$). The average slope is 1.57. Farmers above the line manage a higher richness of FVar+FSpe in their *milpas*. Four farmers of the MedAlt and three farmers of the HigAlt belong to this group. One farmer in HigAlt stands out as very specialized who cultivates only eight species but 27 variants, mainly of *P. coccineus* and *P. vulgaris*. Farmers at LowAlt and HigAlt sites tend to cultivate less species and FVar+FSpe than farmers at the MedAlt. The slope of FVar+FSpe vs. species is also higher for MedAlt, 1.60, than for LowAlt and HigAlt, with 1.49 and 1.36, respectively.

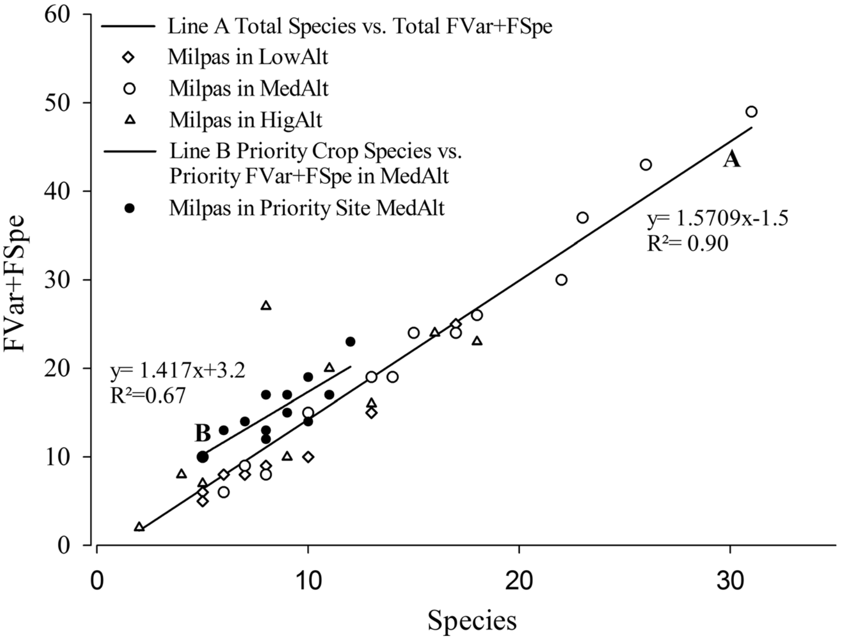

Fig. 3. Correlation between number of species and FVar+FSpe in each *milpa* in the three research localities. Line A: $R = 0.95$ ($P < 0.01$); line B: $R = 0.82$ ($P < 0.01$). LowAlt = low altitude (Poytzen), MedAlt = medium altitude (Jol Mom), HigAlt = high altitude (Unión de Guadalupe). FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer recognized species with no documented variants.

UNIQUENESS BETWEEN THE RESEARCH LOCALITIES AND AT LOCALITY LEVEL

Concerning the distribution of edible plants between the different localities, it is shown that a high proportion of the FVar+FSpe and FVar, 40% and 38% respectively, were registered only once among all the *milpas* inventoried and are considered as unique. Only 16 FVar+FSpe are shared among the three localities (Fig. 4). The MedAlt is the site that shares most FVar+FSpe with the other two localities, 36 with LowAlt and 44 with HigAlt. MedAlt is also the locality with highest proportion of the unique FVar+FSpe (65, 34%) and FVar (38, 27%). Scores of uniqueness are considerably lower for LowAlt and HigAlt.

A similar situation among the *milpas* is presented for the uniqueness and number of shared FVar+FSpe in the same locality. In all three localities, on average 61.2% (SE 4.7%) of the FVar+FSpe are unique to the *milpa* of one farmer. Only a small number of FVar+FSpe is commonly distributed among the *milpas* in the same locality (Table 3). In LowAlt, uniqueness is mostly observed in variants of *Vigna unguiculata* (three) and *Z. mays* variants (four), with the exception of the variant "maíz criollo, amarillo, breve" which is very common and shared by 70% of the farmers in LowAlt. In MedAlt, a high uniqueness is detected in variants of *C. moschata* (five), *Lagenaria siceraria* (Molina) Standl. (four), and *Z. mays* (four). The *C. annuum* variant "chile pico de pájaro" is cultivated in 92% and the *Amaranthus hybridus* L. variant "quelite blanco" in 100% of the *milpas* in MedAlt. In HigAlt, there is a high amount of unique bean variants belonging to the species *P. vulgaris* (12)

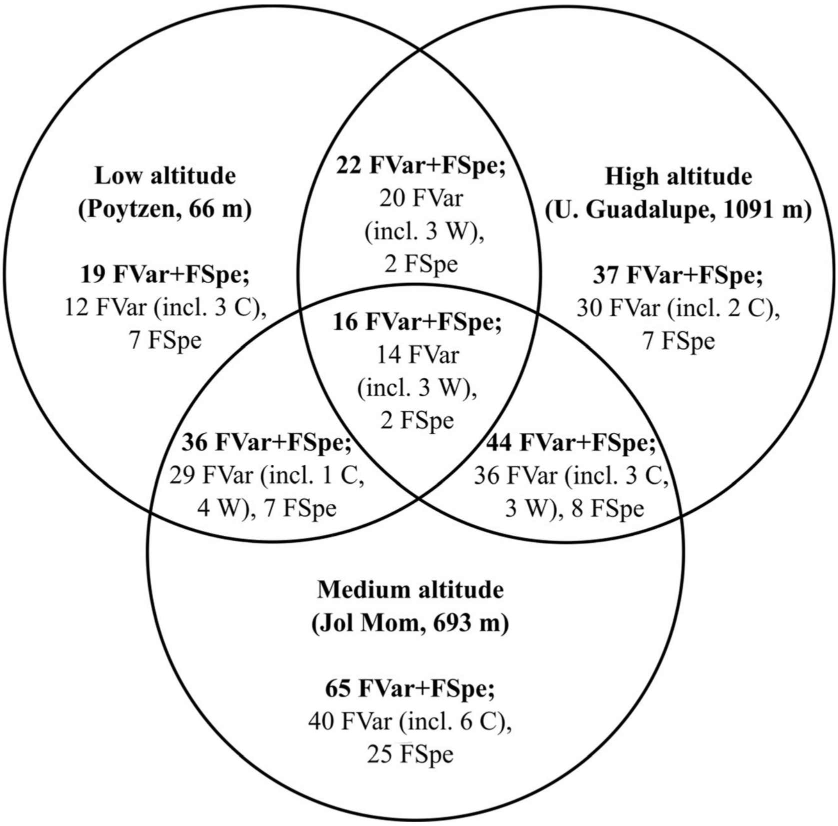

Fig. 4. Distribution of the edible plant diversity of the *milpas* in the three research localities. FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants. C = commercial varieties and W = wild relative of cultivated plants, listed within brackets.

TABLE 3. DISTRIBUTION OF THE EDIBLE PLANT DIVERSITY AMONG THE *MILPAS* IN EACH LOCALITY.

	Low altitude Poytzen 59–67 m			Medium altitude Jol Mom 525–733 m			High altitude U. de Guadalupe 865–1247 m		
	FVar+FSpe	FSpe	FVar	FVar+FSpe	FSpe	FVar	FVar+FSpe	FSpe	FVar
Unique	41	5	36	67	20	47	56	10	46
Rare	8	2	6	34	10	24	23	3	20
Common	11	5	6	24	7	17	7	2	5
Very common	1	0	1	4	0	4	1	0	1
Total	61	12	49	129	37	92	87	15	72

FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants. Unique = one occurrence in the locality, Rare = occurrence < 30% of the *milpas*, Common = occurrence in 30–60% of the *milpas*, Very common = occurrence in > 60% of the *milpas*

and *P. coccineus* (six). The *P. vulgaris* variant "frijol de guía, flojo, negro" is very common and cultivated by 64% of the farmers.

CLASSIFICATION

The TWINSPAN provides information about the indicator species responsible for grouping different *milpas* (Fig. 5). The first division level divided the *milpas* of the HigAlt with a high diversity of *Phaseolus* species and variants from the *milpas* with less or no *Phaseolus* species and variants in the LowAlt, MedAlt, and HigAlt sites. The second division level separated two groups of *milpas*, one consisting exclusively of *milpas* of LowAlt and a second group that consists mainly of *milpas* of MedAlt and some *milpas* from the other altitudes that share similar patterns of edible plant diversity. The indicator species were *C. annuum* and *A. hybridus*, among others. Eight end groups were distinguished at the fifth level of division. In these, *milpas* are grouped according to the altitudinal level and some *milpa* groups are particularly important for certain assemblies of FVar+FSpe. *Milpas* in the LowAlt are important reservoirs of *Sesamum indicum* L. variants and exclusively contain *Hibiscus sabdariffa* L. and *Sabal mexicana* Mart., a tolerated species. The fourth group, mainly consisting of *milpas* from the MedAlt, has the highest diversity of *C. moschata*, with a high preference for *A. hybridus*, an edible weed species tolerated and cultivated only in this altitude, as well as for the *C. annuum* variant "chile pico de pájaro."

The *milpas* of the HigAlt belong to four different end groups that include maize variants with different lengths of growing cycle (short, medium, and long). This also shows that farmers with a preference for short-cycle maize have less *Phaseolus* diversity in their *milpas* and vice versa. Long-cycle maize is not represented in the MedAlt and LowAlt. The *milpas* of the HigAlt are an important reservoir of the intraspecific richness of different bean species, especially of *P. vulgaris* and *P. coccineus* with a total of 27 FVar.

The list of species including authors is presented in Appendix 1, ESM.

PROPOSAL OF A METHOD FOR FURTHER INTERPRETATION AND APPLICATION OF RESULTS

(a) Definition of the priority crop species

Based on the IV reference point of 18.2, 26 priority species were preliminarily identified (Fig. 2; Table 1 of Appendix 2, ESM). Of these 26 species, five perennial crops were excluded because they are not intrinsically related to the *milpa* system. Their growth cycle or use exceeds the time of the *milpa*. Furthermore, three edible, agrestal weed species *Physalis pubescens* L., *Portulaca oleracea* L., and *Porophyllum ruderale* (Jacq.) Cass were excluded from the list.

All the other 18 species were selected as priority crop species consisting of 93 FVar+FSpe of the total 191 (48.7%) found in the area (Table 1 of Appendix 2, ESM). After excluding perennials and agrestal weeds from the three sites, 130 FVar+FSpe remain as crops that are more closely related to the *milpa* system. The 93 FVar+FSpe in the 18 priority species comprise 71.5% of these 130 crops.

With the use of the summed IV, it is shown that several FVar or FSpe did have a high importance value

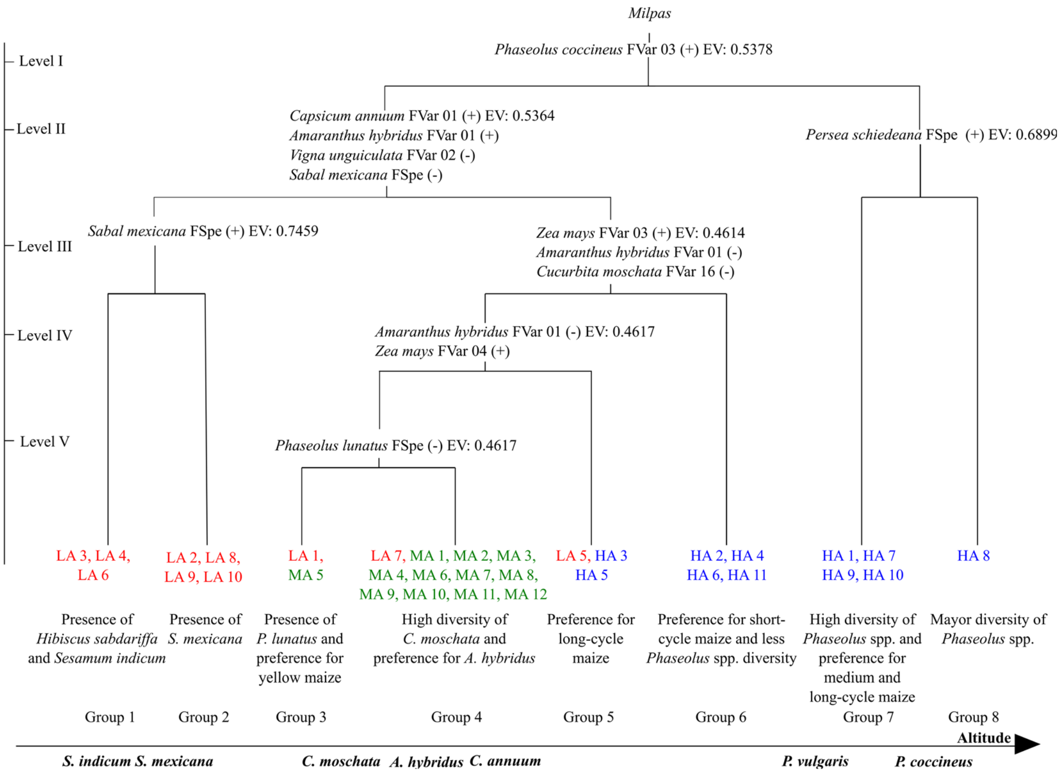

Fig. 5. Dendrogram based on the TWINSPAN. The (+) mark is the indicator for the groups of *milpas* that lie to the right and (–) to the left. The *milpas* are marked with numbers and capital letters to refer to their location: LA = low altitude (Poytzen), MA = medium altitude (Jol Mom), HA = high altitude (Unión de Guadalupe). FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants. EV = eigenvalue for each division. The list of species including authors is presented in Appendix 1, ESM.

in only one locality but were absent from the other two. For example, one *C. annuum* FVar had an IV of 34.0 in MedAlt but was absent from the other two localities, or one *S. indicum* FVar had an IV of 40.3 in LowAlt but was not present elsewhere. By using the summing method (sum IV above the reference point) these two species were selected as priority species.

(b) Selection of the priority site

The *milpas* in the MedAlt location have the highest number of priority crop species, 17 of 18. The MedAlt site was selected as the priority site. After comparing the three localities, the MedAlt site is confirmed as the priority site since farmers there cultivate most of the total FVar+FSpe (67.5%) and unique and rare FVar+FSpe (101) and have the highest number of FVar+FSpe (96) that overlap with both other sites (Table 3, Fig. 4). However, the MedAlt site lacks one priority crop species completely, *P. coccineus*, which is mainly distributed in the HigAlt site.

(c) Selection of priority farmers

As shown in Fig. 3, line B, the farmers at the priority site MedAlt cultivate between 5 and 12 of the priority species, with an average of 8.58 (SD 2.02). The ratio of FVar+FSpe to priority species is 1.42 with a highly significant correlation ($R = 0.82$, $P < 0.01$).

The upper half of the 12 farmers at MedAlt who cultivate the largest number of priority crop species, an average of 10.2, were selected as priority farmers (Fig. 3). These six farmers also cultivate more FVar+FSpe per priority species with a ratio of 1.72, which is higher than for the rest of the farmers at MedAlt. They also grow 94% of the priority crop species including 6 FSpe and 35 FVar, representing 74.5% of all the priority FVar+FSpe of the MedAlt.

Discussion

Assessment of the Overall Diversity

Traditional polyculture systems, such as the *milpas* managed by indigenous people, harbor a vast amount of plant genetic resources that, in general, have been scarcely recorded and thus underestimated. In 41 *milpas* belonging to 33 farmers in three localities distributed along an altitudinal gradient from 59 to 1247 m, 191 edible plant types were inventoried, comprising 84 species that included 140 farmer-recognized variants and 51 species with no intraspecific variants. These values are higher than reported in other studies about the *milpas* of indigenous people in and outside the research area (examples are provided in Table 1 of Appendix 3, ESM). The detailed fieldwork inventory and the inclusion of an altitudinal gradient may explain these elevated numbers. However, the Shannon–Wiener diversity index values ranged on average from 0.78 to 1.52 for all FVar+FSpe (Table 2), which are lower than values obtained by others, for example, 0.7–3.9 (Salazar–Barrientos et al. 2016) or 3.5 (Interián Kú and Gary 2004). Yet the latter values are higher probably because only the most important crops of the *milpa* were included while in this study all FVar+FSpe were taken into account.

Although it is challenging to produce comparable data on intraspecific diversity, their importance is paramount to provide a complete overview. Based on the experience gained during this investigation, a selection and combination of methods is recommended to obtain thorough inventories, especially when working with traditional farming communities. A combination of surveys, participatory methods, and intensive sampling of the *milpa* plots accompanied by farmers is important to avoid over- and under-estimation of FVar+FSpe and to create comparable baseline data for the future.

The importance value rank–curve (Fig. 2) shows that FVar or FSpe with the highest importance values belong also to the most representative crops of the traditional *milpa*, such as *Z. mays*, *C. annuum*, *Cucurbita agyrosperma* C. Huber, *C. moschata*, and *P. vulgaris* (Birol et al. 2009).

Population size matters when trying to understand how and at what scale the farmers contribute to the permanent evolution of crops or the level of risk of genetic decay or loss that is associated with small populations. Growing a large amount of genetically diverse maize is considered important not only to preserve the extent of diversity in a region but also for the creation of new diversity through mutations. As shown here, the population size of many variants is rather small as it is variable (Table 2 of Appendix 2, ESM), and in those cases, the probability of decay in genetic diversity within the population is increased and creates a risk of losing a whole population (Bellon et al. 2018).

Milpas, as well as any other systems in the natural and humanized environments, are dynamic and a species or variant could be substituted for another one. The identification of loss, substitution, or change in crop diversity is even more complex than in a natural system. In addition to changing abiotic and biotic factors, a wide variety of human-induced pressures of socioeconomic, demographic origin, or private nature also have an impact on the crop diversity that is maintained in farmer fields (Brush 2000; Brush and Perales 2007). It is considered that there is a decline in agrobiodiversity as traditional farming systems in Mexico are substituted by more modern cropping systems (Pérez–García and del Castillo 2016) and *milpa* diversity has been related to economic stratum of farmers (Interián Kú and Gary 2004). Those social, cultural, and economic parameters were not assessed here, but it is worthwhile to investigate them further. Due to a lack of historical baseline data in the region, no statements can be made about the diversity that has been lost in the past. This work remains as a description of the current diversity on *milpa* fields and changes may be evaluated in the future.

A high divergence between the *milpas* at both the farmer and community level was determined. An overall relation of total FVar+FSpe (191) over average richness per farmer was 11.6.

Considering the values for species with the highest intraspecific richness (Table 2 of Appendix 2, ESM), the community richness is sixfold that of farmer richness. This high divergence is in accordance with the finding of Jarvis et al. (2008), who reported that community richness is eightfold that of farm richness. The fact that only

8.4% of the FVar+FSpe is shared among the three localities (Fig. 4) highlights the heterogeneity of farming systems among the localities along an altitudinal gradient at a relatively small spatial scale.

Specific Holders of Edible Plant Diversity

Despite the divergence of diversity between the localities and at farmers' level, the MedAlt location is the main reservoir of FVar+FSpe with 67.5% of the total. One explanation is that this transitional zone allows an integration of plants from other altitudinal levels while conserving their unique diversity at the locality level (Fig. 4, Table 3).

The TWINSPAN (Fig. 5) formed eight *milpa* groups distributed along the altitudinal gradient in the region. The application of this tool visualized the distinctiveness of the farmers' production strategies in the three research sites. Each *milpa* group serves as a specific pool of different assemblies of intraspecific diversity of certain crop species. These results also indicate that the *milpa* as a system should be considered the basic management unit for research, use, and conservation efforts, including prioritization.

A further finding was that the most frequent and staple crop species of the *milpa* are also those that show major richness regarding the number of variants (Table 2 of Appendix 2, ESM). This is in accordance with Jarvis et al. (2008), where it is shown that farming communities maintain a higher varietal richness of major staples than of non-staples. In the same study, including data from different farming communities in Mexico, Peru, Nepal, and Hungary, the average varietal richness of 27 selected crops is 1.38–4.25 per farmer. Among the Tének, the average value per farmer is 16.4 FVar+FSpe out of 84 species of staples and non-staples. In comparison to other studies about the average varietal richness of the main crops per farmer, it is shown that Tének farmers are important managers of squash and bean variants (examples of other studies are provided in Table 2 of Appendix 3, ESM). The total varietal richness of beans and squashes of the Tének communities is also higher than reported for other indigenous communities in Mexico (examples are provided in Table 3 of Appendix 3, ESM).

Proposal for Further Interpretation and Application of Results

According to the proposal to establish priorities when needed, the 18 priority crop species that were defined include most of the FVar+FSpe more closely related to the *milpa* system. The focus on these crops might help to develop further research and decide on conservation efforts in the Huasteca Potosina that coincide with farmer production strategies.

A second result was that the MedAlt location was established as the priority site. If resources are limited and the aim is to promote most of the diversity of the Tének region, the focus on the MedAlt is the most efficient option. If the aim is to assess all the priority crops, the HigAlt site has to be included because the bean group is better represented there. This evidences the need to broaden the scope when specific target crops are considered.

The selection of the priority farmers as the third step is the most challenging part. Even though it was rather simple to select farmers that manage a higher richness and diversity in their *milpas*, other criteria such as the presence of a large number of unique species adds complexity to prioritization. The importance of the whole farming community in maintaining the full inventory of crop genetic resources was already mentioned; however, due to practical reasons compromises must be made.

As this exercise showed, there are many and variable elements that can be used to prioritize crops, sites, and farmers to fit goals and resources of future initiatives. Moreover, prioritization serves as an entry point for further initiatives that may eventually expand number of crops, sites, and farmers as needed.

Conclusions

The *milpas* of the Tének of the Huasteca Potosina are highly crop-diverse farming systems that are relevant for the use and conservation of a broad range of crop genetic resources. The persistence of those resources remains uncertain because, interdependent with other reasons like climate change and rural migration, the populations of many of the FVar and FSpe are rather small and are not evenly distributed. Thus, conservation measures are needed if these resources are to be preserved or promoted since they may be at risk.

A detailed characterization of heterogeneous agricultural systems, such as the one conducted here, is necessary to understand their complexity and guide use and conservation measures. However, the farmers are the decision–makers at the *milpa* level, and the whole farming community is eventually needed to maintain the complete inventory of crop genetic resources.

This study shows, once again, that indigenous farming communities in Mexico are key actors for the use and conservation of vast crop genetic diversity. Moreover, it is possible that when more detailed studies are conducted in other communities, much larger crop diversity than is currently known will be found there as well. To characterize at the proper level the richness of the managed world's crop genetic capital seems an unavoidable step.

Acknowledgments

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Appendix 1 ESM Table 1. List of Farmer–recognized Edible Plant Diversity of the *Milpas* in Three *Tének* Localities

	Scientific name	Type	Local name	Huastec name	IV LowAlt	IV MedAlt	IV HigAlt	IV Total
1	*Abelmoschus esculentus* (L.) Moench	FSpe	Café bomba/ bombóm	Bombaj kapéj	15.025	–	–	15.025
2	*Allium longifolium* (Kunth)	FSpe	Cebollín	Xunnakat	–	16.938	–	16.938
3	*Amaranthus hybridus* L.	FVar	Quelite blanco	Dhak chidh	–	57.014	–	57.014
4	*Amaranthus hybridus* L.	FVar	Quelite rojo	Tsak chidh	–	33.705	–	33.705
5	*Ananas comosus* (L.) Merr.	FSpe	Piña	Chabcham	–	4.172	–	4.172
6	*Annona reticulata* L.	FSpe	Anona amarilla	Manu‘ kukay	–	4.168	–	4.168
7	*Arachis hypogaea* L.	FSpe	Cacahuate blanco	Dhak kakaw	5.005	12.592	–	17.597
8	*Averrhoa carambola* L.	FSpe	Garambolo	Papayuelo	–	4.174	–	4.174
9	*Bunchosia lindeniana* A.Juss.	FSpe		Min té	–	4.167	–	4.167
10	*Cajanus cajan* (L.) Millsp.	FVar	Lenteja de árbol negra		–	4.167	–	4.167
11	*Cajanus cajan* (L.) Millsp.	FVar	Lenteja de árbol pinto		–	4.167	–	4.167
12	*Capsicum annuum* L.	FVar*	Chile cuerno de chivo		–	4.167	–	4.167
13	*Capsicum annuum* L.	FVar	Chile pico de pájaro	Wi’ ts’itsin its	–	54.854	22.904	77.758
14	*Capsicum annuum* var. *glabriusculum* (Dunal) Heiser & Pickersgill	FVar**	Chile piquín	Kulum its, Ts’akam its	5.006	12.502	4.547	22.055

15	*Capsicum annuum* L.	FVar	Chile piquín bolita	Muldha' its, Kulum its	–	34.034	–	34.034
16	*Capsicum annuum* L.	FVar*	Chile poblano	Poblano its	–	4.168	–	4.168
17	*Carica papaya* L.	FVar	Papaya chica	Chuwdha utsun	–	4.167	–	4.167
18	*Carica papaya* L.	FVar**	Papaya del monte	Alte' utsun	20.045	25.230	–	45.275
19	*Carica papaya* L.	FVar	Papaya grande	Pakdha' utsun	5.004	12.513	–	17.517
20	*Carica papaya* L.[1]	FVar	Papaya larga	Nakat utsun	–	4.168	–	4.168
21	*Carica papaya* L.	FVar	Papaya mamey	Bolom it'adh utsun	5.036	4.174	–	9.210
22	*Cinnamomum verum* J.Presl	FSpe	Canela		–	4.173	–	4.173
23	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	FVar*	Sandía commercial	Baléyaj	5.009	–	–	5.009
24	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	FVar	Sandía criolla	Tének baléyaj	5.001	–	–	5.001
25	*Citrus aurantium* L.	FVar	Naranja cucho criolla	Tének lanáx cucho, dhimalón lanáx	5.001	–	–	5.001
26	*Citrus aurantiifolia* (Christm.) Swingle	FVar	Limón agrio criollo	Tének jili lanáx	5.002	12.502	–	17.504
27	*Citrus aurantiifolia* (Christm.) Swingle	FVar*	Limón agrio amarillo injertado	Manu' jili limón tsátadh kán			4.177	4.177
28	*Citrus limetta* Risso	FVar	Lima dulce		–	4.174	4.546	8.720
29	*Citrus reticulata* Blanco	FVar	Mandarina criolla	Tének mandarín	–	8.334	4.546	12.880
30	*Citrus reticulata* Blanco	FVar*	Mandarina injertada	Mandarín tsátadh kán	–	4.167	4.546	8.713

31	*Citrus sinensis* (L.) Osbeck	FVar	Naranja criolla	Tének lej lanáx	–	4.168	9.093	13.261
32	*Citrus sinensis* (L.) Osbeck	FVar*	Naranja Navel injertada	Navel lanáx	–	4.168	–	4.168
33	*Citrus sinensis* (L.) Osbeck	FVar*	Naranja Valencia injertada	Valencia lanáx	–	–	9.124	9.124
34	*Coriandrum sativum* L.	FSpe	Cilantro criollo	Tének kulantuj	–	42.346	4.549	46.895
35	*Cucumis melo* L.	FVar	Melón amarillo	Manu‘ melón	10.011	–	–	10.011
36	*Cucumis melo* L.	FVar	Melón café	Tsokoy melón	5.009	–	–	5.009
37	*Cucurbita argyrosperma* C.Huber	FVar	Calabaza pipián blanca, redonda	Dhuk’uk k’alam dhakni’ ani kwechodh/mulúlidh	10.049	–	–	10.049
38	*Cucurbita argyrosperma* C.Huber	FVar	Calabaza pipián rayada, redonda	Dhuk’uk k’alam podhmach ani kwechodh/mulúlidh	10.043	20.865	27.300	58.208
39	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, blanca, redonda	Dhak k’alam ja’much kwechodh/mulúlidh	–	4.168	–	4.168
40	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde de bola	T’unu’/Yax k’alam ja’much ani bolidh	–	–	4.550	4.550
41	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde de bola grande	T’unu’/Yax k’alam ja’much ani na’kadh bolidh	–	8.338	4.552	12.890
42	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde, redonda	T’unu’/Yax k’alam ja’much ani mulúlidh	–	8.335	–	8.335
43	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde rayada de bola	T’unu’/Yax mili’ k’alam ja’much ani tijaj bolidh	–	4.169	–	4.169

44	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde rayada de bola grande	T’unu’/Yax mili’ k’alam ja’much ani na’kadh bolidh	–	20.850	–	20.850
45	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde rayada de botella	T’unu’/Yax mili’ k’alam ja’much ani xomomlidh	–	4.168	4.552	8.719
46	*Cucurbita moschata* Duchesne	FVar	Calabaza aguada, negra/verde, rayada, redonda	T’unu’/Yax mili’ k’alam ja’much ani mulúlidh	5.010	12.505	–	17.515
47	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, blanca rayada de bola grande	Mo’odhidh k’alam dhakni’ mili’ ani na’kadh bolidh	–	4.167	–	4.167
48	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, blanca rayada de botella	Mo’odhidh k’alam, dhakni’ mili’ ani xomomlidh	–	4.168	4.546	8.714
49	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, blanca rayada, redonda	Mo’odhidh k’alam dhakni’ mili’ ani mulúlidh	–	16.671	–	16.671
50	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde de bola grande	Mo’odhidh k’alam t’unu’/yaxu’ ani na’kadh bolidh	–	16.672	–	16.672
51	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde de botella	Mo’odhidh k’alam t’unu’ /yaxu’ ani xomomlidh	–	25.012	–	25.012

52	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde, redonda	Mo’odhidh k’alam t’unu’/yaxu’ ani mulúlidh	–	12.502	4.565	17.067
53	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde rayada de bola	Mo’odhidh k’alam t’unu’/yaxu’ mili’ ani bolidh	–	25.007	–	25.007
54	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde rayada de bola chica	Mo’odhidh k’alam t’unu’/yaxu’ mili’ ani t’ijax mulúlidh	–	8.339	–	8.339
55	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde rayada de bola grande	Mo’odhidh k’alam t’unu’/yaxu’ ani na’kadh bolidh	10.005	33.345	9.096	52.445
56	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/verde rayada de botella	Mo’odhidh k’alam t’unu’/yaxu’ mili’ ani xomomlidh	–	25.007	–	25.007
57	*Cucurbita moschata* Duchesne	FVar	Calabaza seca, negra/ verde rayada, redonda	Mo’odhidh k’alam t’unu’/yaxu’ mili’ ani mulúlidh	15.028	29.178	–	44.205
58	*Cucurbita pepo* L.	FVar	Calabaza atomite, amarilla, chica, redonda	Mo’odhidh k’alam dhakni’ tum tum ani t’ijax mulúlidh	–	–	4.549	4.549

59	*Cucurbita pepo* L.	FVar	Calabaza atomite seca, blanca, chica, redonda	Mo'odhidh k'alam manu' tum tum, ani t'ijax mulúlidh	–	–	4.549	4.549
60	*Curcuma longa* L.	FSpe	Azafrán		–	8.367	–	8.367
61	*Dioscorea alata* L.	FSpe	Camote real blanco	Dhak láb idh	–	12.514	9.101	21.615
62	*Diospyros nigra* (J.F.Gmel.) Perrier	FSpe	Zapote negro	Munek'	–	4.174	–	4.174
63	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	FSpe	Epazote	Tijtson	–	13.027	–	13.027
64	*Eriobotrya japonica* (Thunb.) Lindl.	FSpe	Níspero		–	–	4.546	4.546
65	*Erythrina americana* Mill.	FSpe	Pemoche	Jutukú'	–	8.346	–	8.346
66	*Fragaria* sp.	FSpe	Fresa		–	–	9.123	9.123
67	*Helianthus annuus* L.	FSpe	Girasol	Met'al k'icháj	–	4.177	–	4.177
68	*Hibiscus sabdariffa* L.	FSpe	Jamaica	Jamaica wits	15.184	–	–	15.184
69	*Inga vera* Willd.	FSpe	Chalahuite de monte	Ts'akam dhubchik	–	–	4.546	4.546
70	*Ipomoea batatas* (L.) Lam.	FVar	Camote dulce amarillo	Manu' idh	–	8.336	–	8.336
71	*Ipomoea batatas* (L.) Lam.	FVar	Camote dulce blanco	Dhak idh	–	4.168	–	4.168
72	*Ipomoea batatas* (L.) Lam.	FVar	Camote dulce rojo	Tsak idh	5.004	4.168	4.549	13.721
73	*Ipomoea elongata* Choisy	FSpe	Suyo de hoja aguda; Suyo rojo	Ts'updha' dhuyu'; tsak dhuyu'	–	17.401	18.224	35.625

74	*Ipomoea dumosa* (Benth.) L.O. Williams	FSpe	Suyo de hoja grande; Suyo blanco	Kwexdha’ dhuyu’; dhak dhuyu’	–	12.794	13.696	26.490
75	*Jaltomata procumbens* (Cav.) J.L.Gentry	FSpe	Ojo de Guajolote	Wál palat’s	–	4.169	–	4.169
76	*Jatropha curcas* L.	FSpe	Pipián; Piñón	Dhakpénte’	–	4.167	–	4.167
77	*Lagenaria siceraria* (Molina) Standl.	FVar	Guaje chico de botella	Ts’akam xomom	–	4.169	–	4.169
78	*Lagenaria siceraria* (Molina) Standl.	FVar	Guaje grande de botella	Pakdha’ xomom	–	4.168	–	4.168
79	*Lagenaria siceraria* (Molina) Standl.	FVar	Guaje largo y grande	Nakdha’ pulik xomom	–	4.168	–	4.168
80	*Lagenaria siceraria* (Molina) Standl.	FVar	Guaje redondo	Kwentú	–	4.172	–	4.172
81	*Mangifera indica* L.	FVar	Mango criollo	Tének mango	5.001	4.168	–	9.169
82	*Mangifera indica* L.	Fvar*	Mango Manila injerto		–	4.167	4.546	8.713
83	*Manihot esculenta* Crantz	FVar	Yuca blanca	Dhak t’inche’	5.005	8.345	4.549	17.899
84	*Manihot esculenta* Crantz	FVar	Yuca roja	Tsak t’inche’	–	4.167	9.093	13.259
85	*Manilkara zapota* (L.) P.Royen	FSpe	Mamey	Bolom it’adh	–	4.167	–	4.167
86	*Mentha* sp.	FSpe	Hierba buena	Elbenax	–	8.336	–	8.336
87	Mucuna *pruriens* var. *utilis* (Wall. ex Wight) L.H.Bailey	FSpe	Frijol nescafé, Frijol pica pica		15.020	–	–	15.020
88	*Musa* sp.	FVar	Plátano Costillón/Jamaica	Pek’em it’adh	15.040	8.348	13.646	37.034

89	*Musa* sp.	FVar	Plátano Macho	Lej it’adh	–	16.680	–	16.680
90	*Musa* sp.	FVar	Plátano Manzana	Manzano it’adh	5.002	8.337	18.190	31.529
91	*Musa* sp.	FVar	Plátano Melón	Melón it’adh	–	16.683	9.093	25.776
92	*Musa* sp.	FVar	Plátano Morado/rojo	Tsak it’adh	–	4.181	4.547	8.729
93	*Musa* sp.	FVar	Plátano Roatán	Rátan it’adh	–	12.513	9.096	21.608
94	*Musa* sp.	FVar	Plátano Tabasco	Tabasco it’adh	–	4.175	4.549	8.724
95	*Nopalea cochenillifera* (L.) Salm–Dyck	FVar	Nopal redondo sin espinas	Kwexdha’ pak’ak’ yab k’idhadh	–	–	9.092	9.092
96	*Nopalea cochenillifera* (L.) Salm–Dyck	FVar	Nopal largo sin espinas	Nakat pak’ak’ yab k’idhadh	5.002	8.766	9.093	22.861
97	*Opuntia engelmannii* subsp. *lindheimeri* (Engelm.) U. Guzmán & Mandujano	FSpe	Nopal grande	Pulik pak’ak’	5.001	12.738	4.546	22.285
98	*Oxalis latifolia* Kunth	FSpe	Trébol	Jilil	–	10.180	–	10.180
99	*Pachyrhizus erosus* (L.) Urb.	FSpe	Jícama de agua	Kobeem	5.101	4.177	–	9.278
100	*Passiflora edulis* f. *flavicarpa* O. Deg.	FSpe	Maracuyá amarilla	Manu‘ owal pa	–	20.854	4.546	25.400
101	*Persea americana* Mill.	FVar	Aguacate corriente negro, redondo	T’unu’ uj ani mulúlchik	–	8.337	–	8.337
102	*Persea americana* Mill.	FVar	Aguacate corriente verde, redondo	Yax uj ani mulúlchik	5.001	4.168	–	9.168
103	*Persea americana* Mill.	FVar*	Aguacate Hass	Láb uj	–	12.512	–	12.512

			Hass avocado					
104	*Persea americana* Mill.	FVar	Aguacate oloroso negro, redondo	T’unu’ oj ani mulúlchik	5.001	8.349	–	13.350
105	*Persea americana* Mill.	FVar	Aguacate oloroso verde, largo	Yax oj ani nakat	–	4.167	–	4.167
106	*Persea schiedeana* Nees	FSpe	Aguacate pahua	Xomom uj	–	–	4.546	4.546
107	*Phaseolus coccineus* L.	FVar	Frijol coloni blanco	Dhak k’oloni’	5.001	–	13.724	18.725
108	*Phaseolus coccineus* L.	FVar	Frijol coloni café	Tsokoy k’oloni’	5.001	–	9.225	14.225
109	*Phaseolus coccineus* L.	FVar	Frijol coloni morado	Morado k’oloni’	–	–	4.546	4.546
110	*Phaseolus coccineus* L.	FVar	Frijol coloni naranjo	Lanáx k’oloni’	–	–	13.773	13.773
111	*Phaseolus coccineus* L.	FVar	Frijol coloni negro	T’unu’ k’oloni’	5.001	–	9.095	14.096
112	*Phaseolus coccineus* L.	FVar	Frijol coloni jaspeado gris	Gris mili’ k’oloni’	5.001	–	9.097	14.098
113	*Phaseolus coccineus* L.	FVar	Frijol coloni jaspeado morado	Morado mili’ k’oloni’	–	–	4.547	4.547
114	*Phaseolus coccineus* L.	FVar	Frijol coloni jaspeado naranjo	Lanáx mili’ k’oloni’	–	–	4.546	4.546
115	*Phaseolus coccineus* L.	FVar	Frijol coloni pinto blanco	Dhak tukmichik k’oloni’	5.001	–	4.547	9.547
116	*Phaseolus coccineus* L.	FVar	Frijol coloni pinto morado	Morado tukmichik k’oloni’	–	–	4.546	4.546
117	*Phaseolus coccineus* L.	FVar	Frijol coloni pinto naranjo	Lanáx tukmichik k’oloni’	–	–	4.546	4.546
118	*Phaseolus dumosus* L.	FSpe	Frijol cáscara blanda negro	T’unu’ paluw ot’ol	–	4.216	4.566	8.782
119	*Phaseolus lunatus* L.	FSpe	Frijol wet negro	Wet’ t’unu’	5.014	4.172	–	9.186

120	*Phaseolus vulgaris* L.	FVar	Frijol bayo de guía, breve, pinto negro	T’unu’ bayo tukmichik malte’ ani adhik	–	–	4.723	4.723
121	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, blanco	Dhak malte’ ani adhik	–	–	5.787	5.787
122	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, morado	Morado malte’ ani adhik	–	–	6.051	6.051
123	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, negro	T’unu’ malte’ ani adhik	5.077	–	14.038	19.114
124	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, rojo	Tsak malte’ ani adhik	–	–	6.013	6.013
125	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, ojo de cabra, morado	Morado mili’ t’sixo malte’ ani adhik	–	–	5.562	5.562
126	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, ojo de cabra, rojo	Tsak mili’ t’sixo malte’ ani adhik	–	–	4.805	4.805
127	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, pinto morado	Morado tukmichik malte’ an adhik	–	–	4.658	4.658
128	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, pinto negro	T’unu’ tukmichik malte’ ani adhik	–	–	4.658	4.658
129	*Phaseolus vulgaris* L.	FVar	Frijol de guía, breve, pinto rojo–blanco	Tsak tukmichik malte’ ani adhik	–	–	5.110	5.110
130	*Phaseolus vulgaris* L.	FVar	Frijol bayo de guía, flojo	Dhak bayo malte’ ani k’ayum	–	4.171	9.376	13.547
131	*Phaseolus vulgaris* L.	FVar	Frijol de guía, flojo, blanco	Dhak malte’ ani k’ayum	–	–	10.373	10.373
132	*Phaseolus vulgaris* L.	FVar	Frijol de guía, flojo, negro	T’unu’ malte’ ani k’ayum	5.004	17.680	47.729	70.413

133	*Phaseolus vulgaris* L.	FVar	Frijol de guía, flojo, rojo	Tsak malte’ ani k’ayum	–	–	4.614	4.614
134	*Phaseolus vulgaris* L.	FVar	Frijol de guía, flojo, rojo jaspeado	Tsak mili’ malte’ ani k’ayum	–	–	5.609	5.609
135	*Phaseolus vulgaris* L.	FVar	Frijol de mata, breve, negro de cáscara negra	T’unu’ puk’úl ani adhik tunu’ ot’ol	–	7.631	–	7.631
136	*Phaseolus vulgaris* L.	FVar*	Frijol Michigan de mata, negro, breve	Michigan puk’úl t’unu’ ani adhik	–	23.379	5.759	29.138
137	*Phaseolus vulgaris* L.	FVar*	Frijol Nayarit de mata, negro, flojo	Nayarit puk’úl t’unu’ ani k’ayum	–	4.692	–	4.692
138	*Physalis cinerascens* (Dunal) Hitchc.	FSpe	Tomatito del monte	Alte’ tudhey an ot‘odh	–	4.168	–	4.168
139	*Physalis pubescens* L.	FSpe	Tomatito dulce del monte	Alte’ ts’ik tudhey an ot’odh	5.031	–	–	5.031
140	*Physalis* sp.	FSpe	Tomatito silvestre verde chico	Alte’ yax ts’akam tudhey an ot’odh	15.217	4.181	4.557	23.954
141	*Physalis tamayoi* O. Vargas, M. Martínez & Dávila	FSpe	Tomatito verde del monte	Alte’ yax tudhey an ot’odh	5.024	–	–	5.024
142	*Piper* sp.	FSpe	Hoja santa	Tiyá’	–	–	4.546	4.546
143	*Pistacia vera* L.	FSpe	Pistache		–	4.167	–	4.167
144	*Porophyllum ruderale* (Jacq.) Cass.	FSpe	Tepehua	Midhidh	10.021	21.945	–	31.966
145	*Portulaca oleracea* L.	FSpe	Verdolaga	Pitsits wal	–	28.375	–	28.375

146	*Prunus persica* (L.) Batsch	FVar	Durazno criollo rojo	Tének tsak tulaxnúj	–	4.167	–	4.167
147	*Prunus persica* (L.) Batsch	FVar*	Durazno amarillo injertado	Manu’ tulaxnúj tsátadh kán	–	–	4.575	4.575
148	*Psidium guajava* L.	FVar	Guayaba amarilla criolla redonda	Manu’ muldha’ bek	–	4.167	–	4.167
149	*Psidium guajava* L.	FVar**	Guayaba del monte	Alte’ bek	5.002	4.169	9.092	18.263
150	*Psidium guajava* L.	FVar	Guayaba morada	Morado bek	5.002	4.167	–	9.169
151	*Rumex crispus* L.	FSpe	Lengua de vaca	Lek’áb pakax		4.273	–	4.273
152	*Ruta angustifolia* Pers.	FSpe	Ruda		–	4.184	–	4.184
153	*Sabal mexicana* Mart.	FSpe	Palma de palmito y techo	Apats’akual	20.187	–	–	20.187
154	*Saccharum officinarum* L.	FVar	Caña blanca criolla	Dhak pakab	–	8.349	4.551	12.900
155	*Saccharum officinarum* L.	FVar	Caña morada criolla	Tsak pakab	–	4.171	4.546	8.717
156	*Saccharum officinarum* L.	FVar*	Caña RD	Pakab RD	10.038	–	–	10.038
157	*Saurauia scabrida* Hemsl.	FSpe	Mameycillo dulce	May te‘	–	–	18.183	18.183
158	*Sechium edule* (Jacq.) Sw.	FVar	Chayote aguado blanco, sin espinas, sin cáscara	Dhak ja’much tsiw’ yab k’idhadh yab ot’odh	–	4.168	4.548	8.716
159	*Sechium edule* (Jacq.) Sw.	FVar	Chayote aguado negro/verde, sin espinas, con cáscara	T’unu’/Yax ja’much tsiw’ yab k’idhadh ani ot’odh	–	4.167	–	4.167
160	*Sechium edule* (Jacq.) Sw.	FVar	Chayote seco, negro/verde, sin espinas, con cáscara	T’unu’/Yax mo’dhidh tsiw’ yab k’idhadh ani ot’odh	–	8.336	–	8.336

161	*Sechium edule* (Jacq.) Sw.	FVar	Chayote seco, negro/verde con espinas, con cáscara	T'unu'/Yax mo'dhidh tsiw' k'idhadh ani ot'odh	–	12.503	13.639	26.142
162	*Sesamum indicum* L.	FVar	Ajonjolí blanco criollo	Tének dhakpén dhakni'	11.672	–	–	11.672
163	*Sesamum indicum* L.	FVar	Ajonjolí crema/café criollo	Tének dhakpén tsokoy	40.344	–	–	40.344
164	*Sesamum indicum* L.	FVar	Ajonjolí negro, criollo	Tének dhakpén t'unu'	7.579	5.428	–	13.007
165	*Solanum lycopersicum* L.	FVar*	Tomate saladi	Tudhey saladi	5.006	4.167	–	9.173
166	*Solanum lycopersicum* var. *cerasiforme* (Dunal) D.M. Spooner, G.J. Anderson & R.K. Jansen	FVar**	Tomate coyol chico	Tének ts'akam tudhey	5.002	16.728	4.546	26.276
167	*Solanum lycopersicum* var. *cerasiforme* (Dunal) D.M. Spooner, G.J. Anderson & R.K. Jansen	FVar	Tomate coyol grande	Tének pakdha' tudhey	–	8.347	–	8.347
168	*Spondias mombin* L.	FSpe	Jobo	K'inim	10.003	–	–	10.003
169	*Vanilla planifolia* Jacks. ex Andrews	FSpe	Vainilla		–	8.334	–	8.334
170	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda negro, largo, flojo	K'ayum pakdha' t'unu' láb tsanak'w	15.898	–	–	15.898
171	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda negro, largo, flojo, de cáscara morada	K'ayum pakdha' t'unu' láb tsanak'w ani morado ot'ól	5.067	21.096	–	26.163

172	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda negro, mediano, flojo	K’ayum t’unu’ láb tsanak’w	5.267	–	–	5.267
173	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda negro, largo, breve	Adhik pakdha’ t’unu’ láb tsanak’w	–	–	4.566	4.566
174	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda café, mediano, breve	Adhik tsokoy láb tsanak’w	5.030	12.633	–	17.663
175	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda negro, mediano, breve	Adhik t’unu’ láb tsanak’w	–	–	4.584	4.584
176	*Vigna unguiculata* (L.) Walp.	FVar	Frijol sarabanda rojo, mediano, breve	Adhik tsakni’ láb tsanak’w	–	4.174	–	4.174
177	*Vitis* sp.	FSpe	Uva de monte chica	Alte’ ts’akam t’udhup	–	16.976	–	16.976
178	*Xanthosoma sagittifolium* (L.) Schott	FSpe	Luum rojo	Tsak lúm	–	4.168	–	4.168
179	*Xanthosoma* sp.	FSpe	Luum blanco	Dhak lúm	–	–	4.546	4.546
180	*Zea mays* L.	FVar	Maíz criollo, amarillo claro, breve	Adhik tének dhakni’adh manu’idhidh	18.083	4.479	–	22.562
181	*Zea mays* L.	FVar	Maíz criollo, amarillo, breve	Adhik tének manu’idhidh	62.899	67.819	5.129	135.847
182	*Zea mays* L.	FVar	Maíz criollo, blanco, breve	Adhik tének dhakni’idhidh	16.792	10.021	41.559	68.372
183	*Zea mays* L.	FVar	Maíz criollo, azul/negro/prieto, breve	Adhik tének tsulu‘/t’unu’ idhidh	22.548	5.042	–	27.590

184	*Zea mays* L.	FVar	Maíz criollo, pinto blanco con morado, breve	Adhik tének mili‘/tukmichik dhakni’ an tsulu’ idhidh	14.887	–	–	14.887
185	*Zea mays* L.	FVar	Maíz criollo, pinto, breve	Adhik tének idhidh mili‘/tukmichik	7.656	6.195	6.888	20.739
186	*Zea mays* L.	FVar	Maíz criollo, azul/negro/prieto, medio breve y flojo	Tsulu’/t’unu’ tének idhidh yab adhik yab k’ayum	–	–	7.058	7.058
187	*Zea mays* L.	FVar	Maíz criollo, pinto azul/negro/prieto, medio breve y flojo	Mili’/tukmichik/tsulu’ tének idhidh yab adhik yab k’ayum	–	–	31.410	31.410
188	*Zea mays* L.	FVar	Maíz criollo, blanco, flojo	K’ayum dhakni’tének idhidh	–	–	43.646	43.646
189	*Zea mays* L.	Fvar*	Maíz híbrido, amarillo, breve	Adhik híbrido manu’ idhidh	–	6.667	–	6.667
190	*Zea mays* L.	FVar*	Maíz híbrido, blanco, breve	Adhik híbrido dhakni’ idhidh	–	–	4.790	4.790
191	*Zingiber officinale* Roscoe	FSpe	Jenjibre		–	4.172	–	4.172

FVar = farmer–recognized variants including *commercial varieties and **wild relatives of cultivated plants. Hybrids between cultivated plants and their wild relatives are not further distinguished.

FSpe = farmer–recognized species without documented variants.

IV= Importance value.

LAlt= Low altitude (Poytzen, 59–67 m)

MAlt= Medium altitude (Jol Mom, 525–733 m)

HAlt= High altitude (U. de Guadalupe, 865–1247 m)

[1] Fruits probably have a long–shaped form because it is a hermaphrodite plant and it is considered a variant.

Notes:

1. The local names and names in Huastec language refer to a proper name or descriptions made by farmers to distinguish the FVar and FSpe. No literal translations are presented and the word order can change. The list was reviewed by the Tének farmers of the research area and linguistic experts. Literal translations can be requested contacting the author or under: http://nenek.inali.gob.mx/ES/?opc=dictionary
2. There is no Huastec term for the color "morado" (purple). In some cases, similar color terms are used. If nothing was proposed the English term has been used instead.
3. In some cases, more than one local or Tének name exists for the same species or variant. A slash indicates both terms are used as synonyms.

Appendix 2 ESM Table 1. Identified Priority Crop Species, in Alphabetic Order, of the *Milpas* Managed by the *Tének* in the Huasteca Potosina, Mexico.

	Priority crop species	Type[1]	Number per type per locality			Total FVar or FSpe[3]
			Low	Medium	High	
1	*Amaranthus hybridus* L.	FVar	0	2	0	2
2	*Capsicum annuum* L.	FVar	1	5	2	5
3	*Coriandrum sativum* L	FSpe	1	1	1	1
4	*Cucurbita argyrosperma* C. Huber	FVar	2	1	1	2
5	*Cucurbita moschata* Duchesne	FVar	3	18	6	19
6	*Dioscorea alata* L.	FSpe	0	1	1	1
7	*Ipomoea dumosa* (Benth.) L.O. Williams	FSpe	0	1	1	1
8	*Ipomoea elongata* Choisy	FSpe	0	1	1	1
9	*Nopalea cochenillifera* (L.) Salm–Dyck	FVar	1	1	2	2
10	*Opuntia engelmannii* subsp. *lindheimeri* (Engelm.) U. Guzmán & Mandujano	FSpe	1	1	1	1
11	*Passiflora. edulis* f. *flavicarpa* O.Deg	FSpe	0	1	1	1
12	*Phaseolus coccineus* L.	FVar	5	0	11	11
13	*Phaseolus vulgaris* L.	FVar	2	5	16	18
14	*Sechium edule* (Jacq.) Sw.	FVar	0	4	2	4
15	*Sesamum indicum* L.	FVar	3	1	0	3
16	*Solanum lycopersicum* L.	FVar	2	3	1	3
17	*Vigna unguiculata* (L.) Walp.	FVar	4	3	2	7
18	*Zea mays* L.	FVar	6	6	7	11
		Total FVar+FSpe[3]	31	55	56	93

[1] FVar = Farmer recognized variants, FSpe = Farmer recognized species with no documented variants.

[2] Low altitude (Poytzen), Medium altitude (Jol Mom), High altitude (Unión de Guadalupe).

[3] FVar+FSpe = the priority farmers' edible plant diversity consisting of the farmer–recognized variants and farmer– recognized species with no documented variants.

Note: *N. cochenillifera* and *Opuntia engelmannii* subsp. *lindheimeri* even though they are perennial crops, the farmers only use them as long as the *milpa* field is managed. They harvest the tender stems for food consumption. If left unattended, the plants have difficulty to survive. Hence, they remain included in the list of priority crops.

Appendix 2 ESM Table 2. Species with most Intraspecific Richness in the Research Localities

Species	LowAlt	MedAlt	HigAlt	Total	Average number of individuals per FVar or Fspe
Cucurbita moschata Duchesne	3 (0.6; 1.0)	18 (5.2; 1.8)	6 (0.6; 1.0)	19	25 (22)
Phaseolus vulgaris L.	2 (0.2; 0.4)	5 (1.0; 0.7)	16 (2.4; 2.3)	18	5999 (12462)
Phaseolus coccineus L.	5[1] (0.5; 1.6)	–	11 (1.6; 3.4)	11	111 (182)
Zea mays L.	6 (1.4; 0.5)	6 (1.1; 0.5)	7 (1.4; 0.5)	11	44358 (49491)

Vigna unguiculata (L.) Walp.	4 (0.6; 0.5)	3 (0.8; 0.5)	2 (0.2; 0.4)	7	495 (536)
Musa sp.	2 (0.4; 0.7)	7 (1.4; 2.2)	6 (1.2; 1.4)	7	51 (37)

LowAlt = Low altitude (Poytzen), MedAlt = Medium altitude (Jol Mom), HigAlt = High altitude (Unión de Guadalupe).

The values in brackets refer to the average number of variants per farmer followed by the corresponding SD–value, with the exception of the last column where only SD is shown.

[1] Five FVar being cultivated experimentally for the first time by one farmer in the LowAlt site.

Appendix 3 ESM Table 1. Species and Variant Richness of Indigenous *Milpas* in Mexico.

Indigenous people	Species richness	Variant richness	Reference
Chinantec	58^{ab}	33	Mateos–Maces et al. (2016)
Huastec	84 (84)^{ab}	141	This study
Huastec	15 (15)^{a}	–	Cilia–López et al. (2015)
Huastec	124 (51)^{ab}	–	Alcorn (1984)
Maya	56 (56)^{ab}	57	Nations and Nigh (1980)
Maya	28^{ab}	95	Teran and Rasmussen (1995)
Maya	88 (25)^{ab}	17	Lara Ponce et al. (2012)
Totonac	72 (43)^{ab}	–	Toledo et al. (1994)

^{a}Cultivated, ^{b}Non– cultivated. The number in brackets refers to edible plants.

Appendix 3 ESM Table 2. Comparison of the Average Variant Richness per Farm.

Maize	Beans	Squash	Chilies	Reference
1.27	2.03	2.81	0.84	This study
1.23–2.26	1.12–2.68	1.15–1.68	1.22–1.58	Jarvis et al. (2008)
2.3	1.3	1.2	1.8	Lope–Alzina and Chávez–Servia (2004)

Appendix 3 ESM Table 3. Comparison of the Total Variant Richness for some Selected Crops

Maize	Beans	Calabaza	Chilies	Yuca	Reference
11	38	23	5	3	This study
5	21	4	–	3	Mateos–Macas et al. (2016)
8	6	–	–	–	Ortiz–Timoteo et al. (2014)

10	8	–	–	–	Lara Ponce et al. (2012)
15	6	3	6	–	Arias et al. (2004)

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CHAPTER II

More than Maize, Coffee and Bananas: The Rich Inter- and Intraspecific Edible Plant Diversity in the Agroecosystem Complex of *Tének* Indigenous Communities in Mexico

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Abstract

Traditional land use systems managed by small-scale farmers, often indigenous, are a reservoir of plant genetic resources. The *Tének* farmers in the Huasteca Potosina region in Mexico manage highly diverse food biota that are grown in agroecosystem complexes comprised of swidden maize fields locally known as *milpas*, agroforestry systems and home gardens. Until now, data of the total edible plant diversity found in these different land use systems that are simultaneously managed by the farmers are scarce, but necessary to reveal the importance of traditional agroecosystem complexes for *in situ* conservation of edible plant diversity.

The aim of this study was to characterize the total, specific and intraspecific diversity of food crops in the *Tének* agroecosystem complex and to show how diversity parameters change, interrelate or co-vary within and between three localities at different altitudes.

The *Tének* cultivate a high and (so far incomparable) diversity of different food crops at both inter- and intraspecific levels. In total, 149 botanical species that form a total number of 347 farmer recognized variants (FVar) and farmer-recognized species with no registered variants (FSpe) were documented. The highest diversity was found at the medium altitude locality. Intraspecific diversity accounts for 68.6% of the total farmer-recognized edible plant diversity.

The similarity between and within the different land use systems is low and they all serve as a specific pool for plant genetic resources. The number of FVar in the *milpa* can be used as indicator for the total FVar+FSpe in the agroecosystem complex. However, the identification of variables or predictors for crop diversity is challenging, but marginal conditions (rockiness, slope gradient, walking time) seem to play a significant role.

In the context of population growth and adaptation to the climate emergency, identifying and mainstreaming crop genetic resources at the intraspecific level and in the farmers’ agroecosystem complex becomes a necessity, in order to understand to which extent traditional farmers contribute to the *in situ* conservation of plant genetic resources and to identify synergies in productive landscapes between rural development, conservation and food security.

Key words: agrobiodiversity, ethnobotany, home garden, land use system, *milpa*, *te’lom*

Introduction

Traditional land use systems are a reservoir of plant genetic resources and are considered a backbone for secure agricultural food production (Altieri and Merrick 1987; Thrupp 2000). They are mainly managed by small-scale farmers who interact with the environment based on gained experiences and knowledge throughout generations (Stolton et al. 2006). These farmers usually do not have access to scientific information, external inputs, capital, credit and developed markets (Altieri and Merrick 1987). Traditional farmers often live in marginal areas and crop genetic diversity is critical to optimize use of resources and to produce crops under diverse and often adverse conditions, which is especially important for them to assure food security and sustainable agriculture (Stolton et al. 2006). Farmers' optimization of crop diversity in these cropping systems is a risk-minimizing strategy in order to have access to multiple products, whether to cover subsistence needs or to produce income by selling their products (Toledo et al. 2003). Further, diversity in cropping systems contribute to the diversification of diets and supports the functionality of the whole production system (Girardello et al. 2019; Gübel 2019; Kremen et al. 2012).

Traditional land use systems are very often the origin of landraces and variants of important food crops or serve as a refuge for crop wild relatives from the natural surroundings (Galluzzi et al. 2010; Stolton et al. 2006; Thrupp 1998). They usually have a high plant diversity in time and space (Stolton et al. 2006, Toledo et al. 2003). Yet current tendencies to abandon agriculture and to emphasize the use of modern or commercial variants threaten the continuation of their role (e.g., Swaminathan 2000; Wale 2011).

Even though the value of traditional land use systems for maintaining genetic diversity is widely acknowledged by several authors (e.g., Agbogidi and Adolor 2013; Altieri and Merrick 1987; Gbedomon et al. 2017), only a few studies have included information on intraspecific diversity in order to strengthen this argument and to assess agrobiodiversity in traditional land use systems in a more formal and comparable way (e.g., Gbedomon et al. 2017; Heindorf et al. 2019, Chpt. 1). Also, there is little information on how the agrobiodiversity is distributed in the different production units

Indigenous cultures of Mesoamerica, one of the centers of crop diversity and domestication in the world (Vavilov 1935), follow a multiuse strategy of the landscape that involves different land use systems ranging from home gardens, *milpa* fields, agroforestry systems and managed forests. Indigenous people in tropical Mexico tend to have polyculture agricultural systems with a high number of edible plants. These polyculture management systems contain species with different degrees of humanization as well as protected, tolerated and promoted species (Alcorn 1984; Perales and Aguirre 2008; Toledo et al. 2003). All systems together are referred to as an agroecosystem complex.

The *Tének* farmers in the Huasteca Potosina region in Mexico still manage a variety of food plants in the agroecosystem complex that include swidden maize fields locally known as *milpas*, agroforestry systems mainly dedicated to coffee and fruit tree production (*te'loms*), and home gardens (Alcorn 1984; Heindorf et al. 2019, Chpt. 1). Except for the work by Heindorf et al. (2019), describing the rich intraspecific agrobiodiversity of the *Tének milpas*, the overall inter- and intraspecific diversity, including of their *te'loms* and home gardens, has not been characterized nor is its role understood.

The aim of this study was to document the total diversity, specific- and intraspecific, of food crops of the agroecosystem complex of the *Tének* and to show how diversity parameters interrelate or co-vary considering the three main production systems at farmer and community level for three communities along an altitudinal gradient. A further objective was to describe the similarity within and between the different land use systems. General environmental and socioeconomic factors were included to understand which external factors influence food crop diversity at crop specific and intraspecific level in the different land use systems.

Methods

Research Site

This study forms part of larger research project for which three *Tének* localities were selected (Heindorf et al. 2019, Chpt. 1). The *Tének* manage three main agricultural production systems, mainly for subsistence, that shape the highly heterogenous landscape of the Huasteca Potosina (Alcorn 1984; Heindorf et al. 2019, Chpt. 1). The Huasteca Potosina belongs to the Eastern part of the state of San Luis Potosí in Northeastern Mexico and four main ethnic groups, the *Tének*, *Nahuas*, *Xi'oi* and Mestizo people live in the region. The *Tének* (or Huastec) are a Mayan people and have managed and shaped the biota of the Huasteca Potosina for 3,000 years (Alcorn 1984). As previous studies show, they are knowledgeable managers of plant diversity for different purposes (e.g. Alcorn 1984; Heindorf et al. 2019, Chpt 1).

To survey edible plant richness of the *Tének*, three localities distributed along an altitudinal gradient were selected. The selection was based on a small survey of 55 merchants of four open-air traditional markets during exploratory field visits to the research area. The merchants were asked about the origin of their products and, based on their information, some *Tének* communities were preselected. The most important locality-selection criteria were the persistence of *Tének* language, practice of subsistence agriculture and its altitude (m) (see Heindorf et al. 2019, Chpt. 1 for more information). The climate in the three selected research sites ranges from subtropical to tropical and the vegetation changes from tropical deciduous forest in the research site Poytzen at low altitude (LowAlt, 59-67 m) to tropical rain forest and cloud forest in Jol Mom at medium altitude (MedAlt, 533-725 m) and cloud forest and oak pine forest in Unión de Guadalupe at high altitude (HigAlt, 825-1180 m).

Data Collection and Inventory

Thirty-three farmers were selected preferentially as key informants. All of them managed and cultivated crops in the three most representative production systems, consisting of: (1) *milpas*, that are mainly swidden polyculture maize-based fields; (2) home gardens, which are agroforestry systems close to the house; and (3) *te'loms*, which can be described as agroforestry systems consisting of patches of secondary forest usually mixed with fruit trees and coffee plants in combination with perennial crops, including high value crops like vanilla (*Vanilla planifolia*) and chili (*Capsicum* spp.). *Te'loms* mainly dedicated to coffee production are also named *fincas*.

The three aforementioned land use systems of each farmer were inventoried. Each *milpa* was visited at least twice to inventory all crop species that may change according to the different harvest cycles of the year. A detailed description of the inventory methods applied for the *milpas* as well as the additional measurements to describe the *milpas* and their setting was provided by Heindorf et al. (2019, Chpt. 1). For the home gardens, all the edible plants were counted. For dense herbaceous vegetation (e.g., *Capsicum annuum*, *Rumex crispus*), sample plots of 1 m^2 were arranged randomly in order to estimate the number of plant individuals. The size of the home gardens was measured. Due to the extended size of the *te'loms* (mostly >1 ha and up to 4 ha) and the patchy presence of edible plants, farmers were asked to guide the investigator to these patches of edible plants to take data about the number of individuals of each edible plant species and variants. The farmer was asked to provide the original number of trees and shrubs, e.g., *Coffea* sp., planted. This was especially useful when sample plots were impossible to establish due to the inaccessibility of the terrain. Additionally, the key informants were interviewed with a semi-structured interview on socio-economic aspects and the destination of traded crops.

Specimens of each species were collected for identification and deposited in the herbarium of the IIZD of the UASLP (http://slpm.uaslp.mx/). Information on intraspecific diversity was mainly gathered by asking the farmers to name their variants as these were being inventoried. Afterwards, specified questionnaires for each farmer were developed to do a second key informant interview about the edible food plant diversity to double check the information previously gathered. In order to avoid over- and under-estimation of intraspecific diversity because of inconsistency in naming, a photo collection of all edible plants and their variants was used as a tool to discuss naming and identification with seven expert farmers. Also, two participatory workshops were held at each locality as well as one seed fair where names of farmer recognized species and variants were discussed. The names were all documented in the local Spanish and *Tének* names. Detailed information on the methodology to understand *Tének* folk taxonomy is presented in Chpt. 3.

Farmer recognized species and variants were used as the taxonomic units for the edible plant diversity. For this research, variants from the three research sites that shared the same name and labels, and which had no clearly contrasting traits were considered as the same variants. The acronym “FVar” refers to farmer recognized variants and “FSpe” to farmer recognized species with no documented intraspecific variation. Farmer-recognized variants should not be confused with folk varietals or folk specifics which are identified following a strict folk taxonomic approach (Chpt. 3). The total farmer edible plant diversity is expressed as “FVar +FSpe”. Total botanical species refers to FSpe plus the species that conform the FVar.

Data Analysis

For each land use system of each farmer the Shannon-Wiener diversity index and the Simpson diversity index were determined, separately for the “FVar +FSpe” and for the FVar.

The Shannon Wiener index (*H’*, Magurran 1991) was calculated as:

$$H'_{\text{FVar+FSpe}} = -\sum p_i \cdot \ln(p_i)$$

where $\mathrm{p}i = \frac{\mathrm{n}i}{N}$

n_i = number of individuals of the i-th FVar+FSpe;

N = total number of individuals of FVar+FSpe

and

$$H'_{\text{FVar}} = -\sum p_i \cdot \ln(p_i)$$

where $\mathrm{p}i = \frac{\mathrm{n}i}{N}$

n_i = number of individuals of the i-th FVar;

N = total number of individuals of FVar

The Simpson diversity index (*D*, Magurran 1991) was calculated as:

$$D_{\text{FVar+FSpe}} = 1 - \sum {p_i}^2$$

where $\mathrm{p}i = \frac{\mathrm{n}i}{N}$

n_i = number of individuals of the i-th FVar+FSpe;

N = total number of individuals of FVar+FSpe

and

$$D_{\text{FVar}} = 1 - \sum {p_i}^2$$

where $\mathrm{p}i = \frac{\mathrm{n}i}{N}$

n_i = number of individuals of the i-th FVar;

N = total number of individuals of FVar

Both indexes were used because it was considered important to evaluate diversity from different perspectives, seeking for potential subtle differences that one of them may or may not properly emphasize. Although both indexes form part of the same family of indexes to measure ecological diversity, their differences may mask or evidence salient features that are worth noting. Particularly, *H'*- index is more sensitive to rare species than *D*- index (Morris et al. 2014). Nonetheless, to the extent that results from both indexes yield equivalent results for the cases where they are applied, results will be used citing both indexes not attempting to separate between them.

An analysis of variance (ANOVA) was performed to compare the means of edible plant richness and diversity and the indexes between different land use systems for the three sites. Normal distribution was examined using the Shapiro-Wilk Test. In case of normal distribution, a Brown-Forsythe ANOVA was calculated followed by a Holm-Sidak post hoc test to determine differences between the groups. For non-normal distribution a Kruskal-Wallis ANOVA on ranks was used followed by the Dunn's multiple comparison method.

A rank abundance curve showed the distribution of edible plant richness in the three systems (Magurran 2004). To complement the description of the different land use systems in terms of FVar+FSpe composition the Similarity Percentage (SIMPER) analysis identified the FVar+FSpe that contributed most to the similarity of the same system and dissimilarity between the different land use systems. The SIMPER analysis is based on the Bray Curtis measure of similarity (Clarke 1993).

Regression analyses using Pearson's correlation were performed to determine relations between different sets of diversity data and between them and different sets of ecologic and social data. The variables used for correlation included information on environmental aspects such as rockiness (%), slope gradient (°), annual precipitation (mm), mean annual temperature (°C), exposition (cardinal orientation) and field size (ha), and social-demographic aspects such as farmer's age (yr), farmer's experience (yr), number of family members that depend on the crop products and walking time (h) to the production system. Separate correlations were made for the different localities and production systems to explain in more detail the set of variables that best predict crop diversity. Variables showing significant correlations ($P < 0.05$), were used for multiple regression analysis to attempt to establish their combined influence on the expression of the edible plant diversity. Different multiple regressions, following the approach of bidirectional elimination of independent variables, were made to obtain the most suitable set of data used to quantify the influence on the edible plant diversity.

In order to prove the approached sampling completeness, rarefaction curves (Mao Tao) for the different land use systems and localities were made (Colwell et al. 2004). To provide information on the number of samples needed for completeness ($y = 0$), a linear extrapolation was made via linear correlation using the last ten values of the output data (with slope = difference in number of new taxa between samples) of the rarefaction curves. This method is used as an alternative to extrapolations proposed by other authors, as for example the analytical formula and simulation by randomizing the samples with EstimateS (Colwell 2001; Colwell et al. 2012; Ugland et al. 2003), where extrapolations are suggested that assume that sample completeness is not likely to be achieved (y always > 0). However, considering the fact that sampling was made in an agricultural environment and the taxa sampled refer to FVar+FSpe that are known by the farmers and that are mainly cultivated, the probability of new taxa is expected to be lower in contrast to natural environments, where the unpredictability inhibits predictability. Therefore, in this research, as an alternative, the linear equation correlation model is used for extrapolation, which is:

0 (number of new taxa) = m (number of samples needed for completeness, n) + b,

where m is the slope and b the intercept.

A subsequent equation was used to determine the number of FVar+FSpe that would be inventoried reaching the number of samples necessary to achieve sampling completeness:

Number of new taxa expected = m (number of samples needed for completeness - number of samples in the research) + b

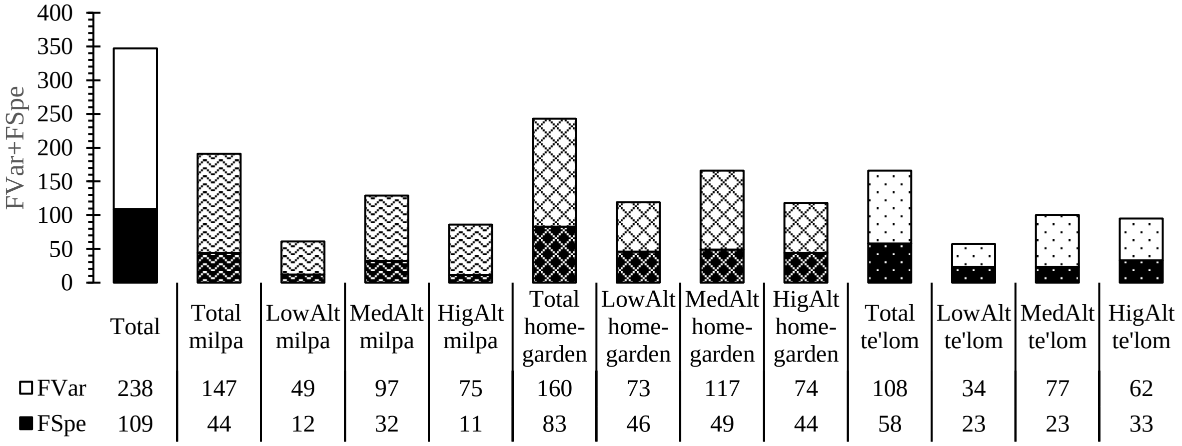
ANOVA, correlations and multiple regressions were made using Sigma Plot V. 14.0 (https://systatsoftware.com/). Diversity indices and the rarefaction curves were calculated using Past 3.20. The SIMPER analysis was made using CAP 6 from PISCES (http://www.pisces-conservation.com/).

Results

General Description of Richness and Diversity

In total 149 botanical species that consist of 108 genera and belong to 53 plant families were registered in the *milpas*, home gardens and *te'loms*, for a total number of 347 FVar+FSpe that consist of 109 FSpe and 238 FVar. The number includes commercial varieties and wild ancestors of cultivated plants. FVar comprise 68.6% of the total farmer-recognized edible plant diversity, highlighting the dominance of intraspecific diversity in the agroecosystem complex.

For the MedAlt locality a total of 244 FVar+FSpe were registered, followed by HigAlt and LowAlt with 203 and 175 FVar+FSpe, respectively. The highest numbers of FVar+FSpe for each land use system were documented for the home gardens (243 FVar+FSpe). For the *milpas* 191 FVar+FSpe were documented and 166 FVar+FSpe for the *te'loms* (Figure 1). The MedAlt is the locality with the highest number of FSpe and FVar for each land use system, especially the number of FVar+FSpe are considerable higher in the home gardens (166) and *milpas* (129). The LA locality has the lowest richness for *milpas* and *te'loms*. The number for the home garden is almost equal for LowAlt (119) and HigAlt (118).



	Total	Total milpa	LowAlt milpa	MedAlt milpa	HigAlt milpa	Total home-garden	LowAlt home-garden	MedAlt home-garden	HigAlt home-garden	Total te'lom	LowAlt te'lom	MedAlt te'lom	HigAlt te'lom
□FVar	238	147	49	97	75	160	73	117	74	108	34	77	62
■FSpe	109	44	12	32	11	83	46	49	44	58	23	23	33

Figure 1. Richness of edible plants in three *Tének* localities with different altitude in the Huasteca Potosina, Mexico. LowAlt = Low altitude (Poytzen), MedAlt = Medium altitude (Jol Mom), HigAlt = High altitude (Union de Guadalupe). FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

The biodiversity indexes, both the Shannon-Weaver index (*H'*) and Simpson index (*D*) for the FVar+FSpe are slightly yet consistently higher than for the FVar for each system in the three altitudes (Table 1). The *milpas* have, on average, the lowest values of diversity of FVar+FSpe (*H'* = 1.06 and *D* = 0.52) and FVar (*H'* = 0.91 and *D* = 0.48). It is also the only crop production system with statistically significant differences between the means of the other two research sites. The Shannon and Simpson indexes of the *milpa* FVar+FSpe are significantly higher for the MedAlt

(*H'* = 1.53 and *D* = 0.67). In case of the *milpa* FVar the biodiversity indexes are also the highest for MedAlt (*H'* = 1.20 and *D* = 0.58). There exists no statistically significant difference for the Simpson index between the different land use systems for the three altitudes, but the Shannon index is statistically different between MedAlt (*H'*= 1.20) and LowAlt (*H'* = 0.71). This may be explained by the fact that the FVar are more evenly distributed in all three land use systems, but species richness and occurrence of less abundance differ a lot between the *milpas* of MedAlt and LowAlt. Notably, this was the only case where there was a difference in the results obtained from both indexes. The mean Shannon index of HigAlt (*H'* = 0.79), however, is not statistically different from the LowAlt nor from the MedAlt (Table 1).

The home gardens show the highest value for both the Simpson and Shannon indexes in the three different localities, with a total FVar+FSpe average value of 0.81 and 2.30, respectively. The same applies to the FVar with 0.74 and 1.94, respectively. A comparison between production systems for the different altitudes (lower part Table 1) shows that both for FVar+FSpe and FVar, for both indixes, home garden values are significantly larger than those for *milpa* and *te'lom*.

However, the standard deviation (SD) values are rather high (except for home gardens), as expressed by high coefficients of variation (> 31%) obtained from the data, that indicate a high variability of the biodiversity indexes for the different system of each farmer (Table 1).

Table 1. Diversity indexes (mean values) for edible plant diversity in *Tének* localities with three different altitudes (standard deviation): low (Poytzen), medium (Jol Mom) and high (Unión de Guadalupe) in the Huasteca Potosina, Mexico.

	Low altitude	Medium altitude	High altitude	Mean for all altitudes
Milpa				
FVar+FSpe				
Simpson *D*	0.43a[1] (0.34)	0.67b (0.21)	0.43a (0.24)	0.52 (0.24)
Shannon *H'*	0.79a (0.34)	1.53b (0.51)	0.81a (0.48)	1.06 (0.56)
FVar				
Simpson *D*	0.41a (0.21)	0.58a (0.22)	0.42a (0.24)	0.48 (0.23)
Shannon *H'*	0.71ab (0.36)	1.20c (0.48)	0.79bc (0.48)	0.91 (0.48)
Home garden				
FVar+FSpe				
Simpson *D*	0.82a (0.12)	0.78a (0.22)	0.83a (0.13)	0.81 (0.16)
Shannon *H'*	2.39a (0.45)	2.25a (0.82)	2.28a (0.72)	2.30 (0.67)
FVar				
Simpson *D*	0.73a (0.16)	0.71a (0.30)	0.77a (0.14)	0.74 (0.21)
Shannon *H'*	1.96a (0.49)	1.96a (0.90)	1.92a (0.69)	1.94 (0.70)
Te'lom				
FVar+FSpe				
Simpson *D*	0.60a (0.15)	0.64a (0.17)	0.49a (0.32)	0.61 (0.22)
Shannon *H'*	1.59a (0.50)	1.40a (0.56)	1.27a (0.83)	1.44 (0.62)
FVar				
Simpson *D*	0.58a (0.14)	0.53a (0.27)	0.46a (0.29)	0.53 (0.24)
Shannon *H'*	1.16a (0.38)	1.14a (0.69)	1.07a (0.64)	1.13 (0.57)
Comparison between production systems at the three altitudes				
FVar+FSpe	*Milpa*	*Home garden*	*Te'lom*	
Simpson *D*	0.52b (0.24)	0.81a (0.16)	0.61b (0.22)	
Shannon *H'*	1.06b (0.56)	2.30a (0.67)	1.44b (0.62)	
FVar				
Simpson *D*	0.48b[2] (0.23)	0.74a (0.21)	0.53b (0.24)	
Shannon *H'*	0.91b (0.48)	1.94a (0.70)	1.13b (0.57)	

FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer recognized species with no documented variants.

[1] Means within a row for the three altitudes followed by a different letter are significantly different from each other ($P < 0.05$).

[2] Means within a row for the three production systems at each altitude followed by a different letter are significantly different from each other ($P < 0.05$). Data are the means for all altitudes.

The standard deviation values are presented in brackets.

Distribution of Edible Plant Diversity in the Different Land Use Systems and Localities

The rank abundance curves show that the total FVar+FSpe are unevenly distributed (Figure 2). The median value of the abundance is 17 plants and range from 1 (e.g., *Byrsonima crassifolia* [golden spoon] and *Passiflora hahni* [push luk]) to 159,290 (*Zea mays* [yellow local short-cycled maize]). Only 12.7% of all the FVar+FSpe consist of more than 1,000 plants. Annual crops in the *milpa*, like *Z. mays* and *Phaseolus vulgaris* are most abundant and make up 74.2% of the total number of plants cultivated. More than a third FVar+FSpe (125), most of them in the home garden, consist of less than 10 plants each. The curves also show that the FVar+FSpe of the home gardens are more evenly distributed compared to the *milpas* and *te'loms*. Plant numbers in home gardens range from 1 (e.g. *Spondias purpurea* [yellow Campechana plum], *Tamarindus indica* [local sour tamarind]) to 1,028 (*Coffea* sp., local red shade tolerant coffee).

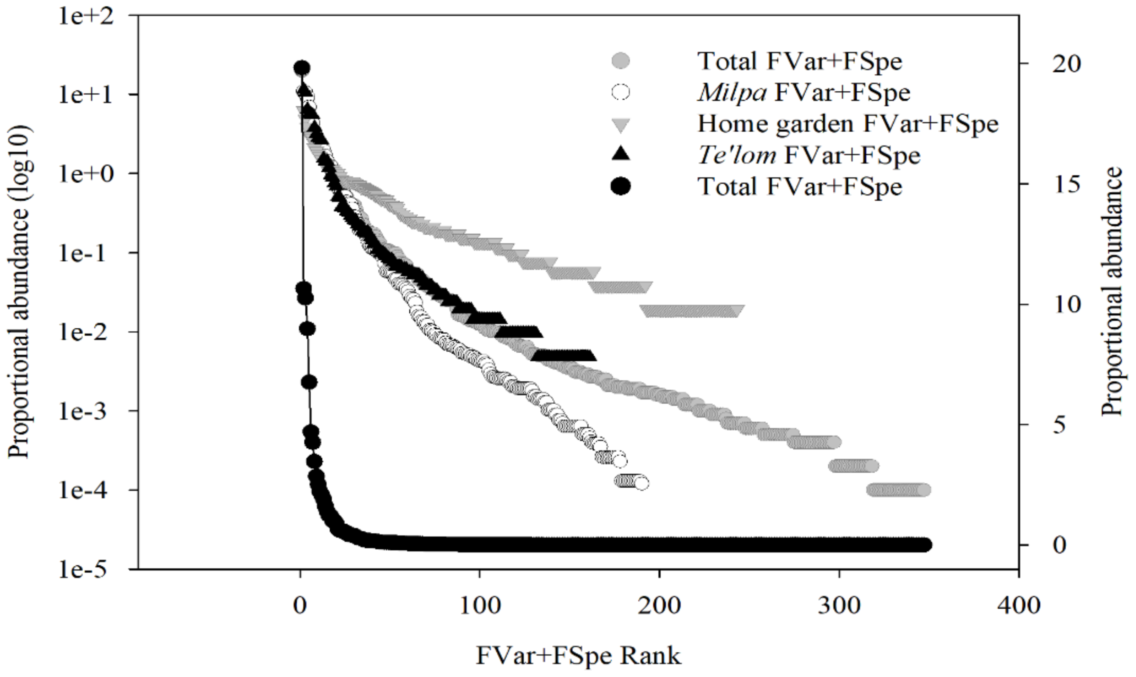


Figure 2. Rank-abundance curve of the edible plant diversity of three *Tének* land use systems in the Huasteca Potosina, Mexico. Both linear and log scales are used to show the actual shape of the distribution and its comparative detail, respectively.

The y-linear scale refers to the total FVar+FSpe marked with black-filled circles. The other curves belong to the y-log10 scale. FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

Richness per Farmer and Land Use System

Farmers manage and cultivate on average 33.3 edible botanical species and 48.7 FVar+FSpe in their agroecosystem complex (Table 2). The proportion of Fvar, with respect to FVar+Fspe, managed by each farmer is high (71%). Farmers in MedAlt manage the highest richness of both FVar+FSpe (60) and FVar (44) and the values are significantly higher compared to the LowAlt and to LowAlt and HigAlt, respectively. However, there exists no significant difference in botanical species between the three different altitudes (Table 2).

Concerning the richness of edible plants per farmer in the different land use systems significant differences exist only for the *milpas* between MedAlt and the two other sites (see also Heindorf et al. 2019, Chpt. 1). For the other two land use systems, even though farmers in the MedAlt cultivate a higher inter- and intraspecific richness, the differences are not significant compared to the other two sites. Numbers also show that home gardens, in general, in terms of richness of FVar+FSpe and FVar have the highest values ranging from 2-60 and 2-46, respectively. Again, the range of farmers' food plant diversity varies a lot indicated by the high SD-values at farmer level.

Table 2. Average richness of edible plants per famer in *Tének* localities with three different altitudes: low (Poytzen), medium (Jol Mom) and high (Unión de Guadalupe) in the Huasteca Potosina, Mexico.

	Low Altitude		Medium Altitude		High altitude		Total	
Per Farmer	Richness	Range	Richness	Range	Richness	Range	Richness	Range
Total								
FVar+FSpe	39.0a[1] (15.8)	23-69	60.0b (20.6)	20-94	45.1ab (13.9)	29-74	48.7 (18.9)	20-94
FVar	26.0b (7.3)	16-40	44.0a (16.4)	17-71	31.8b (9.7)	20-55	34.5 (14.0)	16-71
Botanical spp.	31.5a (13.3)	21-55	38.1a (9.4)	21-54	29.8a (7.8)	19-42	33.3 (10.6)	19-55
Milpa								
FVar+FSpe	10.0a (6.0)	5-25	26.0b (11.8)	10-49	13.5a (8.6)	2-27	17.0 (11.4)	2-49
FVar	7.5a (4.3)	4-19	19.9b (9.3)	10-38	11.5ab (7.5)	2-27	13.4 (9.0)	2-38
Home garden								
FVar+FSpe	23.0a (9.3)	12-41	28.1a (15.1)	11-60	20.4a (11.7)	2-39	24.0 (12.5)	2-60
FVar	15.2a (4.6)	8-22	19.9a (11.9)	6-46	13.3a (7.6)	2-25	16.3 (9.0)	2-46
T'elom								
FVar+FSpe	10.1a (6.2)	5-27	16.7a (9.8)	4-34	17.3a (6.6)	3-28	14.9 (8.2)	3-34
FVar	6.0a (3.6)	2-15	12.4b (7.6)	1-23	11.6b (5.4)	0-19	10.2 (6.4)	0-23

FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

The standard deviation values are presented in brackets.

[1] Means within a row for the three altitudes followed by a different letter are significantly different from each other ($P < 0.05$).

Uniqueness and Shared Edible Plant Diversity Among Farmers, Localities and Production Systems

Most of the total 347 FVar+FSpe (74.1%) are considered as rare because they are cultivated in less than 30% of all the systems inventoried (Figure 3). Almost a quarter (24.8%) of the total FVar+FSpe are registered only once and only a very small portion (1.2%) is commonly found and cultivated in more than 60% of all the systems. Results are similar regarding the frequency of FVar+FSpe separately for each land use system. Here, the number of rare FVar+FSpe exceeds half of the edible plants for each different type of land use system. The number of FVar+FSpe which are only listed once is less, but considerable, and ranges from 35.4% in home gardens to up to 39.8% in *milpas* and only a small portion (< 6%) is commonly found in the different land use systems (Figure 3).

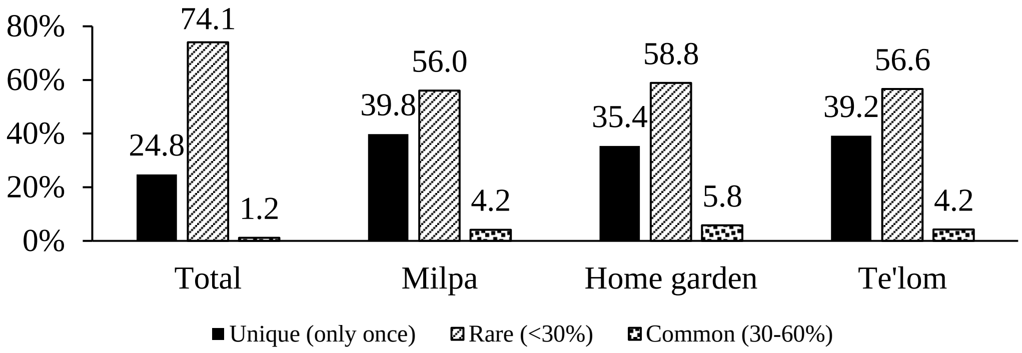


Figure 3. Relative distribution of edible plant diversity in the land use system complex of *Tének* farmers in the Huasteca Potosina, Mexico.

The shared edible plants between each farmer's different land use system is rather low indicating the different specific production purposes. Only 0.4 FVar+FSpe are cultivated by a farmer in all three systems. Examples include FVar of *Musa* sp., *Capsicum annuum* and FSpe *Vanilla planifolia*. *Milpas* and *te'loms* share on average only 1.2 FVar+Fspe (e.g., FVar of *Capsicum* *annuum*). Home gardens and *te'loms* share most of the edible plants with an average of 3.4 (e.g., FVar of *Citrus* spp. and *Musa* sp.). *Milpas* and home gardens share 2.3 FVar+Spe (e.g., FVar of *Amaranthus hybridus* and *Carica papaya*) (Table 4). A list of more examples is provided in the Supplementary Table 1.

Table 3. Average number of shared edible plant diversity between the different land use systems of the same farmer in three *Tének* communities in Mexico.

Home garden and *Te'lom*	*Milpa* and Home garden	*Milpa* and *Te'lom*	Between all the systems
3.4 (3.2)a[1]	2.3 (3.3)ab	1.2 (1.8)bc	0.4 (1.1)c

[1] Means within a row followed by a different letter are significantly different from each other ($P < 0.05$). The standard deviation of the means is presented in brackets.

Considering the total FVar+FSpe that are shared between different land use systems among the three different localities it is shown that only 19.3% (67) of the total FVar+FSpe were documented in all three land use systems (Figure 4). Most of the FVar+FSpe were found in both home gardens and *te'loms* (38.3%, 133). The number of shared species between *milpas* and home gardens is also high (32.3%, 112). *Te'loms* and *milpas* share only 22.1% (75).

Regarding the shared FVar+Spe between home gardens and *te'loms* among the three communities at different altitude, it is shown that MedAlt and HigAlt share most of the FVar+FSpe (Figure 4). Furthermore, the MedAlt is the locality with the land use systems that share most of the edible plant diversity with the two other localities at LowAlt and HigAlt. Figure 4 also shows that most of the home garden plants are exclusively found at MedAlt (57, 34.3%). In case of the *te'loms*, HigAlt has the highest proportion of unique FVar+FSpe (37, 38.9%).

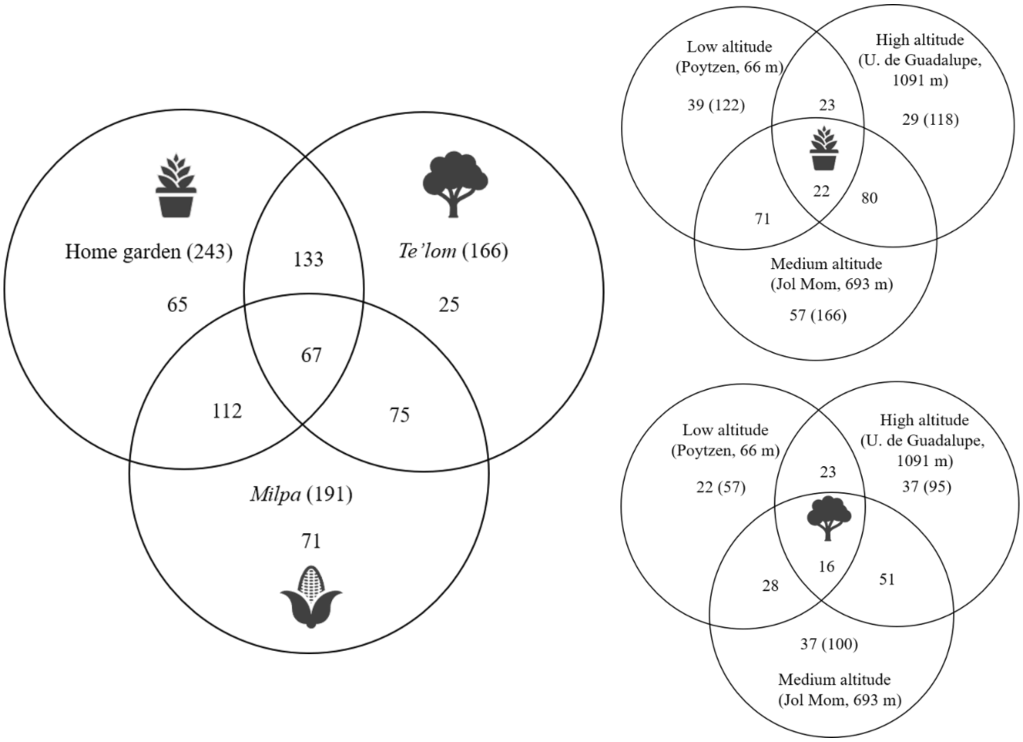


Figure 4: Shared FVar+FSpe between the different land use systems of three *Tének* localities in the Huasteca Potosina, Mexico (left) and shared FVar+FSpe between home gardens (upper right) and *te'loms* (lower right). Information on *milpas* was taken from Heindorf et al. (2019, Chpt. 1). The numbers in brackets refer to the total of FVar+Spe.

FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

Typifying FVar+FSpe and Similarity Between and Within the Land Use Systems

Even though the different land use systems share some portion of the same FVar+FSpe (Figure 4), the dissimilarity between the different land use systems is high. The Bray Curtis dissimilarity measure for the botanical species is 99.91% for *milpas* and home gardens, 99.90% for *milpas* and *te'loms,* and 89.82% for home garden and *te'loms*, with the lowest dissimilarity.

The most important discriminating species that contributes in percentages to the dissimilarity between home gardens and *te'loms* is *Coffea* sp. (45.93%), which is more abundant and frequent in the *te'loms*; it is also a clear discriminating species between *milpa* and *te'loms* (35.21%). Even though *milpas* and home gardens share 112 FVar+Spe (Figure 4), the dissimilarity between the two groups is practically the same as between *milpas* and *te'loms*. However, there are no clearly defined discriminating species between those two land use systems, indicated by the lower percentage of contribution to dissimilarity of the first-ranked discriminating species (*Zea mays:* 17.72% and *Musa* sp. 14.28%), but also by the low average increment of the cumulative percentage value, which is 1.49. Furthermore, most of the discriminating species in each pair of systems compared vary a lot in the average abundance value (e.g., *Phaseolus vulgaris* in *milpas*: 3271.98 compared to *P. vulgaris* in *te'loms*: 0.36) (Supplementary Table 2).

The composition of species varies also within the same land use system, as shown by the relatively low average similarity values. The average similarity of all the *milpas* inventoried is 39.62%. Similarities are lower among *te'loms* (23.42 %) and among home gardens (26.73 %).

Only five species of the *milpas* are the main contributors of the similarity within the group. The most important one is *Zea mays* (72.46%). In case of the home gardens 22 species contribute to the similarity. The most important is *Musa* sp. (24.06%). For the *te'lom* the most contributing species is *Coffea* sp. (49.96%). The complete list of species that contribute to the similarity within the groups is presented in Supplementary Table 3.

The similarity of the FVar+FSpe composition within the different land use systems but separately for the different altitudes is even lower (Table 4), which shows that the farmer's preferences in terms of FVar+FSpe composition varies considerably at each locality. However, even though similarity values are low the SIMPER analysis allows to determine some patterns in terms of the composition of edible plant diversity for the land use systems at different altitudes.

Table 4. Average similarity (%) within the different land use system at different altitudes concerning the composition of FVar+FSpe = the total farmers' edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

	Home garden	*Milpa*	*Te'lom*
High altitude	8.83	12.89	14.39
Medium altitude	19.91	16.96	13.68
Low Altitude	6.42	24.38	7.05

Further, FVar+FSpe that typify most the different land use systems vary in number and percentage of contribution to the similarity within each group (Figure 5). For example, for the *milpas* only two (in LowAlt), three (in HigAlt) and five (in MedAlt) typifying FVar+FSpe were identified, which shows that farmers in this land use system focus on the production of a few specific FVar+FSpe. An example is the yellow short-cycle maize in the LowAlt with 81.31% of contribution to similarity within this group.

For all *milpas* at different altitude a maize variant is the first-ranked typifying crop (see Supplementary Table 4). However, for the maize variants in MedAlt and HigAlt the percentage of contribution is considerably lower with 30.64 % and 49.52 %, respectively. Furthermore, in HigAlt the first ranked FVar+Spe includes a different maize variant that is preferred (local white fast-growing maize). For the home gardens and *te'loms* the number of FVar+FSpe that contribute to the similarity within each land use system at different altitude are higher. For the home gardens numbers range from 17 FVar+FSpe in HigAlt to 29 FVar+FSpe in MedAlt (Figure 5). For the *te'loms* numbers range from 8 FVar+FSpe in LowAlt and HigAlt to 14 FVar+FSpe in MedAlt. Famers in LowAlt have a clear preference for the Jamaica banana (*Musa* sp [50.80%]), meanwhile farmers in HigAlt cultivate mostly the Manila banana (19.01%) and for MedAlt, even though different variants of banana are counted as typifying crops, the first-ranked typifying crop for the home garden in this site is the wild chili (*Capsicum annuum* var. *glabriusculum* [21.9%]).

Concerning the *te'loms,* a clearly different production strategy is demonstrated which is related to the number of different crop variants that were determined as typifying FVar+FSpe. The farmers in the *te'loms* in LowAlt focus mainly on different variants of fruit tree species. The most important one is, again, the Jamaica banana (42.72%), followed by the Mexican lime (*Citrus aurantiifolia* [29.24%]). The farmers in the HigAlt focus mainly on coffee production. All the typifying FVar+FSpe are coffee variants with exception of *Inga vera* (4.27%), which is also used as a shade-providing tree for the coffee plants. However, farmers in HigAlt strongly prefer the yellow local coffee (49.50%), whereas the other coffee variants have considerably lower values (3.13% - 16.72%). *Te'loms* in MedAlt do not have a clearly typifying FVar+FSpe. The first six FVar+FSpe include coffee variants but also some fruit trees and chili variants. However, the contribution value of the latter two crop groups is low and ranges from 1.15% - 2.36% (Figure 4, Supplementary Table 4).

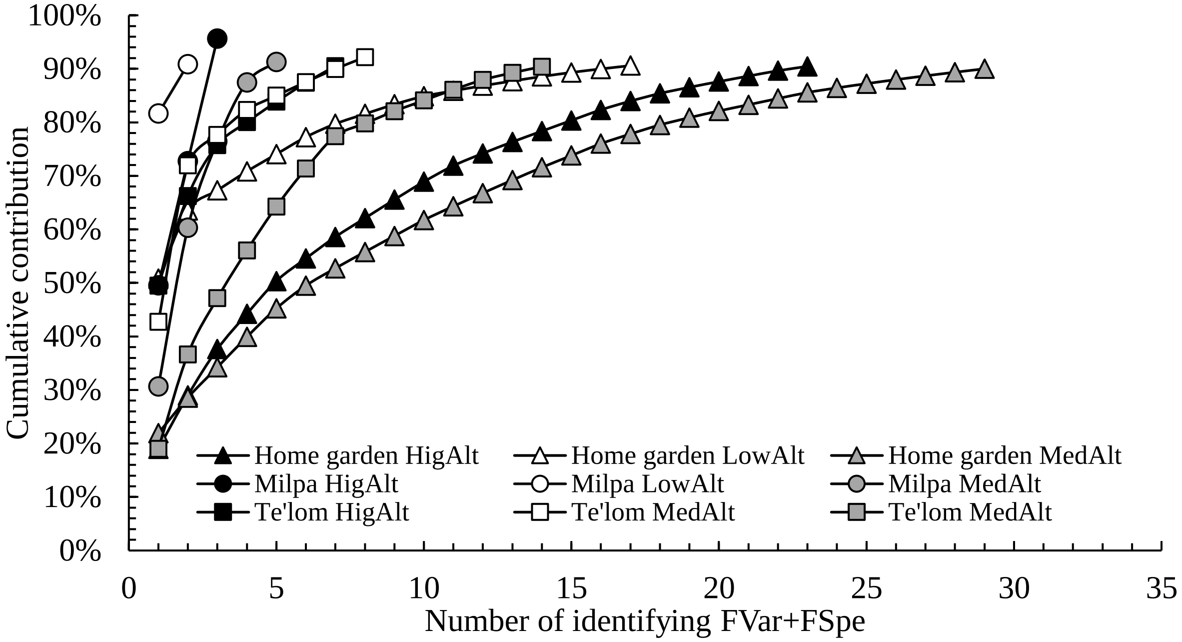


Figure 5. The cumulative percentage and number of identifying typifying FVar+FSpe through SIMPER analysis for each land use system and altitude (locality).

FVar+FSpe = the total farmers’ edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

Correlation of Diversity Parameters and Factors Explaining Crop Diversity Distribution

After the characterization of edible plant diversity and differences/similitudes in floristic composition, the question remains on how its distribution is related among itself between systems and localities and to other factors, and what dependent variables exist between the different diversity parameters.

The average proportion of FVar+FSpe per botanical species is 2.33 and the average proportion of FVar+FSpe per FVar is 1.45, indicating the importance of intraspecific richness in the farming systems. There exists a significant correlation between the number of botanical species and the number of farmer-recognized variants ($P < 0.01$), together and separately for the three altitudes (Figure 6). The covariation between these two diversity parameters indicates that farmers who manage a high richness of botanical species tend to focus on more intraspecific diversity and vice versa.

However, there are differences between altitudes. MedAlt shows a stronger reliance on the use of variants as the slope of 1.50 indicates. The particular position of MedAlt is also underlined by the fact that the slope of the MedAlt correlation is the only one above the value (1.49) of the slope of the correlation for the three localities together, which is nearly 1.0 (0.97, Figure 6, Line total). The other two sites have a lower slope. LowAlt and HigAlt and have less than 1.0 variants per botanical species evidenced by slopes of 0.45 and 0.89, respectively.

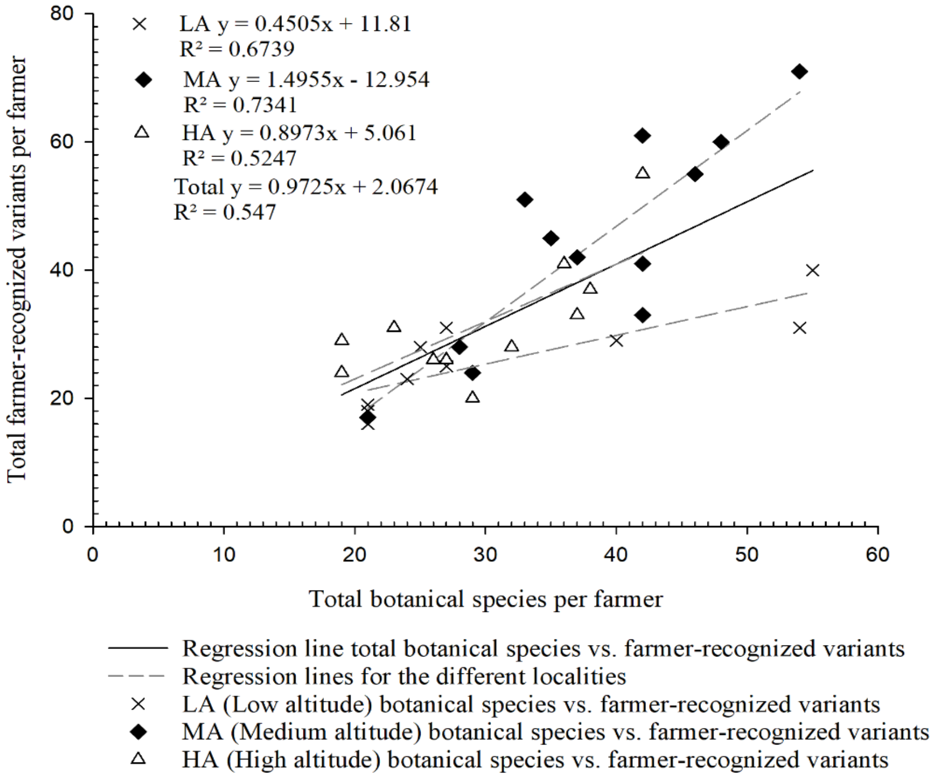


Figure 6. Correlation between total number of botanical species of each farmer and the total number of farmer-recognized variants (FVar) in the agroecosystem complex of each farmer and separately for each altitude. Line total: R = 0.74 (*P* < 0.01); Line LowAlt: R = 0.82 (*P* < 0.01); Line MedAlt: R = 0.86 (*P* < 0.01); and Line HigAlt: R = 0.72 (*P* < 0.01).

Predicting Variables for Edible Plant Richness

After a battery of correlations were made with information from the different land use systems, the *milpa* stands as the land use system that predicts best the amount of FVar and FVar+Spe in the land use system complex. As line ‘a’ in Figure 7 shows, there is a highly significant correlation (*P* < 0.01) between the FVar in the *milpas* of each farmer and the total FVar+FSpe of the agroecosystem complex of each farmer (R = 0.76), as well as shown for line ‘b’ which is the correlation for the FVar in *milpa* fields and the total FVar in all land use systems simultaneously managed by the farmers (R = 0.83; *P* < 0.01).

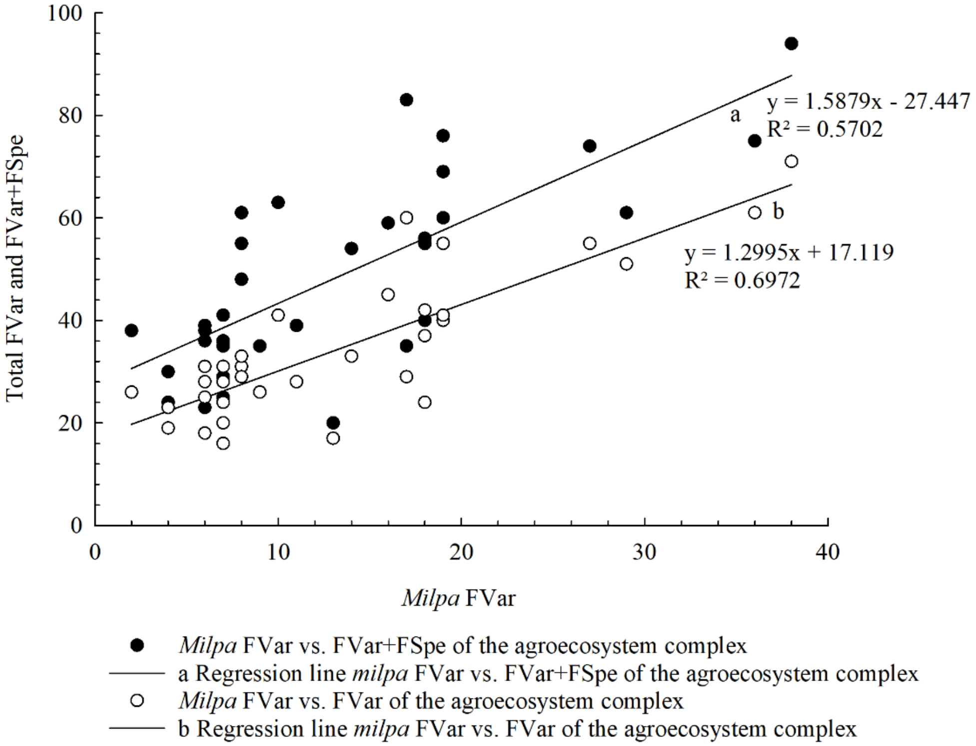


Figure 7. Correlation between the number of FVar in the *milpa* fields of each farmer and the total number of FVar+FSpe in the agroecosystem complex of each farmer. Line a: R = 0.76 ($P < 0.01$) for correlation between the number of FVar in the *milpa* fields of each farmer and the total FVar in the agroecosystem complex of each farmer; Line b: $R = 0.83$ ($P < 0.01$) for FVar in the *milpa* vs. in the agroecosystem complex of each farmer. FVar+FSpe = the total edible plant diversity consisting of FVar = farmer-recognized variants and FSpe = farmer-recognized species with no documented variants.

The results of several lineal regression analyses between parameters of *milpa* diversity vs. environmental and social data show that correlations vary among the localities and land use systems. As examples, there was no significant correlation between number of family members depending on the *milpa* products and the richness of FVar+FSpe in *milpa* fields (R = 0.032), nor between the size (ha) of the *milpa* and number of FVar+FSpe (R = 0.33). An example for a strong variation in the results were farmers' age vs. richness of FVar+FSpe. While for the MedAlt and HigAlt localities there is a positive, but not significant correlation (R = 0.16 and 0.27 respectively), for the LowAlt site the correlation is negative and significant between farmers' age and the number of FVar+FSpe (R = -0.65; $P < 0.05$).

Based on the results that the richness of FVar in the *milpa* fields is an adequate indicator for the total richness managed by the farmers (Figure 7), from the battery of systematic multiple regression analyses conducted to establish groups of variables that explain or predict the richness in *milpa* fields, it is shown that the only set of exclusively significant predicting variables were slope gradient ($P = 0.011$), walking time (h) to the *milpa* field ($P = 0.024$) and rockiness (%) ($P < 0.001$). These three variables together explain 42.2 % ($R^2 = 0.422$, $P < 0.05$) of the total *milpa* FVar per farmer.

The multiple regression equation is:

$$\textit{Milpa}\ \text{FVar} = 12.592 - (0.185 \times \text{Slope gradient}) + (0.301 \times \text{Rockiness}) - (0.193 \times \text{Walking time})$$

However, when this equation is examined more closely and supported by different separate analyses, a more detailed picture is obtained on how the different predicting variables actually function in the different localities.

Slope Gradient

The separated correlation of slope gradient vs. *milpa* FVar for each of the three sites resulted in slightly positive correlation (slope: 0.0058) yet not statistically significant (R = 0.01). This is probably explained by the fact that data for LowAlt with nearly no slope gradients were included. The same correlation with only MedAlt and HigAlt was negative and statistically significant (R = -0.40, $P < 0.05$). However, differences exist between the sites. The correlation for MedAlt was rather weak (slope = 0.30) and not statistically significant (R = 0.14) and contrary to HigAlt, for which the correlation is stronger and significant (slope = 1.64, R = 0.56, $P < 0.05$). However, in combination with the other variables in the multiple regression equation, overall the slope gradient of the *milpas* proved a significant variable to predict or explain diversity as embodied in FVar.

Rockiness

In the case of the relation between *milpa* rockiness and FVar for the three sites, the correlation was positive and statistically significant (R = 0.47, $P < 0.05$), yet there are also differences in the correlations for the different sites. The correlation of rockiness with FVar together for MedAlt and HigAlt was only slightly positive (slope 0.0558) and not statistically significant (R = 0.24). However, since this resulted in an accepted and significant predicting variable in the multiple regression it shows, similar to the case of the slope gradient, that marginal conditions when grouped together have an impact on the number of FVar. This is demonstrated when comparing these values with the LowAlt locality, which has no marginal conditions in term of the physical condition of the terrain, where farmers tend to focus on a limited number of different crops. The only marginal eco-physical condition LowAlt farmers are confronted with is less rainfall during the year. A separate correlation of precipitation and *milpa* FVar was positive and statistically significant ($P < 0.05$, R = 0.58), however precipitation was not significant as a predicting variable in the multiple regression model.

Walking time

Walking time was determined as the least significant predicting variable in the multiple regression model. A separate correlation for all three sites showed also a weaker correlation (slope 0.22) which was not statistically significant (R = 0.10). The correlation for LowAlt and HigAlt locations, separately, was positive but not statistically significant (R = 0.48 and 0.11 respectively). However, there was a strong negative correlation with statistical significance for the MedAlt location (R = -0.68, $P < 0.05$), thus “Walking time” was also included as a negative correlating, but least determinant variable in the multiple regression equation.

Adding more variables to the multiple regression model, e.g., number of family members, farmers’ age, size of the *milpa* fields and precipitation, among others, even though often resulting in a higher R^2 (e.g. 0.556), resulted in rejection to use them as part of the predicting set of independent variables for the FVar in the *milpa* fields ($P > 0.05$). However, adding only the variable *milpa* size to the equation results in a higher R^2 (0.487) and contributes as an additional variable to the prediction of FVar in the *milpa*. Even though the combination of variables was accepted, the P value of 0.071 is insufficient to include *milpa* size in combination with slope gradient, walking time and rockiness to predict the number of FVar in the *milpas*. This is largely explained by the fact that the size of the *milpa* together for all three localities, which is positively correlated to the number of FVar, is not statistically significant (with R = 0.40).

Sampling Completeness

The modified rarefaction analysis based on the linear equation model conducted evidenced that the taxa inventoried were close to 100% of the hypothetical total for all the land use systems in the different altitudes, which could be found if the sample size of farmers were to be increased (Table 5). For example, for total taxa (347) for the three systems and three localities, 99.6% of the taxa that could be found by increasing the number of samples to 165 were found with the total sample of 99 used here.

Table 5. Data and results from extrapolating rarefaction curves, based on the last ten values of each curve, for different systems and localities, made to determine percentage of total extrapolated taxa achieved in this study with the sample size used.

Total sampled (n)		Total taxa	R^2	Linear equation (y =)	n at y = 0	Number of new taxa that could be found if sample is n at y = 0	Total taxa if n at y = 0	% of taxa achieved with n used here
FVar+FSpe								
Milpas	33	191	.995	-0.0981x + 5.479	55.85	3.24 (1.7%)	194.2	98.4
Home gardens	33	243	.996	-0.134x + 6.992	52.18	4.42 (1.8%)	247.4	98.2
Te'loms	33	166	.995	-.0895x + 4.896	54.7	2.95 (1.8%)	169.0	98.2
All systems	99	347	.993	-.0131x +2.163	165.12	1.3 (0.4%)	348.3	99.6
Botanical species								
Milpas	33	82	.996	-0.0382x + 1.945	50.92	1.26 (1.5%)	83.3	98.4
Home gardens	33	121	.993	-0.0456x + 2.609	57.21	1.51 (1.2%)	122.5	98.8
Te'loms	33	87	.994	-0.0384x + 2.195	57.16	1.27 (1.5%)	88.3	98.5

All systems	99	150	.850	-0.0045x + 0.726	161.33	0.45 (0.3%)	150.5	99.7
All land use systems and FVar+FSpe								
High altitude	33	203	.995	-0.0839x + 5.743	68.45	2.77 (1.4%)	205.8	98.6
Medium altitude	36	244	.993	-0.092x + 5.610	60.98	3.31(1.4%)	247.3	98.7
Low altitude	30	175	.994	-0.1268x + 6.294	49.64	3.80 (2.2)	178.8	97.9

Discussion

According to the results of this research: (1) The *Tének* in the Huasteca Potosina cultivate a high (and so far incomparable) diversity of different foods crops at both inter- and intraspecific levels, with the medium altitude site showing the highest diversity; (2) all land use systems that form part of the agroecosystem complex serve as a specific pool for plant genetic resources, and there is low similarity between and within systems and localities, especially at intraspecific level, making it necessary to prioritize depending on conservation and other efforts; (3) the FVar in the *milpa* serves as a significant indicator of the total FVar+FSpe in the agroecosystem complex, derived from the fact that diversity covaries within and between production systems; and, (4) the identification of variables or predictors for crop diversity is challenging, yet marginal conditions (distance, slope and rockiness) seem to play an important role.

The High Diversity in the *Tének* Agroecosystem Complex

As do other indigenous peoples, the *Tének* in the Huasteca Potosina manage different land use systems that form the agroecosystem complex (Toledo et al. 2003). Comparisons for the different land use systems of the *Tének* with other studies show that in case of *milpas* the number of 191 FVar+FSpe, as already shown by Heindorf et al. (2019, Chpt. 1), clearly exceeds the number of edible *milpa* plants in other studies (e.g., Lara Ponce et al. 2012, Mateos-Maces et al. 2016). This was also the case for the richness of FVar+FSpe at farmers' level and community level. In the case of home gardens, Toledo et al. (2003) provided a sum of 360 food plants that are used by a total of ten different indigenous groups. Here, for only one ethnic group and considering data from only 33 farmers, a total of 347 FVar+FSpe were documented, which are composed of 149 botanical species.

Separating the data for the different land use systems, Toledo et al. (2003) documented 136 edible plants in home gardens of the different indigenous groups. Other home garden studies in Mexico document a richness of 42-50, 40 and 60 edible plants species (Chablé-Pascual et al. 2015; Pulido-Salas et al. 2017 and Ortíz-Sánchez et al. 2015, respectively). In this study, 120 edible plant species were registered.

In their metanalysis, Toledo et al. (2003) also provide information on 168 edible food plants from the secondary forests used by the ten different indigenous groups. The secondary forests are comparable to the *te'loms* of the *Tének*, where a total of 164 FVar+FSpe, including 89 botanical species were registered in this study. Angel Martínez et al. (2007) provide information on 129 edible plants species in coffee-agroforestry systems in Mexico, a higher number than presented here, but considering the fact that their study includes information of more than 20 different studies, complemented with additional inventories in more than 25 municipalities, the documented edible plant richness of the *Tének* remains remarkable. However, to our knowledge, there exists no published study on intraspecific diversity in a similar agroecosystem complex, thus no comparison on intraspecific food plant diversity is possible for now.

Nevertheless, an interesting comparison can be made with the work of Alcorn (1984), who documented more than 900 plant species in the *Tének* region of the Huasteca Potosina. Out of this vast list of useful plants registered in different land use systems and natural environments, 204 plant species were classified as used for food. In this study, a total of 149 edible plant species were registered of which 107 coincide with the plants used for food registered by Alcorn almost 40 years ago. The higher number of plants used for food documented by Alcorn (1984) could point to a probable loss of local knowledge on edible plants and their importance in the intervening decades, yet, it may also be explained by differences in focus, design and collection effort of the two studies. Alcorn (1984) documented plants from 22 *Tének* localities whereas in this study information was gathered in only three *Tének* localities, none of which was included in the study by Alcorn. Furthermore, Alcorn (1984) also included food plants from non-managed environments like the forests and riverside, not considered in this study.

However, of several plants that were listed in non-managed ecosystems, but also in *milpas* and *te'loms, s*ix of them refer to plants that are used in times of food shortages, like *Bytneria aculeata* or *Croton reflexifolius.* Furthermore, several of these plants, even though some parts of them might be edible, are considered by the local people as weeds rather than as a proper and appreciated ingredient of foods or food on themselves. These plants were not identified as edible plants by the farmers in this study, e.g., *Adelia barbinervism*, *Guazuma ulmifolia* and *Bidens pilosa*, which are commonly found in the *milpa* and *te'loms* but are not used as food anymore.

On the other hand, in this study 16 plant species, e.g., *Hibiscus sabdarrifa* and *Muntingia calabura*, were identified by the farmers as food plants but were not listed as food plants by Alcorn (1984).

This is surprising because *H. sabdarrifa* is broadly used as a beverage or as ingredient of tortillas (Sumaya Martínez et al. 2014) in Mexico and *M. calabura* is widely known for its edible fruits (Pennington and Sarukhán 2005). Explanations are rather speculative but different knowledge on plant use as well as new-gained knowledge on the edibility of the plants during the last decades could be some reasons.

In this study there are also 45 food plants that were not documented by Alcorn (1984). More than half (23) refer to Old World plants like *Averrhoa carambola*, *Beta vulgaris*, *Litchi chinensis*, *Moringa* aff. *oleifera* and were probably introduced more recently. This is the case, for example, of *Artocarpus heterophyllus* which, according to information provided by farmers in this study, was not known and cultivated in the region 10 years ago.

The simple comparison of the lists that separate more than 30 years demonstrates that the use of food crops is dynamic. Based on the information of these studies, it would be promising to have a similar comparison in the near future on the change of intraspecific diversity in *Tének* traditional land use systems. Interestingly, as the rarefaction curve and its extrapolation using linear regression showed, even with the high agrobiodiversity encountered here, the sample size chosen of 33 farmers allowed to inventory 99.6% of the taxa that would have been inventoried as 100% with a sample size five times larger (Table 5). This allows us to believe that the sample size in agricultural inventories can be rather small if sufficient detailedness such as the one used here is applied.

The Components of the Agroecosystem Complex as Pools for Plant Genetic Resources

Almost three quarters of the FVar+FSpe are classified as rare and 24.8% are registered only once (Figure 3). Furthermore, diversity indexes (Table 1) demonstrate that most of the edible plant richness is unevenly distributed and only a small number of FVar+ FSpe show a high abundance (Figure 2), all of them belonging to groups of the most important crops of the *milpas* or the coffee plants and banana plants, which are mainly distributed in the *te'loms* and home gardens. High proportions of rare species were also documented in shifting cultivation systems and home gardens (Blanco et al. 2013 and Trinh et al. 2003, respectively). Small population numbers cannot assure the persistence of genetic diversity in the farmer's cropping systems (Bellón et al. 2018; Heindorf et al. 2019, Chpt. 1) and the edible plant diversity of the *Tének* agroecosystem complex should receive attention in terms of the promotion and use of the edible crop diversity, especially considering the fact that 68.6% of the total FVar+FSpe were identified as FVar, something that underlines the role of this particular agroecosystem complex for on-farm conservation of intraspecific diversity.

The high number of unique species with low individuals, especially in case for fruit trees, highlights the risk of loss of the intraspecific diversity for this particular group of edible plants. In this context, it is convenient to investigate how the crops are propagated, e.g., if farmers tend to focus on asexual propagation which increases the genetic vulnerability of the already small number of populations, or if they use methods of asexual and sexual propagation and inter- and intraspecific hybridization is applied which increases the genetic pool of cultivated germplasm (Bisognin 2011).

The farmers manage on average 48.7 FVar+FSpe in their agroecosystem complex. Similar to the findings in Heindorf et al. (2019, Chpt. 1), the farmers in the MedAlt cultivate more FVar+FSpe with an average of 60, compared to the farmers in the other two sites (Table 2). But there was no statistically significant difference. Analogous to the data on *milpas* provided by Heindorf et al. (2019, Chpt. 1), MedAlt is also the locality that shares most of the home garden and *te'lom* FVar+FSpe with the two other localities. It also hosts most of the exclusively distributed FVar+FSpe in the home gardens and *te'loms* which are factors to consider when choosing a priority site for interventions in favor of crop diversity (Heindorf et al. 2019, Chpt. 1).

A criterion for this selection can be based on diversity indexes as shown for Table 1, where statistically significant differences between altitudes and between production systems were established. For example, the home gardens consistently showed higher diversity indices than the other two system, for both FVar and FVar+FSpe, yet overall population sizes of crops (mainly trees) are rather small in home gardens and this on itself could be another criterion to consider when choosing priority sites for interventions.

As determined by the SIMPER analysis, the similarity within the land use systems is low, especially at intraspecific level. Also, the dissimilarity of the species composition between the different land use systems in paired comparisons is high, showing the heterogeneity in terms of the abundance of species even though a lot of them may be shared between the different systems (Figure 4). This is probably linked to the highly different production purposes of each system (e.g. high number of coffee plant individuals in *te'loms*), which creates a niche for conservation purposes when the population size of target crops plays a crucial role to avoid a genetic decay (Bellón et al. 2018) (Table 4).

At farmers level, the number of shared FVar+FSpe is highest for home gardens and *te'loms* (3.4), which can be explained considering that both systems mainly consist of trees. However, the *milpa* also shares an average of 2.3 FVar+Spe with home gardens. Only a very small amount of the farmers' edible plant diversity is cultivated in all three systems (0.4; Table 3) and just 19.3% of the total FVar+FSpe is shared among all the three systems of the different localities (Figure 4), which supports the argument of favoring an agroecosystem-approach for the *in situ* conservation of plant genetic resources. This would also bring multiple benefits by fostering synergies of the different abiotic and biotic components which support the functionality of the farmers' production systems and provide ecosystem services which contribute to the planet's health in general (Girardello et al. 2019; Vandermeer et al. 1998).

Indicators and Covariation of Edible Plant Diversity

Regarding the correlative analysis, it is shown that there are significant covariations between diversity parameters (Figure 6, 7). The number of *milpa* FVar is significantly and positively correlated to the overall number of FVar+FSpe in the agroecosystem complex managed simultaneously by each farmer. *Milpa* FVar can be selected as an indicator for the overall edible plant diversity that can be found in the complete agroecosystem complex (Figure 7).

However, to determine factors that have a statistically significant influence on the number of *milpa* FVar was challenging. Surprisingly, there was no correlation between milpa size and number of FVar+FSpe, which coincides with the findings of Blanco et al. (2013) who found no correlation of field area with intraspecific richness. Different to other studies which demonstrate that socioeconomic factors such as age and family size have an influence on the number of crops (e.g., Chablé-Pacual 2015; Salazar-Barrientos et al. 2016), in this study no correlations were found nor accepted in the multiple regression model as predicting variables. Nonetheless, three main variables were identified which can be linked to the marginality of the *milpas* in terms of access (walking time to the *milpa* fields) and ecological constraints (slope gradient and rockiness).

To explain each of these variables remains difficult. One explanation for the negative correlation of walking time to the farmers' fields, which was only statistically significant for the MedAlt locality, is that farmers battle with difficult environmental conditions and rely on strong physical input. The climate in MedAlt is hot throughout the year and the walking time to the *milpa* fields is long through hilly and rocky terrain. Less FVar on farmers' fields that lie further away may require less attention and physical labor. Even though the average distance to the *milpa* fields in HigAlt is larger, the temperature is lower during the day, something that probably requires less physical input. Slope gradient and rockiness, however, positively influence the number of FVar in the *milpa* fields. This is probably explained by the fact that farmers look out for a higher variety of crops that occupy the different niches along the rocky and hilly terrain of their *milpa* fields (see examples of a *milpa* in the MedAlt, Figure 8), whereas for example farmers in LowAlt are able to focus on less plants because of more homogenous site conditions. Especially underutilized crops are used in marginal areas and are often adapted to agroecological niches and marginal conditions (Rao et al. 2014). Examples for such an underutilized crop would be *Amaranthus hybridus* and *Ipomoea* spp., plants that can easily be planted between the stones of the *milpas*.

Fig. 8. Milpa in the medium altitude (left). Maize, small plants of chili and amaranth planted in between the limestone rocks of the milpa (right).

The ability of farmers to manage such a high richness in the whole agroecosystem complex and specific diversity in the different land use systems also reveals the in-depth knowledge farming communities have to simultaneously manage such an elevated number of crops (see Bellon 1996; Heindorf et al. 2019, Chpt. 1). This knowledge about the management of the overall biotic and abiotic complexity of the agroecosystems, especially in terms of crop combination and planning of interventions, deserves further investigation.

Concluding, the very high diversity of edible crops managed by the *Tének*, when studied at the intraspecific level, reveals an extraordinary and so far, incomparable richness. The three production systems are a valuable pool of plant genetic resources, underutilized perhaps because it has been under-characterized so far.

While diversity covaries within and between production systems, the *milpa* FVar is an adequate indicator for all the managed edible plant diversity. Yet, the explanation of FVar via external factors, such as terrain conditions, only provided a partial reason of the levels and variations encountered. This, supported by previous works (e.g., Altieri and Merrick 1987; Birol et al. 2009; Perales et al. 2003), including those part of this study (Heindorf et al. 2019, Chpt. 1), lead to conclude that no matter which specific variations due to terrain and other characteristics are given, the use of high diversity fulfills intrinsic and major requirements for subsistence in marginal conditions and the personal choice of farmers and their families.

To the extent that future works emphasize the characterization of intraspecific diversity, which has been shown to have a preponderant role in terms of *Tének* taxonomy and knowledge of their crops, and perhaps indigenous in general, and which is different from the role modern agriculture gives to variants (Chpt. 3), a more complete understanding will be gained of both the level of richness being managed and its purpose. In terms of the need to maintain this richness, both for the benefit of the indigenous communities that own it and for the growing demand in food requirements in the context of population growth and adaptation to the climate emergency, identifying and mainstreaming crop genetic resources at the intraspecific level, well beyond the commonly used interspecific level or the development of improved varieties, becomes a necessity and opportunity.

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Supplementary Table 1. FVar+FSpe that are Shared Between the Different Land Use Systems of the Same Farmer.

The list shows all the shared FVar+FSpe up to the maximum number of three farmers. For the shared FVar+FSpe between all land use systems the number of all cases is shown.

Botanical species	Local name	# farmers
Home garden and *Te’lom*		
Citrus sinensis	Tének lanáx; naranja criolla; local orange	7
Musa sp.	Rátan it’adh; plátano roatan; -	6
Citrus aurantiifolia	Jili limón; limón agrio; Mexican lime	6
Citrus reticulata	Tének mandariin; mandarina criolla; local mandarine	5
Musa sp.	Manzana it’adh; plátano manzana, apple banana	5
Musa sp.	Pek’em it’adh; plátano costillon, Jamaica; -	4
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	3
Passiflora edulis f. flavicarpa	Manu’ maracuyá; Maracuyá amarilla; yellow maracuyá	3
Sabal mexicana	Apats akual; palma de palmito; sabal palm	3
Annona reticulata	(Pakdha') manu kukay; anona amarilla; yellow sugarapple	3
Coffea arabica	Tének manu' kapéj; café criollo amarillo	3
Musa sp.	Baleeya it' adh; plátano melón; melon banana	3
Musa sp.	Manila, malila it’adh; plátano manila; manila banana	3
Yucca sp.	Chocha, k'oyol; Izote; yucca palm	3
Zingiber officinale	-; Jengibre; ginger	3
***Milpa* and home garden**		
Musa sp.	Pek’em it’adh; plátano costillon, Jamaica; -	6
Amaranthus hybridus	Dhak chidh; quelite blanco; edible white amaranth leaves	4
Carica papaya	Alte' utsún; papaya del monte; wild papaya	4
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	3
Capsicum annuum var. *glabriusculum*	Kulum its, alte’ its, ts’akam its; chile del monte; wild chili	3
Citrus sinensis	Tének lanáx; naranja criolla; local orange	3

Musa sp.	Rátan it’adh; plátano roatan; -	3
Milpa* and *te’lom		
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	4
Musa sp.	Pek’em it’adh; plátano costillon, Jamaica; -	3
Milpa*, home garden and *te’lom		
Musa sp.	Pek’em it’adh; plátano costillon/Jamaica; -	2
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	1
Musa sp.	Rátan it’adh; plátano roatan; -	1
Citrus aurantiifolia	Jili limón; limón agrio; Mexican lime	1
Citrus reticulata	Tének mandariin; mandarina criolla; local mandarine	1
Musa sp.	Manzana it’adh; plátano manzana, apple banana	1
Sabal mexicana.	Apats akual; palma de palmito; sabal palm	1
Citrus sinensis	Tének lanáx; naranja criolla; local orange	1
Vanilla planifolia	(Bayniya); vainilla; vanilla	1
Mangifera indica	Tének mango mulul; mango criollo redondo; round-shaped local mango	1
Persea americana	Láb uj; aguacate Hass; Hass avocado	1

Supplementary Table 2. Summary of the SIMPER Results.

Summary of SIMPER results for the argoecosystem complex of the *Tének* in the Huasteca Potosina: average abundance of species of discriminating species for the three different land use systems, their contribution (%) to the dissimilarity between the groups, and cumulative total (%) of contributions (90% cut off).The total Bray-Curtis dissimilarity measure for the botanical species is 89.82% for home gardens and *te'loms*, 99.91% for *milpas* and home gardens, and 99.90% for *milpas* and *te'loms*.

	Average Abundance		Contribution	Cumulative
Botanical species	***Milpa***	**Home garden**		
Zea mays	14786.00	1.55	17.12	17.12
Musa sp.	12.36	20.91	14.28	31.40
Capsicum annuum	859.72	13.82	7.06	38.46
Coffea sp.	0.00	42.70	6.81	45.27
Citrus sinensis	3.73	4.06	5.44	50.71
Phaseolus vulgaris	3271.98	0.36	3.21	53.93
Amaranthus hybridus	1001.09	5.27	2.69	56.61
Nopalea cochenillifera	58.64	3.55	2.08	58.69
Sabal mexicana	9.55	2.58	1.88	60.57
Psidium guajava	0.64	2.61	1.85	62.42
Vigna unguiculata	105.01	4.03	1.77	64.19
Coriandum sativum	1142.48	1.67	1.76	65.95
Sesamum indicum	1363.66	0.00	1.73	67.68
Sechium edulis	1.12	2.36	1.40	69.08
Vitis sp.	0.00	4.79	1.23	70.32
Carica papaya	26.03	1.97	1.22	71.53
Citrus reticulata	0.15	2.15	1.20	72.74
Allium longifolium	23.55	2.76	1.12	73.86
Citrus aurantiifolia	4.58	1.27	1.07	74.93

Zingiber officinale	0.45	2.15	0.98	75.91
Erythrina americana	1.12	1.18	0.90	76.80
Dioscorea alata	2.18	0.97	0.89	77.69
Mangifera indica	0.21	1.21	0.87	78.56
Prunus persica	2.94	1.21	0.82	79.38
Saccharum officinarum	4.27	1.82	0.82	80.20
Persea americana	2.94	1.18	0.79	81.00
Ipomoea purpurea	31.26	1.12	0.71	81.71
Eryngium foetidum	0.00	1.27	0.70	82.41
Agave americana	0.00	1.33	0.69	83.09
Curcuma longa	2.88	1.27	0.67	83.76
Passiflora edulis	1.88	0.85	0.65	84.41
Citrus limetta	0.00	0.64	0.65	85.05
Manihot esculenta	2.39	1.15	0.63	85.69
Spondias purpurea	0.00	0.64	0.62	86.31
Litchi sinensis	0.00	0.58	0.58	86.89
Xanthosoma sagittifolium	0.24	1.36	0.55	87.44
Jatropha curcas	0.06	0.36	0.52	87.96
Bauhinia divaricata	0.00	0.76	0.52	88.47
Oxalis latifolia.	160.03	1.45	0.49	88.97
Fragaria sp.	3.18	0.73	0.48	89.45
Inga vera	0.03	1.24	0.48	89.93
Vanilla planifolia	0.09	0.73	0.45	90.38
	Milpa	***Te'lom***		
Coffea sp.	0.00	508.30	35.21	35.21
Zea mays	14786.00	4.85	15.89	51.10
Musa sp.	12.36	16.06	7.18	58.27
Capsicum annuum	859.72	47.48	4.91	63.18
Citrus aurantiifolia	4.58	1.91	2.97	66.15
Nopalea cochenillifera	58.64	1.94	2.84	68.99
Phaseolus vulgaris	3271.98	1.21	2.71	71.70

Litsea glaucescens	0.00	16.67	2.49	74.19
Sesamum indicum	1363.66	0.00	1.67	75.87
Inga vera	0.03	26.73	1.44	77.31
Amaranthus hybridus	1001.09	0.00	1.42	78.72
Sabal mexicana	9.55	2.33	1.37	80.09
Moringa aff. *oleifera*	0.00	0.33	1.36	81.45
Erythrina americana	1.12	1.00	1.33	82.77
Cnidoscolus angustidens	0.00	1.24	1.17	83.95
Acrocomia aculeata	0.00	0.36	1.03	84.98
Spondia mombin	0.15	0.55	1.02	86.00
Coriandrum sativum	1142.48	0.00	1.01	87.01
Acanthocereus tetragonus	0.00	0.30	0.97	87.98
Citrus sinensis	3.73	6.30	0.88	88.86
Persea americana	2.94	2.42	0.86	89.72
Spondias purpurea	0.00	0.21	0.65	90.37
	Home garden	***Te'lom***		
Coffea sp.	42.70	508.30	45.93	45.93
Musa sp.	20.91	16.06	8.73	54.66
Capsicum annuum	13.82	47.48	5.99	60.65
Litsea glaucescens	0.00	16.67	2.97	63.62
Citrus sinensis	4.06	6.30	2.25	65.87
Inga vera	1.24	26.73	2.03	67.90
Nopalea cochenillifera	3.55	1.94	1.93	69.83
Sabal mexicana	2.58	2.33	1.42	71.26
Citrus aurantiifolia	1.27	1.91	1.40	72.66
Vitis sp.	4.79	2.06	1.21	73.86
Amaranthus hybridus	5.27	0.00	0.91	74.78
Vigna unguiculata	4.03	0.00	0.84	75.62
Persea americana	1.18	2.42	0.81	76.43
Citrus reticulata	2.15	2.06	0.80	77.23
Curcuma longa	1.27	3.15	0.79	78.02

Psidium guajava	2.61	1.06	0.77	78.79
Carica papaya	1.97	1.36	0.76	79.55
Bauhinia divaricata	0.76	2.15	0.74	80.28
Sechium edule	2.36	0.76	0.72	81.01
Xanthosoma sagittifolium	1.36	2.39	0.68	81.68
Allium longifolium	2.76	0.00	0.66	82.35
Erythrina americana	1.18	1.00	0.64	82.99
Saccharum officinarum	1.82	0.85	0.63	83.62
Zea mays	1.55	4.85	0.63	84.25
Zingiber officinale	2.15	0.64	0.63	84.88
Vanilla planifolia	0.73	1.85	0.59	85.47
Cnidoscolus angustidens	0.00	1.24	0.49	85.96
Agave americana	1.33	0.24	0.46	86.43
Mangifera indica	1.21	0.67	0.45	86.88
Prunus persica	1.21	0.36	0.44	87.32
Dioscorea alata	0.97	0.18	0.44	87.76
Moringa aff. *oleifera*	0.09	0.33	0.43	88.19
Coriandrum sativum	1.67	0.00	0.43	88.63
Spondias mombin	0.06	0.55	0.42	89.04
Spondias purpurea	0.64	0.21	0.41	89.46
Manihot esculenta	1.15	0.58	0.41	89.87
Arthrostemma ciliatum	0.00	2.42	0.41	90.28

Supplementary Table 3. Summary of the SIMPER Results for the Botanical Species.

Summary of SIMPER results for the botanical species in the agroecosystem complex of the *Tének* in the Huasteca Potosina: average abundance (Ave. abundance) of species of typifying botanical species for the three different land use systems, their contribution (%) to the similarity of each land use system (90% cut off), and cumulative total (%) of contributions. For the Ave. abund. the square root value is presented.

Botanical species	Ave. abund.	% Contribution	Cumulative %
Milpa			
Zea mays	105.79	72.46	72.46
Phaseolus vulgaris	34.14	9.48	81.94
Capsicum annuum	17.87	4.21	86.15
Amaranthus hybridus	16.89	2.85	89.00
Vigna unguiculata	6.36	2.39	91.39
Home garden			
Musa sp.	3.93	24.06	24.06
Capsicum annuum	2.43	10.77	34.83
Citrus sinensis	1.66	10.38	45.21
Psidium guajava	1.18	6.11	51.33
Coffea sp.	2.76	4.20	55.53
Mangifera indica	0.85	4.09	59.61
Sechium edule	1.05	3.88	63.49
Citrus reticulata	1.00	3.52	67.02
Citrus aurantiifolia	0.78	3.41	70.43
Prunus persica	0.76	3.00	73.43
Erythrina americana	0.72	2.27	75.70
Persea americana	0.67	2.22	77.92
Nopalea cochenillifera	0.96	2.21	80.13

Carica papaya	0.85	2.19	82.32
Litchi chinensis	0.49	1.84	84.16
Citrus limetta	0.46	1.51	85.67
Passiflora edulis	0.53	1.31	86.97
Sabal mexicana	0.74	1.05	88.02
Spondia purpurea	0.38	0.68	88.70
Annona reticulata	0.35	0.63	89.33
Amaranthus hybridus	0.83	0.57	89.90
Ocimum basilicum	0.24	0.54	90.44
Te'lom			
Coffea sp.	16.16	49.96	49.96
Musa sp.	3.02	13.72	63.68
Capsicum annuum	2.92	5.35	69.02
Inga vera	2.53	3.79	72.82
Citrus sinensis	1.41	3.44	76.26
Citrus aurantiifolia	0.73	3.33	79.59
Nopalea cochenillifera	0.70	2.87	82.45
Persea americana	0.92	2.57	85.02
Citrus reticulata	0.87	2.04	87.06
Psidium guajava	0.57	1.74	88.80
Cnidoscolus angustidens	0.60	1.73	90.52

Supplementary Table 4. Summary of the SIMPER Results for the FVar+FSpe.

Summary of SIMPER results for the FVar+FSpe in the agroecosystem complex of the *Tének* in the Huasteca Potosina: Average abundance (Ave. abund.) of species of typifying FVar+FSpe for the three different land use system at the different altitudes, their contribution (Contr. %) similarity of each land use system (90% cut off), and cumulative total (Cum. %) of contributions.

Botanical species	FVar+FSpe names in *Tének*; local Spanish; English	Ave. abund.	Contr %.	Cum. %
***Milpa* Low altitude**				
Zea mays	Adhik manu’ tének idhidh; maize amarillo criollo breve, yellow fast-growing local maize	4695.90	81.63	81.63
Sesamum indicum	(Tének) dhakpen tsokoy; ajonjolí criollo café; local brown-colored sesame	3424.25	9.21	90.84
***Milpa* Medium altitude**				
Zea mays	Adhik manu’ tének idhidh; maize amarillo criollo breve, yellow fast-growing local maize	9202.54	30.64	30.64
Capsicum annuum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	2147.75	29.66	60.30
Amaranthus hybridus	Dhak chidh; quelite blanco; edible white amaranth leaves	1671.51	16.14	76.43
Coriandrum sativum	Tének kulantúj; cilantro criollo; local coriander	3140.98	11.03	87.46
Amaranthus hybridus	Tsak chidh; quelite rojo; edible red amaranth leaves	1081.50	3.83	91.29
***Milpa* High altitude**				
Zea mays	Adhik dhakni’ tének idhidh; maíz blanco criollo breve; white fast-growing local maize	5534.18	49.52	49.52
Phaseolus vulgaris	T’unu’ malte’ ani kayum; frijol negro flojo de guía; black slow-growing climber bean	4675.69	23.21	72.74
Zea mays	Dhak tének idhidh an k'ayum; maíz blanco criollo flojo, white slow-growing local maize	7483.23	22.93	95.67
Home garden Low altitude				
Musa sp.	Pek’em it’adh; plátano costillon, Jamaica; -	20.00	50.80	50.80
Sabal mexicana	Apats akual; palma de palmito; sabal palm	7.70	12.72	63.52
Citrus sinensis	Valencia lanáx tsátadh kán; naranja Valencia injertada; grafted Valencia orange	2.50	3.76	67.28
Citrus aurantiifolia	Jili limón; limón; Mexican lime	1.00	3.55	70.84
Musa sp.	Manzana it’adh; plátano manzana, apple banana	5.00	3.22	74.06
Yucca sp.	Chocha, k'oyol; Izote; Yucca palm	1.20	3.19	77.25
Erythrina americana	Jutukú, pemoche; coral tree	1.00	2.46	79.71
Citrus sinensis	Tének lanáx; naranja criolla; local orange	1.10	1.85	81.57
Mangifera indica	Tének mango mulul; mango criollo redondo; round-shaped local mango	0.90	1.79	83.36
Tamarindus indica	Pulik tamariindu; tamarindo de vaina larga; big tamarind	0.90	1.52	84.88

Spondias purpurea	Tsak tének ten, ciruela criolla roja, local red plum	0.60	1.01	85.89
Carica papaya	Alte' utsún; papaya del monte; wild papaya	1.30	0.95	86.84
Jatropha curcas	Dhakpente'; pipián, piñón; curcas	1.10	0.88	87.72
Capsicum annum	Muldha its, kulum its; chile piquín bolita; tiny round chili	1.10	0.85	88.56
Litchi chinensis	-; Litchi de cascara roja; red litchi	0.40	0.76	89.32
Annona reticulata	(Pakdha') manu' kukay; anona amarilla; yellow sugarapple	0.70	0.66	89.98
Prunus persica	Tének tsakni' tulaxnúj; durazno criollo rojo; local red peach	0.30	0.62	90.60
Home garden Medium altitude				
Capsicum annuum var. *glabriusculum*	Kulum its; alte' its; ts'akam its; chile del monte; wild chili	11.50	21.92	21.92
Musa sp.	Pek'em it'adh; plátano costillon, Jamaica; -	9.50	6.66	28.57
Coffea sp.	Tének tsakni' kapéj (sombra); café criollo (shade-tolerant); local coffee	7.92	5.67	34.25
Nopalea cochenillifera	Nakadh' pak'ak' yab k'idhad; nopal largo sin espinas; large-shaped nopal without spines	2.33	5.66	39.91
Erythrina americana	Jutukú, pemoche; coral tree	1.83	5.33	45.24
Carica papaya	Alte' utsún; papaya del monte; wild papaya	2.08	4.26	49.50
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	19.17	3.24	52.74
Citrus reticulata	Tének mandarin; mandarina criolla; local mandarine	3.33	3.05	55.78
Eryngium foetidum	Láb kulantúj, kulantúj an o'tol, cilantrón; long coriander	3.42	3.00	58.78
Zingiber officinale	-; Jengibre; ginger	4.75	2.96	61.74
Citrus aurantiifolia	Jili limón; limón; Mexican lime	1.00	2.58	64.32
Ruta angustifolia	-; Ruda; rue	1.92	2.47	66.79
Amaranthus hybridus	Dhak chidh; quelite blanco; edible white amaranth leaves	11.50	2.42	69.21
Citrus limetta	Lima dulce injertado; grafted sweet lime	0.33	2.37	71.58
Vitis sp.	Alte' ts'akam t'udhup; uva de monte chica; small wild vine	13.17	2.22	73.80
Musa sp.	Manzana it'adh; plátano manzana, apple banana	1.00	2.21	76.01
Musa sp.	Rátan it'adh; plátano roatan; -	1.50	1.81	77.82
Prunus persica	Tének tsakni' tulaxnúj; durazno criollo rojo; local red peach	0.83	1.69	79.51
Litchi chinensis	-; Litchi de cáscara roja; red litchi	0.50	1.37	80.88
Allium longifolium	(Tének) xunnakat; cebollín criollo; local onion leek	4.58	1.25	82.13
Ocimum basilicum	Tizón ts'ojol; albahaca; basil	0.42	1.16	83.29
Citrus sinensis	Tének lanáx; naranja criolla; local orange	1.92	1.16	84.45
Psidium guajava	Manu' (tének) nakdha bek; guayaba amarilla criolla larga; local large-shaped guava	0.58	1.13	85.57
Citrus sinensis	Valencia lanáx tsátadh kán; naranja Valencia injertada; grafted Valencia orange	0.75	0.86	86.44
Musa sp.	Baleeya it'adh; plátano melón; melón banana	1.42	0.79	87.23
Passiflora edulis f. *flavicarpa*	Manu' maracuyá; Maracuyá amarilla; yellow maracuyá	0.92	0.75	87.98
Coffea sp.	Tének tsakní Kapéj (sombra); café criollo rojo (shade-tolerant); local red coffee	84.42	0.71	88.69
Musa sp.	Tabasco it'adh; plátano tabasco, -	0.92	0.67	89.36

Inga sp.	Pulik dhubchik; chalahuite grande de castilla	0.67	0.64	90.00
Home garden High altitude				
Musa sp.	Manila, malila it'adh; plátano manila; manila banana	6.18	19.01	19.01
Citrus sinensis	Tének lanáx; naranja criolla; local orange	2.27	9.97	28.98
Musa sp.	Rátan it'adh; plátano roatan; -	3.73	8.65	37.62
Citrus sinensis	Nave lanáx tsátadh kán; Naranja navel injertada; grafted Navel orange	1.82	6.59	44.21
Passiflora edulis f. *flavicarpa*	Manu' maracuyá; Maracuyá amarilla; yellow maracuyá	1.27	6.14	50.35
Citrus reticulata	Tének mandarin; mandarina criolla; local mandarine	1.55	4.22	54.57
Bauhinia divaricata	Xobots, tatil bichim; pata de vaca; orchid tree	2.27	4.02	58.60
Musa sp.	Manzana it'adh; plátano manzana, apple banana	3.55	3.50	62.09
Musa sp.	Baleeya it'adh; plátano melón; melón banana	3.27	3.46	65.55
Capsicum annuum var. *glabriusculum*	Kulum its (alte' its), ts'akam its; chile del monte; wild chili	1.00	3.36	68.91
Fragaria sp.	-; Fresa; strawberry	2.18	2.98	71.90
Agave aff. *americana*	Tsi'iimm, wiich; maguey; agave	3.73	2.31	74.20
Eriobotrya japonica	Nesfora; nispero; loquat	1.18	2.15	76.35
Citrus aurantiifolia	Jili limón; limón agrio, Mexican lime	0.45	2.01	78.36
Prunus persica	Tének tsakní tulaxnúj; durazno criollo rojo; local red peach	1.45	2.01	80.36
Saccharum officinarum	(Tének) tsakní pakab; caña morada criolla; local purple sugarcane	2.55	1.97	82.33
Capsicum annum	Wi' ts'itsin its, chile pico de pájaro; bird's beak chili	1.73	1.63	83.96
Sechium edule	Dhak mo'dhidh tsiw' k'idhadh ani ot'odh; chayote blanco seco con cáscara y con espinas; white dry thorny mirliton squash with skin	0.45	1.43	85.40
Sechium edule	Dhak mo'dhidh tsiw' yab k'idhadh yab ot'odh (ok palat); chayote blanco seco sin cáscara y sin espinas, blanco; white dry thornless mirliton squash without skin	0.36	1.15	86.55
Psidium guajava	Manu' (tének) muldha' bek; guayaba amarilla criolla redonda; local round-shaped guava	0.64	1.07	87.62
Citrus sinensis	Valencia lanáx tsátadh kán; naranja Valencia injertada; grafted Valencia orange	0.64	1.03	88.64
Zingiber officinale	-; Jengibre; ginger	1.27	0.99	89.64
Xanthosoma sagittifolium	Tsak lúm; lúm rojo; red arrowleaf elephant ear	2.82	0.82	90.46
***Te'lom* Low altitude**				
Musa sp.	Pek'em it'adh; plátano costillon, Jamaica; -	22.70	42.72	42.72
Citrus aurantiifolia	Jili limón; limón agrio; Mexican lime	5.70	29.24	71.96
Spondias mombin	Jobo; k'inim; hog plum	1.50	5.71	77.67
Sabal mexicana	Apats akual; palma de palmito; sabal palm	2.10	4.65	82.32
Annona globiflora	An chuch; nona del monte; wild anona	0.40	2.66	84.98
Nopalea cochenillifera	Nakadh' pak'ak' an k'idhad; nopal largo con espina; large-shaped nopal with spines	1.10	2.55	87.53
Spondias purpurea	Tsak' tének ten, ciruela criolla roja, local red plum	0.40	2.45	89.98

Cnidoscolus angustidens	Ak; mala mujer; n.i. (*Cnidoscolus angustidens*)	1.30	2.17	92.16
***Te'lom* Medium altitude**				
Coffea sp.	Kapé Costa Rica; café Costa Rica; Costa Rica coffee	95.83	19.01	19.01
Coffea sp.	Manu' Borbón Kapéj (sombra); café Borbón (de sombra) amarillo; yellow (shade-tolerant) borbón coffee	65.83	17.65	36.66
Coffea sp.	Kapéj tsakni' Borbón; Café Borbón rojo de sombra; red (shade-tolerant) Borbón coffee (*Coffea* sp.)	104.17	10.47	47.13
Coffea sp.	Tének manu' kapéj (sombra); café criollo (shade-tolerant) amarillo (*Coffea* sp.)	70.83	8.94	56.07
Coffea sp.	Tének tsakni' kapéj (sombra); café criollo rojo de sombra; red (shade-tolerant) local coffee	141.67	8.20	64.27
Coffea sp.	Kapéj manu' Carturra; café Carturra amarillo; yellow Carturra coffee	47.50	7.08	71.35
Inga vera	Ts'akam dhubchik; chalahuite del monte, small guava	10.67	6.07	77.42
Cnidoscolus angustidens	Ak; mala mujer; n.i. (*Cnidoscolus angustidens*)	2.33	2.36	79.78
Coffea sp.	Kapéj tsakni Carturra café; café Carturra roja; red Carturra coffee	22.08	2.31	82.08
Musa sp.	Pek'em it'adh; plátano costillon, Jamaica; -	7.58	2.01	84.09
Capsicum annum	Wi' ts'itsin its, chile pico de pajaro; bird's beak chili	96.08	2.01	86.10
Capsicum annuum var. *glabriusculum*	Kulum its (alte' its), ts'akam its; chile del monte; wild chili	13.58	1.84	87.94
Coffea sp.	Kapéj mundo nuevo; café mundo nuevo; new world coffee	33.33	1.32	89.26
Citrus sinensis	Tének lanáx; naranja criolla; local orange	9.50	1.15	90.41
***Te'lom* High altitude**				
Coffea sp.	Tének manu' Kapéj (sombra); café criollo (shade-tolerant) amarillo	350.00	49.50	49.50
Coffea sp.	Manu' Borbón Kapéj (sombra); café Borbón (de sombra) amarillo; yellow (shade-tolerant) borbón coffee	192.73	16.72	66.23
Coffea sp.	Tének tsakni' Kapéj (sombra); café criollo (shade-tolerant); local coffee	46.82	9.53	75.75
Inga vera	Ts'akam dhubchik; chalahuite del monte, de sombra café; small guava	68.55	4.27	80.02
Coffea sp.	Tsakni' Carturra café; café Carturra rojo; red Carturra coffee	45.45	3.82	83.84
Coffea sp.	Manu' Carturra Kapéj; café Carturra amarillo; yellow Carturra coffee	61.36	3.55	87.39
Coffea sp.	Tsakni' Borbón café (sombra); café Borbón rojo; red (shade-tolerant) Borbón coffee	9.82	3.14	90.53

CHAPTER III

Folk Taxonomy of the Edible Plants of *Tének* Farmers in Mexico

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Abstract

Understanding how indigenous people name and classify their edible plants enriches current knowledge on food crop diversity. The *Tének* people in the Huasteca Potosina region of Mexico manage a highly diverse food biota and the aim of this study was to describe and analyze their nomenclature and taxonomy of edible plants in their agroecosystem complex.

Special focus was placed on intraspecific diversity, a detail not previously considered by other studies. The descriptors included in naming and labeling the 347 terminal taxa managed by the *Tének* were grouped into descriptor sets for analysis. On average, the *Tének* farmers use 1.82 (SD 0.88) and 2.76 (SD 1.67) descriptor types that form the descriptor sets of folk taxa with interspecific diversity and intraspecific diversity, respectively. There exists a 93.6% correspondence of folk taxa names to Linnaean names.

The findings on how *Tének* classify their edible plants lead to three main postulates: (1) *Tének* people have a deep and specific knowledge about their edible plant diversity; (2) there exists a high correspondence between their folk taxonomy and Linnaean taxonomy; and, (3) to distinguish intraspecific diversity they use a practical classification system based on utility. Also, the information provided here can be used as a basis for future agrobiodiversity inventories in the region.

Keywords: ethnobotany, folk classification, folk nomenclature, Huasteca

Introduction

Like scientific taxonomists, farmers of every language community categorize and name their plants, which is called folk classification (Newmaster et al. 2007). The hierarchical structure behind the classification, its functionality and organic content is called folk taxonomy (Atran et al. 2004; Berlin et al. 1974; Newmaster et al. 2007). Berlin et al. (1974) observed similarities on how different indigenous groups classify their plants and described the general principles of folk taxonomy, based on grouping of organisms or taxa, which are further organized within hierarchical ethnobiological categories. This system is still relevant and used by different authors to describe and analyze the folk classifications of plants (e.g., Hiepko 2006; Khasbagan and Soyolt 2008; Rengalakshmi 2005).

The folk taxa are grouped into the following taxonomic ethnobotanical categories: unique beginner, life form, generic, specific and varietal. A sixth category, called intermediate is often implicit, not named and considered a covert category. Varietal taxa are often missing in folk taxonomies (Berlin et al. 1974). The depth of classification, which is the number of hierarchical taxonomic levels, depends on the mode of subsistence and on the cultural importance of the plants (Berlin 1992; Brown et al. 1985; Holman 2005). However, Berlin's general principles have also been criticized. Folk classifications, in contrast to Linnaean classification, follow a more utilitarian approach thus, it is argued, universal principles cannot be applied to all cultures (Ferreira Júnior et al. 2016; Hunn 1982). Still, folk classification often coincides with Linnaean classification, the universal reference against which folk knowledge is evaluated, yet also vice versa, validating their use, e.g., in biodiversity inventories. This coincidence is measured as the rate of correspondence of the folk taxa to Linnaean names (e.g., Berlin et al. 1974; Khasbaghan and Soyolt 2008).

Indigenous knowledge and folk names are the basis of traditional plant biodiversity knowledge (Khasbagan and Soyolt 2008). Apart from some morphological characters that are commonly used in Linnaean taxonomy, farmers draw on additional sets of functional, adaptive and use-related traits, here also referred to as modifiers or descriptors, to classify their plants (Mekbib 2007). These traits allow the farmers to recognize and name individual landraces (Gibson 2009).

Folk taxonomy is often a faster and simpler method to identify plants in a specific locality because it is based on direct observation and evaluative characteristics, contrary to Linnaean classification that often requires herbarium studies (Kanglin et al. 2000). Compared to scientists, farmers use less, but specific and practical descriptors, to identify their plants and variants correctly (de Haan et al. 2007; Mistura et al. 2016). However, the number of descriptors farmers use may also depend on their level of expertise, which increases the probability of a correct identification of a certain landrace (de Haan et al. 2007).

As with wild plants, folk names are often the first entry point for information on the diversity maintained on farmers' fields and are used for agrobiodiversity inventories (Jarvis et al. 2000; Otieno et al. 2015). However, efforts are especially needed at intraspecific level, where information is still scarce, and become more urgent as local knowledge about crops and plants declines due to the abandonment of agriculture (de Carvalho et al. 2016; Rocha et al. 2008). The use of local names faces several problems. One of the main problems is the inconsistency (e.g., use of antonyms for the same and the use of synonyms for different taxa or diminutives) in folk nomenclature that can result in overestimation or underestimation of diversity. A sound understanding of how people classify and label their crops is required for complete and accurate agrobiodiversity inventories and to gain insights beyond just the listing of taxa.

The *Tének* farmers in Mexico manage different land use systems that include mainly swidden maize fields locally known as *milpas*, agroforestry systems mainly dedicated to coffee and fruit production, and home gardens (Alcorn 1984). *Tének* folk names for plants have been documented by different authors (e.g., Brown 1972; Heindorf et al. 2019, Chpt. 1; Ochoa 1998; Rzedowski 1965a), including the comprehensive study by Alcorn (1984) who documented more than 900 different kind of plant species of the *Tének* environment, providing *Tének* names for most of them. However, excepting Brown et al. (1972), who provided the first folk taxonomic analysis on 304 *Tének* taxa, including folk specific and varietal taxa, there is a lack of information on classification below the folk generic level. Since the *Tének* still manage highly diverse cropping systems (Heindorf et al. 2019; Chpt. 1), to describe their rich intraspecific food crop diversity through the lens of folk taxonomy is an addition to contemporary ethnobiology.

The aim of this study is to describe and understand the inter- and intraspecific folk taxonomy of the edible plants of the *Tének* and to provide information on the minimum set of contrasting descriptors they use to distinguish food plants. Then, the principles of the *Tének* edible plant classification system are discussed.

Methods

Study Area

Mexico is a multicultural country where 21% of the population is indigenous (INEGI 2015). The Huasteca Potosina in northeastern Mexico, is a multiethnic region with high diversity and agrobiodiversity richness (Alcorn 1984; Heindorf et al. 2019, Chpt. 1). Three main ethnolinguistic groups live in the Huasteca Potosina: *Pame*, *Nahua*, and *Huastec,* apart from the Spanish speaking *mestizos*.

The Huastec language belongs to the Mayan linguistic family which is centered in the Southern Yucatán Peninsula of Mexico and other parts of Mesoamerica. Archaeologic evidence shows the *Tének* in the northern part of the Gulf coast from Mexico around 1500 B.C. (Solís Olguín 2006) bordering the Huasteca Potosina. Linguistically, the Huastec were the first to separate from the main Mayan language family, around 1,000 B.C. (Campbell and Kaufman 1985). Today, there are 161,120 Huastec speakers, who live in villages of the Huasteca Potosina and Huasteca Veracruzana. Their language has three varieties: Western Huastec (84,092 speakers), in the state of San Luis Potosí, Central Huastec (41,888 speakers) and Eastern Huastec (5,964 speakers), both present in the state of Veracruz. The risk of extinction of the three language varieties ranges from high risk for Eastern Huastec (Grade 2) to no immediate risk (Grade 4) for the Central Huastec and Western Huastec (Embriz Osorio et al. 2012). The autonym for the Huastec people and their language is *Tének,* also spelled *Teenek.*

This study included three *Tének* localities along an altitudinal gradient. The three localities are in San Luis Potosí and comprise Poytzen (98°59’11’’, 21°20’18’’, 60 m) in the municipality of

Tancanhuitz, Jol Mom (99°03’04’’, 21°32’32’’, 600 m) and Unión de Guadalupe (99°06’20’’, 21°36’07’’, 976 m) in the municipality of Aquismón. The average proportion of indigenous speakers (> three years old) for the three localities ranges from 50.3% in U. de Guadalupe (336 inhabitants) to 86.7% in Aldzulup Poytzen (488 inhabitants) to 95.2% in Jol Mom (728 inhabitants). The number of bilingual speakers (Spanish and indigenous language) is 100%, 83.4% and 57.4%, respectively (INEGI 2010).

In the study area, the vegetation types range from subtropical and tropical forests in the lower altitudes (50-800 m) to cloud and pine oak forests in the higher altitudes (600-2000 m) (Rzedowski 1965b). Farming systems are composed of *milpas*, agroforestry systems and home gardens, and production is mostly used for subsistence (Alcorn 1984; Heindorf et al. 2019, Chpt. 1).

Data Collection

Fieldwork started in February 2016 and ended in January 2019. Sixteen one- to three-week field visits were made. As part of a larger research project, all edible plants of the *milpas*, home gardens and agroforestry systems of 33 farmers, selected as key informants, were inventoried (Heindorf et al. 2019, Chpt. 1, see also Chpt. 2). Several of these field visits involved living in the houses of the local people to familiarize the author with local customs and to learn the language.

Different research activities were applied to further document and understand *Tének* folk taxonomy, mostly through participant observation (DeWalt and DeWalt 2002). Ten local markets were visited, an intercultural seed fair was set up, and in each of the three localities two workshops were organized with all key informants and with approximately 40 other farmers of the villages to discuss the naming and classification of the crops and descriptors used for identification.

Whereas field visits were mostly undertaken with men, women were often more helpful and knowledgeable for the identification and discussion on *Tének* names of the collected plant material. Frequent contact via Whatsapp and telephone was kept with some key informants who were consulted on specific information.

In the three localities, four folk experts in the nomenclature and classification of species and variants were identified and visited frequently to discuss the naming. Additionally, Benigno Robles, a *Tének* expert in folk names and plant knowledge, who lives in the research area, provided details on *Tének* plant classification. Members of one farming household in each locality were chosen to double-check the reported names and descriptors. A linguistic professor of *Tének* origin, Gudelia Cruz Aguilar, reviewed the spelling of the *Tének* names according to the local consensus of the native speakers who were involved in a Huastec language standardization process.

In addition, each species and variant were photographed, and plant material was deposited in the Herbarium SLPM at the Autonomous University of San Luis Potosí (http://slpm.uaslp.mx/). A photographic database provided supporting material for discussions with individuals and groups on the plant diversity of the study area.

Data Analysis and Presentation

For the general description of *Tének* food plant taxonomy, the principles of Berlin et al. (1974) were followed. The plant taxa were grouped into different ethnobiological taxonomic categories that are arranged hierarchically. The taxon of the unique beginner category belongs to the taxonomic level zero and lifeform taxa to level one. Generic taxa occur mostly at level two or, if not, at level one, depending if affiliated or non-affiliated to a supraordinate category (life form), respectively. Folk specific taxa are included in level three or at level two if they belong to the generic taxon at level one. Folk varietals belong to level four, or to level three if the generic taxon occurs at level two (Berlin et al. 1974).

To show the correspondence of *Tének* folk classification with Linnaean classification the folk generic names were compared with the information on the identified biological plant species according to the working list of all known plant species (http://www.theplantlist.org/). Two generic taxa (*Musa* sp. and *Coffea* sp.) were excluded from this comparison because of difficulties and debates concerning species taxonomy due to high degrees of hybridization (e.g., Clarke 2003; Surya Prakash et al. 2002; Valmayor et al. 2000). For the polytypic generics the same procedure was applied to gather information on the correspondence of folk specifics with biological plant species. *Tének* names were used and for the cases when no *Tének* name was provided by the local people, loc. Span. (local Spanish) names were used.

Sets of minimum folk descriptors for all terminal taxa (not further dividable) were identified within the folk names and labels obtained during the above described data collection procedure. For this research minimum descriptors were defined as the principal contrasting descriptors that determine and form part of the label and name of terminal taxa. The different descriptors were grouped into eleven different descriptor types. Similar to the method used to identify taxonomic characters for plant classification of the *Irula* people in India (Newmaster et al. 2007), four descriptor categories were defined that included the eleven different descriptor types that form the descriptor sets used by the *Tének* in the naming and labeling of their taxa: (A) morphological traits; (B) use-related traits; (C) agronomic and adaptive traits; and, (D) comparative traits (Supplementary Table 1). For the minimum descriptor sets, information in *Tének* and loc. Span. was considered, because most of the people use both languages to describe their plants.

To compare the descriptor types used to name and determine the terminal taxa all descriptors were considered for each terminal folk generic. The analysis did not include folk generics that were not further analyzable and thus did not provide information on any descriptor (e.g., peach [*tulaxnúj* in *Tének*, *durazno* in loc. Span.]). For terminal folk specifics and terminal folk varietals that belong to the same supraordinate category and which share the same type of descriptors only one example from the set of minimum folk descriptors was considered. This was done to avoid repetition of the set of minimum folk descriptors that are used to distinguish a group of terminal taxa that share the same descriptors.

Additionally, the different minimum folk descriptor sets used in *Tének* nomenclature were analyzed separately for two categories of terminal taxa: (1) interspecific diversity (diversity between botanical species), which is mostly composed of folk generics and in a few cases of folk specifics; and, (2) intraspecific diversity (diversity within botanical species), composed of folk specifics or folk varietals that belong to the same supraordinate category. To visualize and facilitate analysis of descriptor use an illustrative chart was created, listing presence of descriptor types used for the naming and labeling of each taxon considered. All folk taxa with inter- and intraspecific diversity were listed separately, in ascending order according to the number of different descriptor categories of their descriptor sets. The relationship between the number of descriptor types and the inter- and intraspecific diversity was analyzed with a Pearson correlation from linear regression analysis.

Results

General Information about *Tének* Food Plant Taxonomy

A total of 347 terminal taxa of edible plants were recorded. Four ethnobiological taxonomic categories were identified, which include life forms, folk generics, folk specifics and folk varietals (Table 1). There is no all-inclusive named "unique beginner" category to which all the terminal taxa belong. However, the *Tének* do make a principal distinction between plants in a managed environment considered as cultivated plants which they categorize as *t'ayalab* (lit. "that which is cultivated or planted") and plants that grow spontaneously without intended human intervention, categorized as *alte'* (lit. "forest", "in the forest"). The *t'ayalab* or cultivated plants are grown in the *ts'ulél* (loc. Span. *parcela*) which includes the swidden maize-based field (loc. Span. *milpa*) and *te'loms.* Most *Tének* consider the latter as poorly managed forests with multiple uses such as fruit tree production and cultivation of some perennial and semi- perennial food crops like chili (*Capsicum* spp.) or high value crops like vanilla (*Vanilla planifolia*) but also as an agroforestry system for coffee production, which sometimes is referred to as *finca* as well. A large number of the *t'ayalab* (cultivated plants) can also be found in the home garden, which is called *éleb*. Several *alte'* (forest) plants grow in both the *ts'ulél* (*milpa* and *te'lom*) and the *éleb* (home garden). An example are wild guava (*Psidium guajava*) trees that grow spontaneously in *milpas, te'loms* or home gardens and are referred to as *alte' bek* (loc. Span. *guayaba del monte* [wild guava]). However, not all the plants that grow wild have a lexeme (word) which provides information on that.

The three principal life form categories are *te'* (tree), *ts'ojól* (herb or weed) and *ts'áj* (climbing or creeping plant), which include 61.4% of all taxa (Table 1). There are three minor life form groups that are perceived by the people as subordinate taxa of the *te'* (trees) in case of *wayalom alte'* (shrub or small tree [e.g., *Manihot esculenta*]) and of the *ts'ojól* (herb or weed) in case of *ts'ojól k'apnel* (herbs with edible leaves [e.g., *Amaranthus hybridus*, *Mentha* spp.]) and *ts'ojól tom* (grass-like herb [*Cymbopogon citratus*]). Some people make further divisions, e.g., herbs with spiny texture (*k'ídh ts'ojól* [e.g., *Ananas comosus*]). However, the further divisions are sometimes ambiguous and are not shared by all the informants; hence they were not included in Table 1. There are eleven minor classes that are considered by the local people as non-affiliated generics, e.g., *tsanak'w* (beans [*Phaseolus* spp., *Vigna unguiculata*]), *its* (chili [*Capsicum* spp.]) and *utsun* (papaya [*Carica papaya*]). This group includes mainly culturally relevant crops (Table 1).

The total number of folk generic taxa is 121, of which 78 (64.46%) are monotypic. Ten monotypic generics contain single-named folk specifics. For the rest (68) no subclasses were mentioned by the farmers and are considered terminal folk generics.

The remaining 43 polytypic generics are further divided into 107 terminal folk specifics (levels 2 and 3) and 165 terminal folk varietals (levels 3 and 4) (Table 1, Supplementary Table 2). On average 2.49 (SD 2.31) specifics belong to the same folk generic and contain up to 12 folk specifics (e.g., *it'adh* [*Musa* sp.]). There are 42 polytypic folk specifics that on average include 6.52 (SD 4.73) folk varietals (Table 1, Supplementary Table 2). The folk specifics chayote (*tsiw'* [*Sechium edule*]), and *k'alam* (*Cucurbita moschata*) squash have the highest numbers of folk varietals, 21 and 19 respectively (Supplementary Table 2).

Table 1. Number of taxa according to ethnobiological taxonomic categories and levels. The number of terminal taxa (not further dividable) is shown in brackets.

		Level 1 Life form	**Level 2 Generic**	**Level 3 Specific**	**Level 4 Varietal**
Principal life form					
Tree	*Te'*	(116)	51 (33)	52 (31)	(52)
Herb	*T'sojól*	(20)	13 (8)	12 (12)	0
Climber, creeper	*Ts'áj*	(77)	19 (6)	28 (20)	(51)
Subordinate lifeform					
Shrub, small tree	*Wayalom alte'*	(11)	8 (6)	5 (5)	0
Leaf vegetable	*T'sojól k'apnel*	(21)	18 (14)	7 (7)	0
Grass-like herb	*T'sojól tom*	(1)	1 (1)	0	0
Non-affiliated generics			**Level 1 Generic**	**Level 2 Specific**	**Level 3 Varietal**
Palm	*Apats'*	(2)	1 (0)	2 (2)	0
Flower	*Wits*	(3)	1 (0)	3 (3)	0
Banana	*It'adh*	(12)	1 (0)	12 (12)	0
Maize	*Idhidh*	(11)	1 (0)	2 (0)	(11)
Chili	*Its*	(9)	1 (0)	9 (9)	0
Sugarcane	*Pakab*	(4)	1 (0)	3 (1)	(3)
Nopal	*Pak'ak'*	(6)	1 (0)	4 (2)	(4)
Bean	*Tsanak'w*	(42)	1 (0)	6 (0)	(42)
Papaya	*Utsun*	(8)	1 (0)	8 (8)	0
Coco	*Map*	(3)	1 (0)	2 (1)	(2)
Agave	*Wéy*	(1)	1 (0)	1 (1)	0
	Total:	**(347)**	**121 (68)**	**156 (114)**	**(165)**

Most of the 121 generic taxa (69.2%) are known by both their *Tének* and loc. Span. name. Only five generic taxa are exclusively known in *Tének*. These five plants are naturally distributed in

Mexico, none of them are cultivated or used frequently and are considered not to be culturally important in the *Tének* localities. Examples are *úmu* (*Pithecellobium dulce*) and *pux luk* (*Passiflora hahnii*). Eight of the *Tének* names are loan words, e.g., *kapéj* (*Coffea* sp. [from Spanish: *café*]) or *mandarín* (*Citrus reticulata* [from Spanish: *mandarina*]). The *Tének* names also include five hybrids, which means that the *Tének* names include a lexeme or other element from another language, e.g., *tsa' papas* (*Dioscorea bulbifera* [from Spanish*: papa*]) and *ts'ik lima* (*Citrus limetta* [from Spanish*: lima*]). All loan words and three of the five hybrid names are used for introduced plants.

Thirty-two folk generics (26.4%) are only recognized by their loc. Span. names. Of these, 78.1% are introduced into the area and, except for mango (*Mangifera indica*), litchi (*Litchi chinensis*) and ginger (*Zingiber officinale*), are not frequently cultivated.

In some cases, *Tének* names are more specific than the loc. Span. names, which are used for the same species. For example, people use the loc. Span. name *capulín* as a synonym for different botanical species, but they are labeled differently in *Tének*. The *Tének* names are *chuk baim* (*Eugenia* sp.) and *pék te'* (*Eugenia capuli*), but in loc. Span. all are named *capulín.* Another example is the name for the species *Amaranthus hybridus* which is known as *chidh* in *Tének* and by the name *quelite,* in loc. Span., which is a general term for edible weeds used in Mexico (Linares and Aguirre 1992), but in *Tének* it is exclusively used to name *A. hybridus*.

Tének Folk Taxonomy in Correspondence with Biological Classification

The 119 folk generics (excluding coffee and banana) match a one to one correspondence with 95 Linnaean species and the rate of correspondence is 79.8% (Table 2). A one to one correspondence is given for almost all of the monotypic folk generics (74, 97.4%) and almost half of the polytypic folk generics (21, 48.8%). There are 22 cases of under-differentiation, mostly for the case of polytypic generics (11 type 1 and 10 type 2), and there are two cases of over-differentation.

All the folk generics which resulted in under-differentiation and the unclassifiable taxa have in common that they are further dividable in subclasses. As a second step all the folk specifics of the folk generics that resulted in under-differentiation were compared to Linnaean species. Applying this comparison 51 folk specifics correspond to 52 Linnaean species. However, there is also one case of under-differentiation and nine cases of over-differentiation. Taking into consideration both results from the comparison of 95 folk generics that match one to one with Linnaean species and 51 folk specifics that match with 52 Linnaean species, but adding a total of eleven cases of over-differentiation there is a total of 157 folk generics and folk specifics against a total of 147 Linnaean species. Thus, the total rate of correspondence of Linnaean species equivalent to species as seen by the *Tének* is 93.6%.

Table 2. *Tének* folk nomenclature in Linnaean classification context. Correspondence refers to the equivalency at the level of folk generics and folk specifics between folk classification and Linnaean classification as the universal reference.

Correspondence of folk generics and botanical species			
Type of correspondence	**Total**	**Number and example of cases for MG and PG**	
One to one correspondence[a]	95	74	*Min te'- Bunchosia lindeniana*
		21	*Idhidh- Zea mays*
Under-differentiation Type 1[b]	11	1	*T'udhup- Vitis* aff. *tiliifolia,* and *Vitis* sp.
		10	*Oi- Gonolobus niger, and G. yucatanensis*
Under-differentiation Type 2[c]	10	0	-
		10	*Map- Cocos nucifera* and *Acrocomia aculeata*
Over-differentiation[d]	2	1	*Uj, Oj- Persea americana*
		1	Tangerina, Mandarín- *Citrus reticulata*
Not classifiable*	1	1	*Wey- Agave* aff. *americana*
Total folk generics	119		

Correspondence of folk specifics and Linnaean species		
Type of correspondence	**Total**	**Example**
One to one correspondence[e]	51	*Tének kulantuj- Coriandrum sativum*
		Lab kulantuj- Eryngium foetidum
		Oi esquinudo- G. yucatanensis
		Mulul oi- G. niger
Under-differentiationType 1[f]	1	*T'udhup- Vitis* aff. *tiliifolia* and *Vitis* sp.
Over-differentiation[g]	9	*Tsanak'w malte'* and *t'sanak pukul- P. vulgaris*
Total folk specifics	60	

[a] A single folk generic refers to only one botanical species.

[b] A single folk generic refers to two or more species of the same botanical genus.

[c] A single folk generic refers to two or more species of two or more botanical genera.

[d] More than one folk generics refer to a single botanical species.

[e] A single folk specific refers to only one botanical species.

[f] A single folk specific refers to two or more species of the same botanical genus

[g] More than one folk specific refer to a single botanical species.

Folk Descriptors of Terminal Taxa in the Folk Taxonomy Context

Most of the local folk generic names (90, 74.4%) of the 121 folk generics consist of simple primary lexemes which are single word expressions (Table 3). Some (20, 16.5%) of the folk generic names are productive lexemes and include information on a supraordinate category to which the plant belongs to. There are also a few unproductive lexemes (11, 9.1%) that do not provide any further information on a supraordinate category (Table 3).

Table 3. Nomenclatural properties of edible plant folk names of the *Tének* in the Huasteca Potosina in Mexico. (loc. Span. = local Spanish).

Folk generic type	**Examples**
Simple lexemes	
61 (*Tének* names)	- *Midhidh* (*Porophyllum ruderale*)
29 (Only loc. Span.)	- *Melón* (*Cucumis melo*)
Productive lexemes[a]	
18 (*Tének* names)	- *Min te'* (*Bunchosia lindeniana* [lit. "min tree"])
2 (Only loc. Span.)	- *Lenteja de árbol* (*Cajanus cajan* [lit. "tree lentil"])
Unproductive lexemes[b]	
9 (*Tének* names)	- *Wál palats* (*Jaltomata procumbens* [lit. "turkey eye"])
2 (Only loc. Span.)	- *Padre blanco* (*Piper* sp. [lit. "white father"])

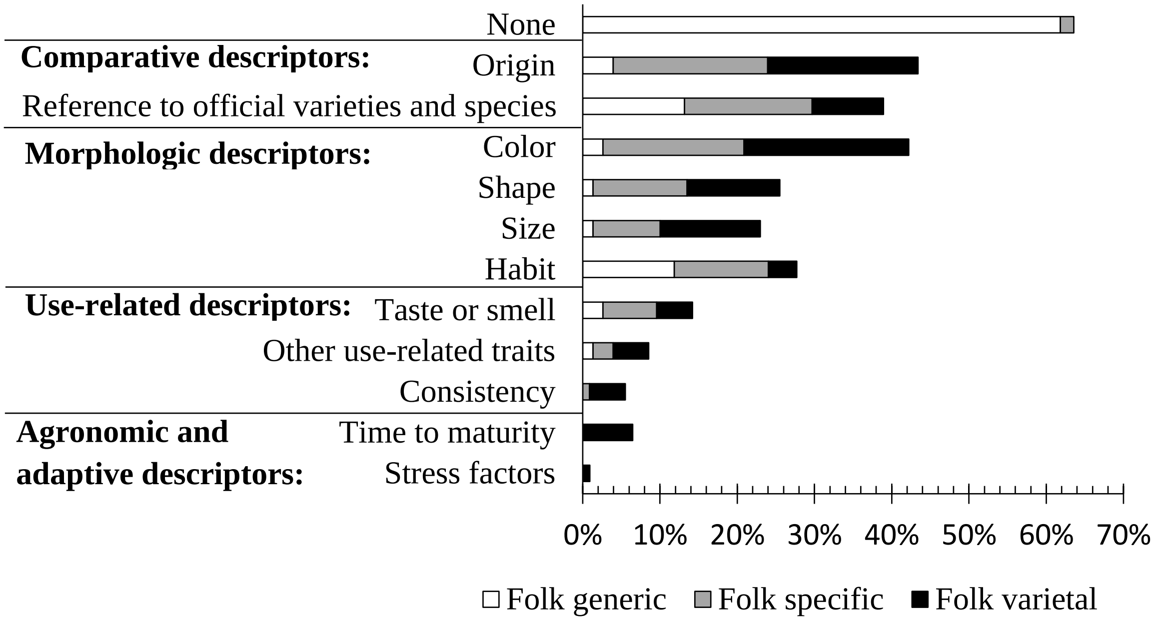
[a] Productive lexemes include information on a supraordinate category.

[b] Unproductive lexemes do not provide any further information on a supraordinate category.

The majority (47, 69.1%) of the 68 folk generic names that are terminal taxa (Table 1; including 39 *Tének* names and 29 loc. Span. names) do not include any descriptors and form part of the "None" category. If their names include analyzable information, the lexemes make a reference to official varieties and species (13.2%) or to their growth habits (11.8%) (Figure 1; see also Supplementary Table 1 for further explanation).

Tének use secondary productive lexemes plus different descriptors or modifiers to name or label their edible plants. They use these to contrast the different folk specifics and folk varietals that are included in a same supraordinate category. Color is the most salient contrasting descriptor type for the folk specifics and folk varietals and is included in 19.8% (SE 1.5%) of the minimum descriptor sets (e.g., folk specific *tsak' it'adh* [red banana]). Shape (12.1%, SE 0.1%) and size (10.8%, SE 2.1%) are also used frequently (e.g., folk specific *mulul oi* [round-shaped Kawayote] and folk specific *ts'akan ts'uhj* [small fig]). Likewise, farmers' names and labels often provide information on the origin of their plants (19.7%, SE 0.4%) (Figure 1). For example, they distinguish between a maize variety native to the area and an introduced or commercial variety. Use-related traits also play a more important role at the lower taxonomic levels, especially in case of the folk varietals where those descriptors are used in 13.9% of the cases. Agronomic traits like time to maturity (6.5%) or adaptation to certain stress factors (0.9%) are uncommon and exclusively used for the names and labels of the folk varietals (Figure 1).

Figure 1: Types of minimum descriptors used for terminal taxa of the generic, specific and varietal categories. The percentage refers to the total descriptor types used for the terminal taxa of each ethnobotanical category.



While folk specifics consist of secondary lexemes formed by the folk generic names and followed by a contrasting label, this is not the case for folk varietals. Here, the order of lexemes and modifiers is highly variable, and no semantic rules can be proposed. Furthermore, synonyms are often used. An example of a synonym is the use of colors in case of chayote or squash where the labels green and black (*yax* and *t'unu'*) refer to the same color type.

Folk Descriptors to Distinguish the Inter- and Intraspecific Diversity of *Tének* Food Plants

There are two types of diversity that are considered here in relation to descriptors used to name or label taxa. One is the intraspecific diversity within botanical species, which in the case of *Tének* classification may relate to folk specifics or folk varietals. The other is interspecific diversity which occur in cases where *Tének* folk generics contain more than one botanical species. The analysis presented here starts with intraspecific diversity and is followed by interspecific diversity.

A schematic overview of how the descriptor types form the descriptor sets for both inter- and intraspecific diversity is shown in Figure 2 for the folk generic bean (*tsanak'w*), which contains four different botanical species, but five folk specifics due to an over differentiation for bush and climbing *Phaseolus vulgaris* bean. Each folk specific has different folk varietals that represent the intraspecific diversity within each species and is exemplified for the case of *P. coccineus* for which its descriptor set is formed by only one descriptor type, color (Figure 2).

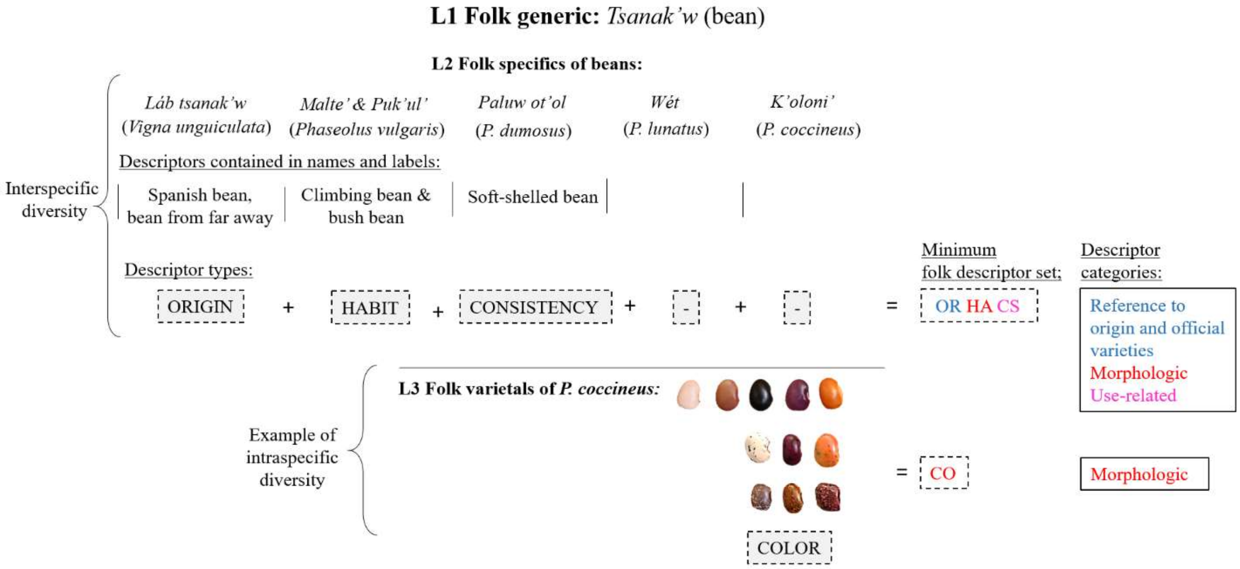


Figure 2. Example of the descriptor types, sets and categories used to distinguish inter- and intraspecific diversity of the bean folk generic. For intraspecific diversity, only the example of the folk specific *k'oloni'* (*P. coccineus*) is presented, illustrating eleven variants distinguished only by the descriptor type color. L1 – L3 = folk taxonomic level.

Twenty-four different descriptor sets are used by *Tének* people to distinguish farmer-recognized variants of the 41 botanical species with intraspecific diversity (Figure 3, upper chart). This highlights the variety of the minimum folk descriptor sets to distinguish 238 farmer-recognized variants. The number of descriptors that are assigned to the different descriptor types can vary from two descriptors for the descriptor type "Stress" (e.g. shade-grown or non-shade grown coffee) to eleven descriptors for the descriptor type "Color" (different color and color mixes for the *Phaseolus coccineus* bean) (Figure 2, see also supplementary Table 1). On average *Tének* people use 2.76 (SD 1.67) out of 11 descriptor types to name and label folk specifics and folk varietals (intraspecific diversity).

Descriptor types
(forming descriptor sets for each taxon)

Folk generics and folk specifics with intraspecific diversity	Co	Or	Sh	Si	Re	Ti	Ta	Ot	Cs	St	Ha	
Amaranthus hybridus (*Chidh*)	🟥											1
Annona reticulata (*Kukay*)	🟥											2
Cajanus cajan (*Árbol de lenteja*)	🟥											3
Cocos nucifera (*Map*)	🟥											4
Cucumis melo (*Melón*)	🟥											5
Hylocereus undatus (*Tsa' tsa'*)	🟥											6
Ipomoea batatas (*Idh*)	🟥											7
Manihot esculenta (*T'inche'*)	🟥											8
Persea schiedeana (*Uj*)	🟥											9
Phaseolus coccineus (*Tsanak'w k'oloni'*)	🟥											10
Phaseolus lunatus (*Wét' tsanak'w*)	🟥											11
Xanthosoma sagittifolium (*Lúm*)	🟥											12
Ananas comosus (*Chabcham*)		●										13
Citrullus lanatus (*Baléyaj*)		●										14
Tamarindus indica (*Tamarinduu*)				🟥								15
Sesamum indicum (*Dhakpén*)	🟥	●										16
Litchi chinensis (*Litchi*)	🟥			🟥								17
Lagenaria siceraria (*Xomom*)			🟥	🟥								18
Nopalea cochenillifera (*Pakak*)			🟥					⬟				19
Prunus persica (*Tulaxnuj*)	🟥	●			●							20
Saccharum officinarum (*Pakab*)	🟥	●			●							21
Spondias purpurea (*Ten*)	🟥	●				★						22
Zea mays (*Idhidh*)	🟥	●				★						23
Cucurbita argyrosperma (*Dhuk'uk*)	🟥		🟥					⬟				24
Vigna unguiculata (*Lab tsanak'w*)	🟥			🟥		★						25
Citrus limetta (*Ts'ik lima*)		●	🟥				⬟					26
Citrus reticulata (*Mandariin*)		●		🟥			⬟					27
Psidium guajava (*Bek*)	🟥	●	🟥	🟥								28
Coffea sp.(*Kapé*)	🟥	●			●					★		29
Cucurbita moschata (*K'alam*)	🟥		🟥	🟥					⬟			30
Cucurbita pepo (*K'alam tum tum*)	🟥		🟥	🟥					⬟			31
Mangifera indica (*Mango*)		●	🟥	🟥	●							32
Solanum lycopersicum var. *cerasiforme*, *S. lycopersicum* (*Tudhey*)		●	🟥	🟥	●							33
Capsicum annuum, *C. annuum* var. *glabriusculum* (*Its*)	🟥	●	🟥	🟥	●							34
Carica papaya (*Utsun*)	🟥	●	🟥	🟥	●							35
Musa sp.(*It'adh*)	🟥	●	🟥	🟥	●							36
Persea americana (*Oj,Uj*)	🟥	●	🟥		●		⬟					37
Phaseolus vulgaris (*Malte', Pukul*)	🟥	●			●	★					🟥	38
Sechium edule (*Tsiw'*)	🟥		🟥	🟥				⬟	⬟			39
Citrus sinensis (*Lanáx*)		●	🟥		●	★	⬟					40
Citrus aurantiifolia(*Jili limón*)	🟥	●	🟥	🟥	●		⬟	⬟				41
Total number of descriptor types to differenciate the intraspecific diversity	**31**	**20**	**16**	**15**	**12**	**5**	**5**	**4**	**3**	**1**	**1**	
Total percentage (rounded value)	27	18	14	13	11	4	4	4	3	1	1	

Folk generics consisting of more than one botanical species (interspecific diversity)	Or	Si	Sh	Ta	Co	Re	Ot	Cs	Ha	St	Ti	
Ficus aff. *americana*, *Ficus* aff. *glaucenscens* (*Ts'uj*)		🟥										42
Inga vera, *Inga* sp.(*Dhubchik*)		🟥										43
Gonolobus yucatanensis, *G. niger* (*Oy*)			🟥									44
Persea americana, *P. schiedeana* (*Új*)			🟥									45
Citrus aurantium, *C. sinensis* (*Lanáx*)				⬟								46
Citrus aurantifolia, *C. medica* (*Jili limón*)						●						47
Costus pulverulentus, *Saccharum officinarum* (*Pakab*)						●						48
Acrocomia aculeata, *Cocos nucifera* (*Map*)	●	🟥										49
Citrullus sp. *Citrullus lanatus* (*Baléyaj*)	●	🟥										50
Dioscorea alata, *Ipomoea batatas* (*Idh*)	●			⬟								51
Psidium guajava, *Syzygium jambos* (*Bek*)	●					●						52
Coriandrum sativum, *Eryngium foetidum* (*Kulantuj*)	●						⬟					53
Acanthocereus tetragonus, *Nopalea spp.*, *Opuntia engelmannii subsp. lindheimeri* (*Pakak*)		🟥	🟥									54
Ipomoea elongata, *I. purpurea* (*Dhuyu'*)			🟥		🟥							55
Passiflora edulis f. flavicarpa, *P. ligularis*, *P. serratifolia* (*Oahl pal*)	●			⬟	🟥							56
Phaseolus coccineus, *P. lunatus*, *P. dumosus*, *P.vulgaris*, *Vigna unguiculata* (*Tsanak'w*)	●							⬟	🟥			57
Physalis cinerascens, *P. pubescens*, *Physalis* sp., *P.* aff. *tamayoi* (*Alte' tudhey an othodh*)		🟥		⬟	🟥		⬟					58
Total number of descriptor types to differentiate the interspecific diversity	**7**	**6**	**4**	**4**	**3**	**3**	**2**	**1**	**1**	**0**	**0**	
Total percentage (rounded value)	23	19	13	13	10	10	6	3	3	0	0	

Descriptor Categories

🟥 Morphologic: Co- Color, Sh-Shape Si- Size, Ha- Habit.
★ Agronomic and adaptive: Ti- Time to maturity, St- Stress.
⬟ Use- related: Cs- Consistency, Ot- Other use-related traits, Ta- Taste and smell.
● Comparative: Or- Origin, Re- Reference to offcial varieties and species.

Figure 3. Minimum folk descriptor sets used to distinguish interspecific diversity (lower chart) of different species that belong to the same folk generic, and intraspecific diversity (upper chart) of

species that in folk taxonomy belong to the same folk generic or folk specific. In case of the intraspecific diversity the names in brackets show either folk specifics or the supraordinate category folk generic. The food plants (rows) are listed in ascending order within upper and lower chart regarding their total number of descriptor types. The descriptor types (columns) are listed in ascending order according to the sum of total descriptor types used for each set.

There is a positive linear relationship between intraspecific diversity of a species and the number of descriptor types used (Figure 4; Line A, R = 0.57, P < 0.01). Edible plants with more intraspecific diversity tend to have more descriptors, such as *Phaseolus vulgaris* (5 descriptors, 19 variants), *Sechium edule* (5, 21), *Citrus sinensis* (5, 5) and *C. aurantiifolia* (7, 6) (Figure 3; see numbers 38, 39, 40 and 41, respectively).

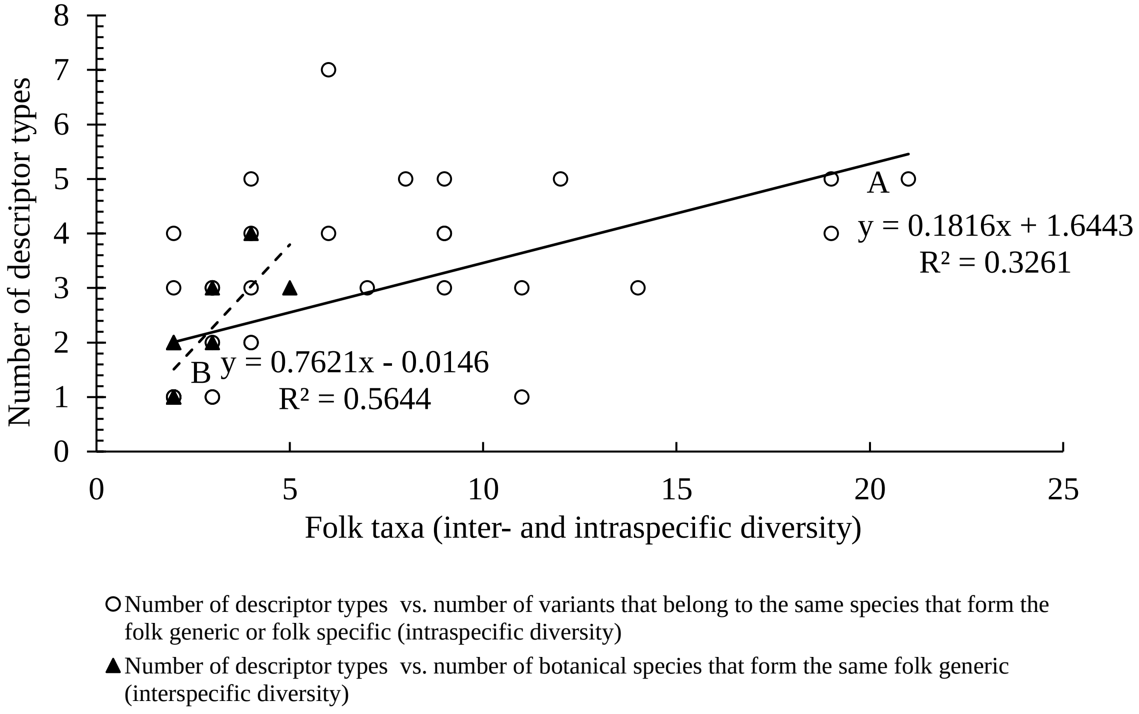


Figure 4. Linear correlation between number of different descriptor types and intraspecific diversity (of variants from upper chart, Figure 3) and interspecific diversity (of species that belong to the same folk generic, from lower chart, Figure 3) of the edible plants of the *Tének* in the Huasteca Potosina, Mexico. Line A, intraspecific (n = 41, R = 0.57, P < 0.01) and Line B, interspecific (n = 17, R = 0.75, P < 0.01).

Folk taxa that share the same set of minimum descriptors do not necessarily belong to the same botanical genus or species. For example, *Prunus persica* and *Saccharum officinarum* share the same three descriptor types (color, origin and reference; see Figure 3, numbers 20 and 21). There is also an irregularity in the use of descriptors by the farmers to distinguish crops at folk specific and varietal level for species that are botanically related. For example, the *Phaseolus vulgaris* folk varietals (see Figure 3, number 38) are described by more and different descriptors than the other crops that belong to the bean group (*P. coccineus*, *Vigna unguiculata*; see Figure 3, numbers 10 and 25, respectively).

Morphologic descriptor types (mostly color [27%], shape [14%] and size [13%]) and comparative descriptor types (mainly origin [18%]) are the main descriptor types used to distinguish intraspecific diversity, often together (Figure 3). Color is frequently used as the only contrasting descriptor type for botanical species without a high intraspecific diversity (e.g., *Manihot esculenta* [red and white]; Figure 3; see numbers 1 to 9, 11 to 12). The exception is *P. coccineus*, with 11 folk varietals that are differentiated only through multiple colors of the beans (Figure 2).

The information about the origin (Or) is mostly mentioned if local people recognize or manage both modern variants and local variants. In those cases, they name their local variant and add a contrasting modifier to the modern variant that provides information on the origin. For example, in the case of avocado the commercial 'Hass' variety is not considered a local variant and is labelled with a proper folk specific name which is '*láb uj*' (lit. Spanish or foreign avocado). In contrast, local avocado varieties are called '*tének uj*' or just '*uj'*. In cases where only local varieties are known the information on the origin remains covert. Even though people recognize that the crop species or variant is local, they are not explicitly labelled as "*tének*" (local). For example, no commercial variety of squash (*Cucurbita* spp.) was documented in the area and people do not add a label referring to the origin. Furthermore, the origin is not used as a descriptor for species that are not domesticated (e.g., *Ipomoea* spp.) or are of lesser cultural importance (e.g., *Gonolobus* spp.) and do not have a local cultivated type in the area, or have been recently introduced to the area, hence do not have a wild type (e.g., *Litchi chinensis*) (see Supplementary Table 2).

Information on shape (Sh) is mostly used for edible plants that produce fruits (e.g., *Cucurbita* spp., *Mangifera indica, Psidium guajava*) (Figure 3; see numbers 24, 30, 31, 32, 28, respectively). Information on the agronomic and adaptive traits are mainly used for crops that are the basis of the diet of the local people, are frequently cultivated and are the most representative crops of the *milpa* (e.g., maize, beans [Figure 3; see numbers 23, 25, 38]), which is the core system for food production (Heindorf et al. 2019, Chpt. 1). Use-related descriptor types form a descriptor set with two or more other descriptor types and are also mostly used for culturally important crops (e.g., *Cucurbita* spp., *Sechium edule* [Figure 3; see numbers 24, 30, 31, 39]).

Only six taxa have agronomic descriptor types. Four of these are the most important crops grown in *milpa* fields (*P. vulgaris*, Z. *mays*) and in agroforestry systems (*Coffea* sp., *Citrus sinensis*) (Figure 3; see numbers 38, 23, 29 and 40, respectively). The agronomic traits refer to site preferences (shade-tolerant coffee), the different time of maturity (e.g., short-cycled maize and beans), or because they mature around a holiday period (e.g., *ciruela San Miguel* [*Spondias purpurea*] and *naranja San Miguel* [*C. sinensis*], referring to San Miguel day, September 29th.

For interspecific diversity, the average number of descriptor types used to distinguish botanical species that belong to the same folk generic, which is the case for 17 folk generics (Figure 3, lower chart), is 1.82 (SD 0.88). The most frequent descriptors include information on the origin (23%), size (19%), and shape and taste (13% each). Color is only the fourth most important descriptor type (10%), though for intraspecific diversity it is the most important (27%). The minimum descriptor category use-related descriptor types (taste, other use related traits, and consistency) are used 22% of the time, while for intraspecific diversity they account for only 11%. There is a strong and positive correlation between the number of different descriptors and the number of botanical species that belong to the same folk generic (Figure 4, Line B, $R = 0.75$, $P < 0.01$).

Even though sometimes the appearance of the folk specifics varies, they belong to the same folk generic. One explanation is the similar use including the same parts of the plants that belong to the same folk generic. For example, *Coriandrum sativum* looks different from *Eryngium foetidum* (Figure 5), yet both species are valued for their leaves that are used for food preparation, including for the same dishes, and belong to the same folk generic, *kulantuj* (Figure 2, number 53). In other parts of the world both species are also used for the same purpose and even share similar names (cilantro and culantro in Spanish, respectively).

Figure 5: The folk specifics *tének kulantuj* (*Coriandrum sativum*) (left) and *láb kulantuj or kulantuj an o‘tol* (*Eryngium foetidum)* (right) that belong to the same folk generic *kulantuj*. The *Tének* names contain information on their origin: *Tének* (lit. local), *láb* (lit. Spanish or comes from far away) or use-related trait: *an o’tol* (lit. with skin).

Discussion

Principles of *Tének* Edible Plant Classification in the General Folk Taxonomy Context

The findings on how *Tének* classify their edible plants lead to three main postulates: (1) *Tének* people have a deep and specific knowledge about their edible plant diversity; (2) there is a high correspondence between folk taxonomy and Linnaean taxonomy; (3) to distinguish intraspecific diversity they use a practical classification system based on utility.

Contrary to the belief that an exhaustive inventory of natural species can never be achieved (see Hunn 1982), *Tének* farmers, managing a limited subset of species and variants, have an exhaustive inventory of existing agricultural species and variants. There is no edible plant species or variant without a name, due to the simple reason that every plant is used and needs to be recognized. The *Tének* follow a general-purpose classification system down to the species level, analogous to Linnaean classification, based on taxonomically organized domains (Berlin et al. 1974) and then they apply a special purpose classification at the intraspecific level, that is based on a few attributes that are of special interest for a particular purpose, which is farming or consumption (see Hunn 1982).

General *Tének* Edible Plant Classification

The unique beginner category that includes all plants does not exist, which is coherent with results from other studies (see Berlin 1992). However, the *Tének* divide their edible plants into two supraordinate groups: *t'ayalab* (cultivated plants) and *alte'* (non-cultivated plants), which are the same categories as documented for this indigenous people by Brown (1972).

The three principal life form categories (Table 1) are in accordance with Brown et al. (1972). Additionally, three subordinate lifeform categories (shrubs and small trees, leafy vegetables and grass-like herbs) were identified, as well as eleven unaffiliated generics (Table 1). The relatively high number of non-affiliated generics can be explained by the value these folk generics have for the farmer, since most of them are economically important (e.g., beans, maize), but also by their morphological conspicuousness (e.g., palms, cacti) and ambiguous life forms (climbing bean and bush-like bean). They are thus incompatible with the other principal life form groups (Berlin et al. 1974).

Most of the terminal taxa belong to folk specifics (112) and folk varietals (167). Berlin et al. (1974) observed that culturally relevant folk generics have more folk specifics, also seen in this study. The same applies for folk specifics. More important ones, like climbing beans and bush-like beans (*P. vulgaris*), watery and dry chayote (*S. edule*), watery and dry squash (*C. moschata*) and short-cycle maize (*Z. mays*) have an elevated number of terminal folk varietals (Supplementary Table 2).

The focus of this study was on food plants which explains that, contrary to studies that describe the general plant taxonomy, folk generics are not the core taxa. The number of folk generics in those studies usually range around 500 (Berlin et al. 1974). Here, only 19.6% belong to the terminal folk generics and the majority (279, 80.4%) belong to the subordinate categories (Table 1). This shows the greater knowledge the *Tének* have about the intraspecific diversity of edible plants which is related to access to and importance of such edible plant resources (Begossi and Silvano 2008; Brown et al. 1985; de Haan et al. 2007). For example, people in urban environments show a greater reliance on categorizing plants into life form groups, whereas indigenous people from forest communities have a better knowledge of folk specifics (Atran 1998).

In this study the information was mainly gathered from active farmers who manage and rely on a great plant diversity for food production. However, depth of classification may change due to farmers' expertise, which depends on the cultural and ecological setting (Atran 1998, Ferreira Júnior et al. 2016). How the detailedness of classification and indigenous knowledge of edible plant diversity change over time due to current trends such as rural migration and standardization processes of the indigenous language (Maffi 2014) should be investigated further.

The salience of ethnobotanical categories at lower folk taxonomic levels used by the *Tének* people to classify their plants, demonstrate both the knowledge and necessity for the identification, utilization and management of the food plant intraspecific diversity in their environment and sociocultural context.

Tének Folk Nomenclature, Minimum Descriptors and Application of Folk Taxonomy Knowledge

Life form and generic names are usually monomial, labelled by primary lexemes, whereas specific and varietal names are labelled by secondary lexemes and additional modifiers. This is consistent with previous works (e.g., Berlin et al. 1974). The secondary lexemes and additional modifiers or labels provide information on traits that in this work were used to define the set of minimum descriptors.

The use of descriptor types of different descriptor categories (morphologic, use-related, comparative, agronomic and adaptive) that are adapted and specific to each crop indicates the multidimensionality in the classification of food crops, especially at lower folk taxonomic levels, as has been described in other folk taxonomic studies (e.g., Mekbib 2007; Newmaster et al. 2007; Rengalakshmi 2005). Morphologic and comparative traits are the most important components for the sets of minimum descriptors (Figure 3). The prevalence of morphological traits to name and classify the farmers' inter and intraspecific crop diversity is common (e.g., Mekbib 2007; Newmaster et al. 2007; Rengalakshmi 2005).

Crops that do not have high intraspecific diversity have less descriptor types (e.g., *Amaranthus. hybridus* and *Manihot esculenta*) (Figures 3, 4, Supplementary Table 2). Farmers recognize their crop variants according to traits that show the greatest range of variation and perceptual salience

(Boster 1985). Hence, crops that do not have a high intraspecific diversity do not need a numerous set of minimum descriptors.

Agronomic and adaptive traits are scarcely used by the farmers to distinguish their variants (Figures 1, 3). One explanation is that farmers' variants are homogenously adapted to the local conditions due to site-specific selection pressures mainly of natural origin, since management strategies of the *Tének* are similar (Heindorf et al. 2019, Chpt. 1). During discussions with the farmers they mentioned that variants from the lowland would probably not grow in the higher altitude and vice versa. Farmers would include a label (e.g., *maíz de la sierra* [maize from the highland]) if discussing their varieties outside the local context. However, farmers may ascribe agronomic traits to their variants, not in naming and labeling them but cognitively. For example, the eleven variants of *k'oloni'* bean, distinguished only based on color, may have agronomic differences between them. Therefore, if the data are used for agrobiodiversity inventories it may be important to link the documented data with climatic and altitudinal information as well as with crop management.

One agronomic trait that has importance for the farmers is the time to maturity. This is especially relevant for the main staple crops maize and beans, around both of which the *milpa* management is planned to assure production and to schedule the number of harvests during the year. It is also used to identify variants that ripen during a holiday period of the year.

Results show that use-related traits are applied more to naming and labeling folk specifics and folk varietals that play an important part in the diet and are used in different ways according to their properties, like consistency, taste and smell (Figures 1, 3). For example, while the dry chayote variants are consumed cooked or baked as a snack, the watery chayote variants are preferred in soups or as fried vegetables to accompany tortillas. However, some of the use-related traits remain covert because they are intrinsically linked to another trait.

Folk taxonomy is used for communication about taxa with people who already understand and even manage the organism being discussed, and significant characteristics are part of the ethnobiological knowledge of the farmers. Accordingly, they are not used to provide information to others without local knowledge about the plants (Raven et al. 1971). For example, when describing the maize variants, all farmers agreed that the flour of the black maize has a smoother taste. Even though maize is the main food crop they do not label this maize differently because they know that all black local maize variants share this same characteristic. This highlights the minimalistic approach farmers follow to categorize and identify their variants and the knowledge about their crops.

However, the diversity managed on farmers' fields is dynamic and cultivar names and labels may change after introduction of new cultivars, resulting in additional descriptors, or the extinction of others, probably leading to a decrease of descriptor-numbers and in the depth of classification. The descriptor about origin is an example for the dynamics of *Tének* classification which sometimes remains a covert category. How the *Tének* classification will change could be investigated in the future, taking the information provided here as a basis.

Comparing these results with those from Alcorn (1984), obtained almost 40 years ago with *Tének* communities in this same region, 107 edible plants species documented here coincide with the edible plant species reported by Alcorn. In terms of linguistic consistence, 22 folk generic *Tének* names are equally written in both studies. Fifty-five *Tének* names are slightly different, e.g. *t'en* (this study) and *teen* (*Spondias pupurea*) or *idh* and *ith* (*Ipomoea batatas*), respectively. However, these slight differences are due maybe to the spelling adopted from current local consensus of the native speakers who were involved in the process of language standardization. There are 15 cases of clear differences in naming which were not a result of language standardization but rather a synonymous use of *Tének* names. For example, *may te'* (*Saurauia scabrida*), sometimes also referred to as *tsab itadh* (this study) is called *ts'een xiixte'* by Alcorn (1984). There are four *Tének* folk generic names provided by Alcorn but not documented in this study. One example is *laab its* for *Zingiber officinale* that could be lit. translated as "foreign, or Spanish chili". Incorporating this information into this work would require a change in the classification and this species would no longer be considered a folk generic but rather a folk specific of the folk generic *its*. This is an example of the local applicability of folk classification and changes that are possible within the same cultural group.

Of the local Spanish names, 56 are the same in both studies and six are slightly different. Alcorn (1984) did not include the local Spanish names for 36 plant species. In this study only five edible plant species had no local Spanish name, all of them coinciding with Alcorn (1984). This indicates that during the last four decades *Tének* people have not generated a local Spanish name for these five plant species. Examples are *puaam* (*Muntingia calabura*) and *k'oloní'* (*Phaselous coccineus*).

Alcorn (1984) provided information on intraspecific diversity for only two edible plants, listing *chuchuu' lima*, which in this study is considered as a folk specific of *Citrus limetta*, and *malte',* here considered as climber bean (*Phaselous vulgaris*).

There are some plant species that were documented by Alcorn with a *Tének* name, which in this study would be considered as folk generics but referring to a folk specific name. An example is *Gonolobus niger* which is called *oi* in Alcorn (1984), while in this study it is named as *mulul oi*, separating it from another folk specific, not registered by Alcorn (1984), *oi eskinudo* (*G. yucatanensis*). Another example is *Ipomoea dumosa*, called *thuuyu'* by Alcorn (1984), while in this study *dhuyu* is the folk generic name to which *tsupdha dhuyu* (*I. elongata*), also not registered by Alcorn (1984), and *kwexdha' dhuyu* (*I. dumosa*) belong to (Figure 6). The incorporation of additional species into the *Tének* farming systems during these intervening decades, that are very similar to existing ones, leads to more specification in naming, thus, to changes in classification.

Figure 6: Folk specifics *kwexdha' dhuyu* (*I. dumosa*) and *tsupdha dhuyu* (*I. elongata*) and *oi eskinudo* (*G. yucatanesis*) and *mulul oi* (*G. niger*), from left to right.

Comparison Between Classification Systems

As in other indigenous societies, the correspondence rate of folk generics and botanical species is high (79.8%, Table 2) and demonstrates the strong relationship between the nature of folk science and western science (Berlin 1973, Soyolt et al. 2013). The correspondence rate is even higher (93.6%) when adding the comparison of folk specifics of the polytypic generics with botanical species, which has been proposed as a complementary method (Berlin 1973). In general, overestimation is rare in folk taxonomies (Berlin et al. 1974). Here, only two taxa were over-differentiated. However, what is identified as overestimation could still be considered as "biologically accurate". In the case of *Persea americana*, people consider the avocados with an anise-like smell and the other avocados as different folk generics. These are also considered as different races and botanical variants of avocado by taxonomists and botanists (Barrientos-Priego 2010). The second case of overestimation when comparing the folk specifics and botanical species refers to the beans. Bush beans and climbing beans belong to one botanical species (*P. vulgaris*) but are assigned to two different folk specifics. These different growth habits were also considered to define different races of common beans by using a scientific approach (Singh et al. 1991).

The comparison of folk varietal classification with formal taxonomy is a difficult approach, if not impossible. Formal Linnaean taxonomy uses a universal language, which follows a common set of rules prescribed by the International Code of Botanical Nomenclature (Turland et al. 2018). The classification of taxa is based on strict general taxonomical parameters as for example found in field guides that provide keys for plant identification (e.g., Pennington and Sarukhán 2005). These keys include measurable information and are applicable on a broader scale, whereas folk taxonomy, as shown here, applies a set of other traits specifically adapted to each crop and cultural preferences.

Formal classification systems of cultivated plants at the varietal level face a similar problem, which adds difficulty to comparing folk taxonomy with Linnaean taxonomy. The difficulties to establish a simple system to universally classify variants of cultivated plants are well known (Hetterscheid et al. 1996; McNeill 2004; Ochsmann 2004). The hierarchical ordering of plants below the rank of species is almost a Sisyphean task. It seems that, in general, both the agronomic and folk taxonomies at lower levels follow a practical approach that impedes universalization.

By providing information on folk descriptors documented here, future investigators can have access to a minimum set of descriptors to document intraspecific diversity like those represented in Figure 3. Such information can be incorporated into agrobiodiversity inventory protocols and *in situ* conservation efforts, helping to minimize the risk of over-and underestimation of crop diversity. Yet, folk taxonomy is used for regional communication (Mekbib 2007), thus it is not universally applicable and limits the usefulness of such basic data in a larger context. The names and descriptors for the taxa may change from community to community, altering classification. However, compiling farmers' sets of descriptors from different regions into one database may help to give a broader overview about crop diversity distribution in relation to the environmental and cultural contexts and preferences of the farming communities.

There is a lot of discussion on how farmers' crop names and descriptors used to differentiate their variants in the field indeed reflect the agro-morphological, biochemical or molecular diversity. Some report a high accuracy and others do not (see Jarvis et al. 2011). However, farmer-recognized terminal taxa, even though not fully identical in their genetic structure, are recognized by the farmers as a same unit. Hence, the identified terminal taxa will undergo the same management practices and selection procedures which will have an impact on their genetic diversity. This will lead to more homogenous populations that share the same key characteristics (Brown and Brubaker 2002). Monitoring those crop populations provides useful indicators on the distribution of genetic diversity on spatial and temporal scales (Sadiki et al. 2007).

In conclusion, studies on folk taxonomy of edible plants open a window to human understanding and knowledge, and provide a variety of opportunities and information that, complemented with scientific efforts, are essential to characterize and manage agrobiodiversity.

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Supplementary Table 1: Description of the Minimum Descriptor Types

Description of the minimum descriptor types (1-11) used by the *Tének* in the Huasteca Potosina, Mexico, to distinguish their edible plant diversity as assigned to four different descriptor categories (A. – D.). Examples of descriptors that belong to established descriptor types are provided in brackets.

A) Morphologic:	
1. Shape	Visible form of botanical organs (e.g., long-shaped, round-shaped fruits).
2. Color	Pigmentation of the peel, seeds, pods and leaves (e.g., red, red-spotted).
3. Size	Qualitative dimension of the plant and its organs (e.g., small, large seed).
4. Habit	Mode of growth of the plant (e.g., climbing, bush-like).
B) Use-related:	
5. Taste	Flavor of the edible parts of the plant (e.g., sour, bitter).
6. Consistency	The perceived texture of the edible parts of the plants (e.g., watery, dry).
7. Other	All those not included in the other use-related descriptors. For example, some fruits have thorns and have edible peel or not (e.g., thorny chayote[a] with edible peel).
C) Agronomic and adaptive:	
8. Stress factors	Information on adaptive behavioral traits to biotic or abiotic stressors (e.g., shade-tolerant).
9. Time to maturity	Rate of growth and development (e.g., fast-growing, slow-growing, plants that mature in a specific time of the year).
D) Comparative:	
10. Origin	Information on the origin of the plant (e.g., local, introduced; the latter attribute includes also commercial and grafted plants that were mostly introduced by governmental programs and seed companies).
11. Reference to official varieties and species	Farmers classify some taxa by labelling them according to the name of the official varieties (e.g., Guacamaya coffee, Nayarit bean). It also includes cases where farmers use other biological taxa as comparative examples to describe the taxa (e.g., melon papaya).

[a] The presence of thorns is considered as a use-related trait, because it is intrinsically linked to the use of the taxa.

Supplementary Table 2: List of the Edible Folk Taxa of *Tének* Communities

List of the edible folk taxa of *Tének* communities in the Huasteca Potosina, Mexico; in alphabetical order.

L1-gn	**Apats'; palma; palm**
L2-sp	Apats' ak'wál; palma de palmito; Rio Grande palmetto (*Sabal mexicana*)
L2-sp	Chocha, k'oyol; izote; yucca palm (*Yucca* sp.)
L1-gn	**Idhidh; maíz; maize**
L2-sp	Híbrido idhidh; maíz híbrido; hybrid maize
L3-vr	Adhik híbrido idhidh an dhakní'; maíz blanco híbrido breve; white fast- growing hybrid maize (*Zea mays*)
L3-vr	Adhik híbrido manu'idhidh; maíz amarillo híbrido breve, yellow fast- growing hybrid maize (*Zea mays*)
L2-sp	Tének idhidh; maíz criollo; local maize
L3-vr	Adhik dhakní'adh manu' tének idhidh; maíz criollo amarillo claro breve; light-yellow short-cycle local maize (*Zea mays*)
L3-vr	Adhik dhakní' tének idhidh; maíz blanco criollo breve; white short-cycle local maize (*Zea mays*)
L3-vr	Adhik manu' tének idhidh; maíz amarillo criollo breve, yellow short-cycle local maize (*Zea mays*)
L3-vr	Adhik tének mili'/tukmichik dhakní' an tsuluw' idhidh; maíz pinto negro con blanco criollo breve, black and white-spotted short-cycle local maize (*Zea mays*)
L3-vr	Adhik tének mili'/tukmichik idhidh; maíz pinto breve criollo; spotted short-cycle local maize (*Zea mays*)
L3-vr	Adhik tsuluw'/t'unu' tének idhidh; maíz azul/negro/prieto criollo breve; black short-cycle local maize (*Zea mays*)
L3-vr	Dhak tének idhidh an k'ayúm; maíz blanco criollo flojo; white long-cycle local maize (*Zea mays*)
L3-vr	Mili'/tukmichik/ tsuluw' tének idhidh yab adhik yan k'axum; maíz pinto azul/negro, prieto medio breve y medio flojo criollo; not fast and not long-cycle black and white-spotted local maize (*Zea mays*)
L3-vr	Tsuluw' tének idhidh yab adhik yan k'ayúm; maíz azul/negro/prieto, medio breve y flojo; black not fast and not long-cycle local maize (*Zea mays*)
L1-gn	**It'adh; plátano; banana, plantain**

  - **L2-sp** Baléyaj it' adh; plátano melón; melón banana (*Musa* sp.)
  - **L2-sp** Chabcham it'adh; plátano piña; pineapple banana (*Musa* sp.)
  - **L2-sp** Lej it'adh; plátano macho; n.i. (*Musa* sp.)
  - **L2-sp** Manila, malila it’adh; plátano manila; manila banana (*Musa* sp.)
  - **L2-sp** Manzana it’adh; plátano manzana; apple banana (*Musa* sp.)
  - **L2-sp** Nukub it’adh; plátano enano; green dwarf banana (*Musa* sp.)
  - **L2-sp** Niwiwíl it’adh; plátano quinilla, guineo; n.i. (*Musa* sp.)
  - **L2-sp** Pek’em it’adh; plátano costillón/Jamaica; n.i. (*Musa* sp.)
  - **L2-sp** Rátan it’adh; plátano roatán; n.i. (*Musa* sp.)
  - **L2-sp** Tabasco it’adh; plátano tabasco; n.i. (*Musa* sp.)
  - **L2-sp** Tsak it’adh; plátano rojo; red banana (*Musa* sp.)
  - **L2-sp** Toro it’adh; plátano cuerno de vaca; n.i. (*Musa* sp.)
- **L1-gn Its; chile; chili**
  - **L2-sp** Cascabel its; chile cascabel; rattle chili (*Capsicum annuum*)
  - **L2-sp** Cuerno de chivo its; chile cuerno de chivo; goat horn chili (*Capsicum annuum*)
  - **L2-sp** Dhak manu' muldha’ its; chile güero bolita; yellow round chili (*Capsicum annuum*)
  - **L2-sp** Wi' ts'itsin its; chile pico de pájaro; bird's beak chili (*Capsicum annuum*)
  - **L2-sp** Kulum its, alte’ its; ts’akam its; chile del monte; wild chili (*Capsicum annuum* var. *glabriusculum*)
  - **L2-sp** Muldha’ its; kulum its; chile piquín bolita; tiny round chili (*Capsicum annuum*)
  - **L2-sp** Poblano its; chile poblano; poblano chili (*Capsicum annuum*)
  - **L2-sp** Puya its; chile puya; puya chili (*Capsicum annuum*)
  - **L2-sp** Serrano its; chile serrano; serrano chili (*Capsicum annuum*)
- **L1-gn Map; coco; coco**
  - **L2-sp** Láb map; palma de coco; cocos palm
    - **L3-vr** Manu’ láb map; coco amarillo; yellow coconut (*Cocos nucifera*)
    - **L3-vr** Yaxu’ láb map; coco verde; green coconut (*Cocos nucifera*)
  - **L2-sp** Ts’akam map, coyol map; palma corozo; coyol palm (*Acrocomia aculeata*)
- **L1-gn Pakab; caña; cane**
  - **L2-sp** Pakab olom; caña de puerco; spiral ginger (*Costus pulverulentus*)

L2-sp (Tének) pakab; caña de azúcar; sugarcane

L3-vr (Tének) dhakni’ pakab; caña blanca criolla (brasileña); local white sugarcane (*Saccharum officinarum*)

L3-vr (Tének) tsakni’ pakab; caña morada criolla; local purple sugarcane (*Saccharum officinarum*)

L2-sp Pakab híbrido; caña híbrida; hybrid sugarcane

L3-vr Pakab RD; caña RD; RD sugarcane (*Saccharum officinarum*)

L1-gn **Pak’ak’; nopal; nopal**

L2-sp Bojol pak’ak’; jacube; triangle cactus (*Acanthocereus tetragonus*)

L2-sp Kwexdha’ pak’ak’; nopal hoja redonda; round-shaped nopal

L3-vr Kwexdha’ pak’ak’ an k’ídhad; nopal hoja redonda con espina; thorny round- shaped cochineal nopal cactus (*Nopalea cochenillifera*)

L3-vr Kwexdha’ pak’ak’ yab k’ídhad; nopal redondo sin espina; thornless round- shaped cochineal nopal cactus (*Nopalea cochenillifera*)

L2-sp Nakadh’ pak’ak’; nopal largo; large-shaped cochineal nopal cactus

L3-vr Nakadh’ pak’ak’ an k’ídhad; nopal largo con espina; thorny large-shaped cochineal nopal cactus (*Nopalea cochenillifera*)

L3-vr Nakadh’ pak’ak’ yab k’ídhad; nopal largo sin espinas; thornless large-shaped cochineal nopal cactus (*Nopalea cochenillifera*)

L2-sp Pulik pak’ak’; nopal grande; cactus apple (*Opuntia engelmannii* ssp. *lindheimeri*)

L1-lf **Te'; árbol; tree**

L2-gn Anchúch; nona del monte; wild anona (*Annona globiflora*)

L2-gn Bek; guayaba; guava

L3-sp (Tének) bek; guayaba criolla; local guava

L4-vr Manu’ (tének) muldha’ bek; guayaba amarilla criolla redonda; local round-shaped guava (*Psidium guajava*)

L4-vr Manu’ (tének) nakdha’ bek; guayaba amarilla criolla larga; local large-shaped guava (*Psidium guajava*)

L4-vr Morado (tének) bek; guayaba criolla morada, local purple guava (*Psidium guajava*)

L3-sp Alte’ bek, guayaba del monte; wild guava

L4-vr Muldha’ alte’ bek; guayaba del monte redondo; round- shaped wild guava (*Psidium guajava*)

L4-vr Nakadh ’alte’ bek; guayaba del monte largo; large- shaped wild guava (*Psidium guajava*)

L3-sp Ts'at'adh bek; guayaba injertada; grafted guayaba

    - **L4-vr** Ts'at'adh pakdha'láb bek; guayaba injerto grande commercial; big commercial grafted guava (*Psidium guajava*)
  - **L3-sp** Láb bek; guayaba puma; malabar plum (*Syzygium jambos*)
- **L2-gn** Bolom it'adh; mamey; mamey sapote (*Pouteria sapota*)
- **L2-gn** Dhakpente'; pipián, piñón; Barbados nut (*Jatropha curcas*)
- **L2-gn** Dhubchik; chalahuite; icecreambean
  - **L3-sp** Ts'akam dhubchik; chalahuite del monte, de sombra café; river koko (*Inga vera*)
  - **L3-sp** Pulik dhubchik; chalahuite grande de castilla; large icecreambean (*Inga* sp.)
- **L2-gn** Jili limón; limón agrio; sour lemon
  - **L3-sp** Tsatadh jili limón; limón agrio injerto; grafted sour lemon
    - **L4-vr** Tsatadh Veracruzana limón; limón Veracruzana de injerto; grafted red sour lemon (*Citrus aurantiifolia*)
    - **L4-vr** Tsatadh jili limón yab ijchidh; limón agrio injerto sin semillas; grafted seedless sour lemon (*Citrus aurantiifolia*)
    - **L4-vr** Tsatadh láb jili manu' limón; limón amarillo agrio injerto; grafted sour lemon (*Citrus aurantiifolia*)
  - **L3-sp** Tének jili limón; limón agrio criollo; local sour lemon
    - **L4-vr** Chuchuw' limón; limón chichona; sour navel lemon (*Citrus aurantiifolia*)
    - **L4-vr** Jili limón; limón; sour lemon (*Citrus aurantiifolia*)
    - **L4-vr** Ts'akam jili limón; limón pequeño; small sour lemon (*Citrus aurantiifolia*)
  - **L3-sp** Tsatadh cidral limón; limón cidral injertado; grafted citron (*Citrus medica*)
- **L2-gn** Jobo; k'inim; hog plum (*Spondias mombin*)
- **L2-gn** Jutukú; pemoche; coral tree (*Erythrina americana*)
- **L2-gn** Kapéj; café; coffee
  - **L3-sp** Kapéj borbón (de sombra); café (de sombra) borbón; shade- tolerant borbon coffee
    - **L4-vr** Manu' Borbón kapéj (sombra); café Borbón (de sombra) amarillo; yellow (shade-tolerant) borbón coffee (*Coffea* sp.)
    - **L4-vr** Tskani Borbón café (sombra); café Borbón rojo; red (shade-tolerant) borbón coffee (*Coffea* sp.)
  - **L3-sp** Kapéj carturra; café Caturra; Caturra coffee
    - **L4-vr** Manu' Caturra kapéj; café Caturra amarillo; yellow Caturra coffee (*Coffea* sp.)
    - **L4-vr** Tsakni' Caturra kapéj; café Caturra rojo; red Caturra coffee (*Coffea* sp.)

- **L3-sp** Kapéj columbia; café Colombia; Colombia coffee (*Coffea* sp.)
- **L3-sp** Kapéj costa rica; café Costa Rica; Costa Rica coffee (*Coffea* sp.)
- **L3-sp** Tének kapéj (sombra); café criollo; local coffee
  - **L4-vr** Tének tsakní kapéj (sombra); café criollo (shade-tolerant); local coffee (*Coffea* sp.)
  - **L4-vr** Tének manu' kapéj (sombra); café criollo (shade-tolerant) amarillo (*Coffea* sp.)
- **L3-sp** Kapéj Garnica (sombra); café garnica (shade-tolerant); garnica coffee (*Coffea* sp.)
- **L3-sp** Kapéj Guacamaya; café Guacamaya; Guacamaya coffee (*Coffea* sp.)
- **L3-sp** Kapéj Marsellesa; café Marsellesa; Marsellesa coffee (*Coffea* sp.)
- **L3-sp** Kapéj Pluma Hidalgo; café Pluma Hidalgo; Pluma Hidalgo coffee (*Coffea* sp.)
- **L3-sp** Kapéj Mundo Nuevo; café Mundo Nuevo; Mundo Novo coffee (*Coffea* sp.)
- **L3-sp** Kapéj Sarchimor; café Sarchimor; Sarchimor coffee (*Coffea* sp.)

L2-gn Kukay; anona; sugar apple

- **L3-sp** (Pakdha’) manu’ kukay; anona amarilla; yellow bullock's-heart (*Annona reticulata*)
- **L3-sp** (Pakdha') tsakní kukay; anona roja; red bullock's-heart (*Annona reticulata*)
- **L3-sp** (Pakdha') yax kukay; anona verde; green bullock's-heart (*Annona reticulata*)

L2-gn Láb hualilab; almendrón; Indian almond (*Terminalia catappa*)

L2-gn Lanáx; naranja; orange

- **L3-sp** Jili lanáx; naranja cucho; sour orange *Citrus aurantium*)
- **L3-sp** Tének lanáx; naranja criolla; local orange (*Citrus sinensis*)
- **L3-sp** Lanáx tsátadh kán; naranja injertada; grafted orange
  - **L4-vr** Valencia lanáx tsátadh kán; naranja Valencia injerto; grafted Valencia orange (*Citrus sinensis*)
  - **L4-vr** San Miguel lanáx tsátadh kán; naranja San Miguel injertada; grafted San Miguel orange (*Citrus sinensis*)
  - **L4-vr** Nave lanáx tsátadh kán Naranja navel injertado; grafted Navel orange (*Citrus sinensis*)

L2-gn Mandarín; mandarina; mandarine

- **L3-sp** Ts’at’adhmandarín; mandarina injerta; grafted mandarine
  - **L4-vr** Pulik mandarín; mandarina grande; big mandarine (*Citrus reticulata*)
  - **L4-vr** Jili mandarín; mandarina agria; sour mandarine (*Citrus reticulata*)
- **L3-sp** Tének mandarín; mandarina criolla; local mandarine (*Citrus reticulata*)

L2-gn May te', tsab it’adh; mameycillo dulce; n.i. (*Saurauia scabrida*)

- **L2-gn** Min té; n.i.; woodland coffee (*Bunchosia lindeniana*)
- **L2-gn** Munek'; zapote negro; black sapote (*Diospyros nigra*)
- **L2-gn** Nésfora; nispero; loquat (*Eriobotrya japonica*)
- **L2-gn** n.i.; canela; cinnamon (*Cinnamomum* sp.)
- **L2-gn** n.i.; capulina; n.i. (*Eugenia* sp.)
- **L2-gn** n.i.; granada; pomegranate (*Punica granatum*)
- **L2-gn** n.i.; guanabana; soursop
  - **L3-sp** n.i.; guanabana injertada; grafted soursop (*Annona muricata*)
- **L2-gn** n.i.; Litchi; litchi
  - **L3-sp** n.i.; litchi de cáscara roja; red litchi (*Litchi chinensis*)
  - **L3-sp** n.i.; litchi de semilla grande, large-seeded litchi (*Litchi chinensis*)
  - **L3-sp** n.i.; litchi largo; large-shaped litchi (*Litchi chinensis*)
- **L2-gn** n.i., macadamia; macadamia nut (*Macadamia integrifolia*)
- **L2-gn** n.i.; Mango; mango
  - **L3-sp** Tének mango; mango criollo; local mango
    - **L4-vr** Tének mango mulul; mango criollo redondo; round-shaped local mango (*Mangifera indica*)
    - **L4-vr** Tének mango ts'akam mulul; mango criollo bolita chica; small round-shaped local mango (*Mangifera indica*)
  - **L3-sp** Mango tsátadh kán; mango injertado; grafted mango
    - **L4-vr** n.i.; Mango Ataulfo; Ataulfo mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango grande injerto; big grafted mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango Haden injerto; grafted Haden mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango Japonés; Japanese mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango Manila; Manila mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango Petacón injerto; grafted Petacon mango (*Mangifera indica*)
    - **L4-vr** n.i.; Mango Tranchete; Tranchete mango (*Mangifera indica*)
- **L2-gn** n.i.; Manzana, apple
  - **L3-sp** n.i.; Manzana injerto; grafted apple (*Malus pumila*)
- **L2-gn** n.i.; moringa; moringa (*Moringa* aff. *oleifera*)

- **L2-gn** n.i.; nanche; golden spoon (*Byrsonima crassifolia*)
- **L2-gn** n.i.; nim; neem (*Azadirachta indica*)
- **L2-gn** n.i.; padre blanco; Veracruz pepper (*Piper auritum*)
- **L2-gn** n.i.; pera; pear (*Pyrus communis*)
- **L2-gn** n.i.; pimienta; allspice (*Pimenta dioica*)
- **L2-gn** n.i.; pistache; pistachio nut (*Pistacia vera*)
- **L2-gn** n.i.; tangerina; n.i. (*Citrus reticulata*)
- **L2-gn** n.i.; toronja; grapefruit (*Citrus paradisi*)
- **L2-gn** n.i.; yaka; jackfruit (*Artocarpus heterophyllus*)
- **L2-gn** Ohox; ojite; breadnut (*Brosimum alicastrum*)
- **L2-gn** Oj; aguacate oloroso; aromatic avocado
  - **L3-sp** (Tének) oj; aguacate oloroso criollo; local aromatic avocado
    - **L4-vr** (Tének) t’unu’ oj ani mulúlchik, aguacate oloroso negro redondo; local black aromatic round-shaped avocado (*Persea americana*)
    - **L4-vr** (Tének) t’unu’ oj ani nakdhachik; aguacate oloroso negro largo; local black aromatic large-shaped avocado (*Persea americana*)
    - **L4-vr** (Tének) yax’ oj ani nakdhachik; aguacate oloroso verde largo; local green aromatic large-shaped avocado (*Persea americana*)
    - **L4-vr** (Tének) yax’ oj ani mulúlchik, aguacate oloroso verde redondo; local green aromatic round-shaped avocado (*Persea americana*)
- **L2-gn** Papayuelo; garambolo; carambola (*Averrhoa carambola*)
- **L2-gn** Pehte', pék te', t'zedte; capulín; blossom berry (*Eugenia capulí*)
- **L2-gn** Puaam; n.i.; strawberrytree (*Muntingia calabura*)
- **L2-gn** Raurel; laurel; Mexican bay leaf (*Litsea glaucescens*)
- **L2-gn** Tamariindu; tamarindo; tamarind
  - **L3-sp** Pulik tamariindu; tamarindo de vaina larga; big tamarind (*Tamarindus indica*)
  - **L3-sp** Tének tamariindu; tamarindo criollo agrio; local sour tamarind (*Tamarindus indica*)
- **L2-gn** T'en; ciruela; plum
  - **L3-sp** Tsatadh ten; ciruela injertada; grafted mombin
    - **L4-vr** Tsatadh manu’ láb ten; ciruela injertada amarilla; yellow grafted mombin (*Spondias purpurea*)

L3-sp	Tének ten, ciruela criolla, local mombin
L4-vr	Manu' tének ten, ciruela criolla amarilla, local yellow mombin (*Spondias purpurea*)
L4-vr	Tsak' tének ten, ciruela criolla roja, local red mombin (*Spondias purpurea*)
L3-sp	Z'ilim t'en, ciruela Campechana, ciruela San Miguel; Campechana plum, San Miguel mombin
L4-vr	Manu' z'ilim t'en, ciruela Campechana amarilla, ciruela San Miguel amarilla; yellow Campechana mombin, yellow San Miguel mombin (*Spondias purpurea*)
L4-vr	Tsak z'ilim t'en, ciruela Campechana roja, ciruela San Miguel roja; red Campechana mombin, red San Miguel mombin (*Spondias purpurea*)
L3-sp	China t'en, tének t'en; ciruela china, ciruela criolla; local mombin
L4-vr	Manu' china t'en; yellow ciruela china, yellow Chinese mombin (*Spondias purpurea*)
L4-vr	Tsak china t'en; ciruela roja china, red Chinese mombin (*Spondias purpurea*)
L2-gn	Tsabak; tequesquite; tempisque (*Sideroxylon capiri* subsp. *tempisque*)
L2-gn	Tsab it’ ath; chicozapote; sapodilla (*Manilkara zapota*)
L2-gn	Ts’ik lima; lima dulce; sweet lime
L3-sp	Chuchuw' ts’ik lima; lima dulce chichona; sweet navel lime (*Citrus limetta*)
L3-sp	Ts’ik lima; lima dulce criolla, local sweet lime (*Citrus limetta*)
L3-sp	Lima dulce injertada; grafted sweet lime (*Citrus limetta*)
L2-gn	Tso’te; chote; cuachilote (*Parmentiera aculeata*)
L2-gn	Ts’uhj; higueron; fig
L3-sp	Ts’akan ts’uhj, higerón pequeño; small fig (*Ficus* aff. *americana*)
L3-sp	Pulik/pakdha’ ts’uhj; higuerón grande; big fig (*Ficus* aff. *maxima*)
L2-gn	Tulaxnúj, durazno; peach
L3-sp	Tének tulaxnúj; durazno criollo; local peach
L4-vr	Tének tsakní tulaxnúj; durazno criollo rojo; local red peach (*Prunus persica*)
L3-sp	Ts’at’adhtulaxnúj; durazno injerto; grafted peach
L4-vr	Manu’ tulaxnúj an tsadh; durazno injerto amarillo; yellow grafted peach (*Prunus persica*)
L4-vr	Ts’at’adh láb prisco tulaxnúj; durazno prisco injertado; grafted Prisco peach (*Prunus persica*)
L2-gn	Uj; aguacate; avocado
L3-sp	Láb uj; aguacate Hass; Hass avocado (*Persea americana*)

        - **L3-sp** (Tének uj); aguacate criollo; local avocado
            - **L4-vr** (Tének) t’unu’ uj ani nakadhachik; aguacate criollo negro largo; local black large-shaped avocado (*Persea americana*)
            - **L4-vr** (Tének) t’unu’ uj ani mulúlchik; aguacate criollo negro redondo; local black round-shaped avocado (*Persea americana*)
            - **L4-vr** (Tének) yax' uj ani nakadhchik; aguacate criollo verde largo; local green large-shaped avocado (*Persea americana*)
            - **L4-vr** (Tének) yax’ uj ani mulúlchik; aguacate criollo verde redondo; local green round-shaped avocado (*Persea americana*)
        - **L3-sp** Pawa, xomom uj; aguacate pahua; pagua avocado
            - **L4-vr** T’unu' pawa/xomom uj; aguacate pahua negra, black coyo avocado (*Persea schiedeana*)
            - **L4-vr** Yax’ pawa/xomom uj; aguacate pahua verde, green coyo avocado (*Persea schiedeana*)
    - **L2-gn** Xobots, tatil bichim; pata de vaca; orchid tree (*Bauhinia divaricata*)
- **L1-lf** **Ts'áj; planta que camina; climbing creeping plant**
    - **L2-gn** Bayniya; vainilla; vanilla (*Vanilla planifolia*)
    - **L2-gn** Baléyaj; sandía; watermelon
        - **L3-sp** Ts’akam alte' baléyaj; sandillita de monte; wild melon (*Melothria pendula*)
        - **L3-sp** Baléyaj; sandia; commercial watermelon (*Citrullus lanatus*)
        - **L3-sp** Tének baléyaj; sandia criolla; local watermelon (*Citrullus lanatus*)
    - **L2-gn** Kobeem; jícama; yam bean
        - **L3-sp** Kobeem hamuth; jícama de agua, watery yam bean (*Pachyrhizus erosus*)
    - **L2-gn** Dhut’; zarza; blackberry
        - **L3-sp** Alte' dhut; zarza del monte; wild blackberry (*Rubus* sp.)
    - **L2-gn** Idh; camote; ni
        - **L2-sp** Láb idh; camote real; camote blanco; water yam
        - **L2-sp** Idh; camote dulce; sweet potato
            - **L4-vr** Manu’ idh; camote dulce amarillo; yellow sweetpotato (*Ipomoea batatas*)
            - **L4-vr** Dhak idh; camote dulce blanco; white sweetpotato (*Ipomoea batatas*)
            - **L4-vr** Tsak idh; camote dulce rojo; red sweetpotato (*Ipomoea batatas*)
    - **L2-gn** K’alam; calabaza; squash

- **L3-sp** (K’alam) dhuk'uk; calabaza pipiana; cushaw
  - **L4-vr** Dhuk'uk (k'alam) dhakní’ ani kwechodh/ mulúlidh; calabaza pipián blanca y redonda; white round-shaped cushaw (*Cucurbita argyrosperma*)
  - **L4-vr** Dhuk'uk (k'alam) milí ani kwechodh/ mulúlidh; calabaza pipián borrada/rayada y redonda; striped round-shaped cushaw (*Cucurbita argyrosperma*)
- **L3-sp** K’alam; calabaza; squash
  - **L4-vr** Dhak (k’alam) ja’much kwechodh/mulúlidh, calabaza aguada blanca y redonda; white round-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ (k’alam) ja’much ani nakat bolilidh; calabaza aguada, negra/verde bola larga; black/green large oval-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ míli’ (k’alam) ja’much ani bolilidh; calabaza aguada, negra/verde rayada de bola chica; black/green small oval-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ míli’ (k’alam) ja’much ani nakat bolilidh; calabaza aguada, negra/verde rayada de bola larga; black/green striped large oval-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ míli’ (k’alam) ja’much ani xomomlidh; calabaza aguada negra/verde rayada de botella; black/green striped bottle-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ (k’alam) ja’much ani mulúlidh; calabaza aguada, negra/verde redonda; black/green round-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’(k’alam) ja’much ani nakadh mululidh; calabaza aguada verde redonda grande; black/green big round-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** T’unu’/yaxu’ míli’ (k’alam) ja’much ani mulúlidh; calabaza aguada, negra/verde, rayada, redonda; black/green striped round-shaped watery squash (*Cucurbita moschata*)
  - **L4-vr** Mo’odhidh (k’alam) dhakní’ míli’ ani nakdha’ bolidh; calabaza seca blanca rayada de bola larga; white large bottle-shaped dry squash (*Cucurbita moschata*)
  - **L4-vr** Mo’odhidh (k’alam) dhakní’ míli’ ani xomomlidh; calabaza seca, blanca rayada de botella; white-striped bottle-shaped dry squash (*Cucurbita moschata*)
  - **L4-vr** Mo’odhidh (k’alam) dhakníní míli’ani mulúlidh/mulúlchik; calabaza seca blanca rayada redonda; white round-shaped dry squash (*Cucurbita moschata*)
  - **L4-vr** Mo’odhidh (k’alam) t’unu’/yaxu’ míli’ ani mululidh; calabaza seca, negra/verde rayada redonda; black/green striped round-shaped dry squash (*Cucurbita moschata*)
  - **L4-vr** Mo’odhidh (k’alam) t’unu’/yaxu’ ani bolilidh, calabaza seca negra/verde de bola larga; black/green oval-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ ani xomomlidh; calabaza seca negra/verde de botella; black/green bottle-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ míli’ ani t’ijax bolidh; calabaza seca negra/verde rayada de bola chica; black/green striped small oval-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ míli’ ani nakdha’ bolidh; calabaza seca negra/verde rayada de bola larga; black/green striped big oval-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ míli’ ani xomomlidh; calabaza seca, negra/verde rayada de botella; black/green striped bottle-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ ani mulúlidh; calabaza seca, negra/verde redonda; black/green round-shaped dry squash (*Cucurbita moschata*)

L4-vr Mo’odhidh (k’alam) t’unu’/yaxu’ míli’ ani t’ijax mululidh/mulúlchik; calabaza seca, negra/verde rayada redonda chica; black/green striped small round-shaped dry squash (*Cucurbita moschata*)

L3-sp Kálam tum tum; calabaza atomite; atomite sqash

L4-vr Mo’odhidh (k’alam) dhakní’ tum tum, ani t’ijax mulúlidh/mulúlchik; calabaza atomite seca blanca chica y redonda; white small round-shaped atomite squash (*Cucurbita pepo*)

L4-vr Mo’odhidh (k’alam) tsakní tum tum ani t’ijax mulúlidh/mulúlchik calabaza atomite, naranja, chica y redonda; red small round-shaped atomite squash (*Cucurbita pepo*)

L2-gn n.i.; guadalupe; balsampear (*Momordica charantia*)

L2-gn n.i.; melón, melon

L3-sp n.i.; melón amarillo; yellow melon (*Cucumis melo*)

L3-sp n.i.; melón café; brown-colored melon (*Cucumis melo*)

L2-gn Oahl pal; maracuya; passionfruit

L3-sp Manu’ maracuyá; Maracuyá amarilla; yellow maracuyá (*Passiflora edulis* f. *flavicarpa*)

L3-sp Oahl pal; maracuyá silvestre; wild maracuyá (*Passiflora serratifolia*)

L3-sp Ts’ik oahl pal; granada china; sweet granadilla (*Passiflora ligularis*)

L2-gn Oi; talayote, kawayote; n.i.

L3-sp Mulul oi; talayote/kawayote liso, round-shaped n.i. (*Gonolobus niger*)

L3-sp Oi eskinudo, talayote/kawayote cuadrado, square-shaped n.i. (*Gonolobus yucatanensis*)

L2-gn Push luk; n.i.; n.i. (*Passiflora hahnii*)

L2-gn Tsa’ papas; ik' papaas, jumul ids, kahil wakki; papa voladora; air yam (*Dioscorea bulbifera*)

L2-gn Tsa tsa’; pitaya; nightblooming cactus

L3-sp Tsak tsa tsa’; pitahaya roja; nightblooming cactus (*Hylocereus undatus*)

L2-gn Pok pok; amapola; fetid passionflower (*Passiflora foetida*)

L2-gn Tsiw'; chayote; chayote

L3-sp Tsiw' ja'much, chayote aguado; watery chayote

L4-vr Dhak ja’much tsiw’ an k’ídhadh an ot’odh, chayote blanco aguanoso con cáscara, con espinas; white thorny watery chayote with peel (*Sechium edule*)

L4-vr Dhak ja’much tsiw’ yab k’ídhadh ani ot’odh; chayote blanco aguanoso con cáscara, sin espinas; white watery thornless chayote with peel (*Sechium edule*)

L4-vr Dhak ja’much tsiw’ yab k’ídhadh yab ot’odh; chayote blanco aguanoso sin cáscara, sin espinas; white watery thornless chayote without peel (*Sechium edule*)

L4-vr T’unu’/yax ja’much tsiw’ k’ídhadh ani ot’odh; chayote negro/verde aguanoso con cáscara, con espinas; black/green thorny watery chayote with peel (*Sechium edule*)

L4-vr T’unu’/yax ja’much tsiw’ yab k’ídhadh ani ot’odh; chayote negro/verde aguado con cáscara, sin espinas, black/green watery thornless chayote with peel (*Sechium edule*)

L4-vr T’unu’/yax ja’much tsiw’ k’ídhadh yab ot’odh; chayote negro/verde aguanoso sin cáscara, con espinas; black/green thorny watery chayote without peel (*Sechium edule*)

L3-sp Tsiw’ yab ja’much yab mo’dhidh; chayote medio seco y medio aguado; medium dry and watery chayote

L4-vr Dhak tsiw’ yab ja’much yab mo’dhidh yab k’ídhadh; chayote blanco medio seco con cáscara y sin espinas; black/green medium dry thornless chayote with peel (*Sechium edule*)

L4-vr Dhak tsiw’ yab ja’much yab mo’dhidh yab k’ídhadh yab othodh; chayote blanco medio seco, sin cáscara, sin espinas; white medium dry thornless chayote without peel (*Sechium edule*)

L4-vr T’unu’/yax tsiw’ yab ja’much yab mo’dhidh ani k’ídhadh ani ot’odh; chayote negro/verde medio seco con cáscara, con espinas, black/green medium dry thorny chayote with peel (*Sechium edule*)

L4-vr T’unu’/yax tsiw’ yab ja’much yab mo’dhidh yab othodh yab k'ithad (ok palat); chayote negro/verde medio seco sin cáscara, sin espinas (cabeza de conche); black/green medium dry thornless chayote without peel (*Sechium edule*)

L3-sp Tsiw' mo'odhidh; chayote seco; dry chayote squash (*Sechium edule*)

L4-vr Dhak mo’dhidh tsiw’ k’ídhadh ani ot’odh; chayote blanco seco con cáscara, con espinas; white dry thorny chayote with peel (*Sechium edule*)

L4-vr Dhak mo’dhidh ts’akam tsiw’ k’ídhadh ani ot’odh; chayote blanco seco chico con cáscara, con espinas; small white dry thorny chayote with peel (*Sechium edule*)

L4-vr	Dhak mo’dhidh tsiw’ yab k’ídhadh ani ot’odh; chayote blanco (re)seco con cáscara, sin espinas; white (very) dry thorny chayote with peel (*Sechium edule*)
L4-vr	Dhak mo’dhidh tsiw’ yab k’ídhadh yab ot’odh (ok palat); chayote blanco seco sin cáscara, sin espinas(cabeza de conche), blanco; white dry thornless chayote without peel (*Sechium edule*)
L4-vr	Dhak mo’dhidh ts’akam tsiw’ yab k’ídhadh yab ot’odh (ok palad); chayote chico blanco seco sin cáscara, sin espinas (cabeza de conche); white small dry thornless chayote without peel (*Sechium edule*)
L4-vr	Manu' mo’dhidh tsiw’ k’ídhadh ani ot’odh; chayote amarillo (re)seco con cáscara, con espinas; yellow (very) dry thorny chayotewith peel (*Sechium edule*)
L4-vr	T’unu’/yax mo’dhidh tsiw’ k’ídhadh ani ot’odh; chayote negro/verde seco con cáscara, con espinas; black/green dry thorny chayote with peel (*Sechium edule*)
L4-vr	T’unu’/yax mo’dhidh ts’akam tsiw’ k’ídhadh ani ot’odh; chayote negro/verde chico seco con cáscara y con espinas; small black/green dry thorny chayote with peel (*Sechium edule*)
L4-vr	T’unu’/yax mo’dhidh ts’akam tsiw’ yab k’ídhadh ani ot’odh; chayote negro/verde seco con cáscara y sin espinas; black/green dry thornless chayote without peel (*Sechium edule*)
L4-vr	T’unu’/yax mo’dhidh tsiw’ yab k’ídhadh yab ot’odh (ok palat); chayote negro/verde seco sin cáscara y sin espinas (cabeza de conche); black/green dry thornless chayote without peel (*Sechium edule*)
L4-vr	T’unu’/yax mo’dhidh ts’akam tsiw’ yab k’ídhadh yab ot’odh (ok palat); chayote negro/verde chico seco sin cáscara y sin espinas (cabeza de conche); small black/green dry thornless chayote without peel (*Sechium edule*)
L2-gn	Tudhey; tomate; tomato
L3-sp	Tének tudhey; tomate criollo; wild tomato
L4-vr	Tének pakdha’ tudhey; tomate coyol grande; big wild cherry tomato (*Solanum lycopersicum* var. *cerasiforme*)
L4-vr	Tének ts’akam tudhey; tomate coyol chico; small wild cherry tomato (*Solanum lycopersicum* var. *cerasiforme*)
L3-sp	Bolidh tudhey; tomate de bola; n.i. (*Solanum lycopersicum*)
L3-sp	Tudhey saladi; tomate saladi; saladette tomato (*Solanum lycopersicum*)
L2-gn	T'udhup, uva; vine
L3-sp	Alte' t'udhup; uva de monte; wild vine
L4-vr	Alte' pulik t'udhup; uva de monte grande; big wild vine (*Vitis* aff. *tiliifolia*)

            - **L4-vr** Alte' ts’akam t'udhup; uva de monte chico; small wild vine (*Vitis* sp.)
    - **L2-gn** Ut’, cuelcemeca; n.i. (*Smilax* sp.)
    - **L2-gn** Xomom; guaje; bottle gourd
        - **L3-sp** (Xomom) kwentú/kwechodh; guaje redondo; round-shaped bottle gourd (*Lagenaria siceraria*)
        - **L3-sp** Nakdha’ xomom; guaje largo y grande; big long-shaped bottle gourd (*Lagenaria siceraria*)
        - **L3-sp** Pakdha’ xomom; guaje grande de botella; big bottle-shaped bottle gourd (*Lagenaria siceraria*)
        - **L3-sp** Ts’akam xomom, guaje chico de botella; small bottle-shaped bottle gourd (*Lagenaria siceraria*)
- **L1-gn** Tsanak’w; frijol; bean
    - **L2-sp** (Tsanak’w) malte'; frijol de guía, climber bean
        - **L3-vr** Dhak bayo malte’ ani kayum; frijol bayo de guía flojo blanco/crema; creme-colored slow-growing bayo climber bean (*Phaseolus vulgaris*)
        - **L3-vr** T’unu’ tukmichik bayo malte’ ani adhik; frijol bayo pinto negro breve de guía; black-mottled fast-growing bayo climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Dhak malte’ ani adhik; frijol blanco breve de guía; white short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Morado malte’ ani adhik; frijol morado breve de guía; purple fast- growing climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Morado míli’ t’sixo malte’ ani adhik; frijol ojo de cabra morado breve de guía; purple eye of the goat short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Morado tukmichik malte’ ani adhik; frijol pinto morado breve de guía; purple-mottled short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Tsak malte’ ani adhik; frijol rojo breve de guía; red short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Tsak’ míli’ t’sixo malte’ ani adhik; frijol ojo de cabra rojo breve de guía; red eye of the goat short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Tsak tukmichik malte’ ani adhik; frijol pinto rojo-blanco breve de guía; red and white-mottled short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** T’unu’ malte’ ani adhik; frijol negro breve de guía negro, black short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** T’unu’ tukmichik malte’ ani adhik; frijol pinto negro breve de guía; black-mottled short-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Dhak malte’ ani kayum; frijol blanco flojo de guía; white long-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Tsak malte’ ani kayum; frijol rojo flojo de guía flojo; red long-cycle climber bean (*Phaseolus vulgaris*)
        - **L3-vr** Tsak míli’ malte’ ani kayum; frijol rojo jaspeado flojo de guía; red-speckled long-cycle climber bean (*Phaseolus vulgaris*)

L3-vr	Tunu' malte’ ani kayum; frijol negro flojo de guía; black long-cycle climber bean (*Phaseolus vulgaris*)
L2-sp	(Tsanak’w) puk'ul'; frijol de mata; bush bean
L3-vr	Dhak puk’úl ani adhik an t’unu' ot'ol; frijol blanco de mata breve de cáscara negra; white bush-like short-cycle bean with black pods (*Phaseolus vulgaris*)
L3-vr	T’unu’ puk’úl ani adhik; frijol negro de mata breve de cáscara negra; black bush-like short-cycle bean with black pods (*Phaseolus vulgaris*)
L3-vr	Michigan puk’úl t’unu’ ani adhik; frijol Michigan negro breve de mata; black short-cycle bush-like Michigan bean (*Phaseolus vulgaris*)
L3-vr	Nayarit puk’úl t’unu’ ani kayum; frijol Nayarit negro breve de guía; black short-cycle climbing Nayarit bean (*Phaseolus vulgaris*)
L2-sp	(Tsanak’w) paluw ot’ol; frijol cáscara blanda; soft-shelled bean
L3-vr	T’unu’ paluw ot’ol, frijol cáscara blanda negro, soft-shelled black bean (*Phaseolus dumosus*)
L2-sp	Tsanak’w k’oloni’; frijol koloni; scarlet runner bean
L3-vr	Aku’ míli’ k’oloni’; frijol k’oloni’ jaspeado gris; grey-speckled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Dhak k’oloni’; frijol k’oloni’ blanco; white scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Dhak tukmichik k’oloni’; frijol k’oloni’ pinto blanco con negro; black and white mottled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Lanáx k’oloni’; frijol k’oloni’ naranjo; orange scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Lanáx míli’ k’oloni’; frijol k’oloni’ jaspeado naranjo; orange-speckled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Lanáx tukmichik k’oloni’; frijol k’oloni’ pinto naranjo; orange mottled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Morado k’oloni’, frijol k’oloni’ morado; purple scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Morado míli’ k’oloni’; frijol k’oloni’ jaspeado morado; purple-speckled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Morado tukmichik k’oloni’; frijol k’oloni’ morado pinto, purple mottled scarlet runner bean (*Phaseolus coccineus*)
L3-vr	Tsokoy k’oloni’; frijol k’oloni’café, coffee-colored scarlet runner bean (*Phaseolus coccineus*)
L3-vr	T’unu’ k’oloni’; frijol k’oloni’negro; black scarlet runner bean (*Phaseolus coccineus*)
L2-sp	Wet’ (tsanak’w); frijol huet; lima bean
L3-vr	Dhak wét’; frijol wét’blanco, white lima bean (*Phaseolus lunatus*)
L3-vr	T’unu’ wét’; frijol wét’negro; black lima bean (*Phaseolus lunatus*)
L2-sp	Láb tsanak; frijol sarabanda; cowpea

L3-vr Adhik tsakni’ láb tsanak’w; frijol sarabanda rojo mediano y breve; red short-cycle cowpea with médium long pods (*Vigna unguiculata*)

L3-vr Adhik pakdha’ t’unu’ láb tsanak’w; frijol sarabanda negro largo y breve; black short-cycle cowpea with long pods (*Vigna unguiculata*)

L3-vr Adhik t’unu’ láb tsanak’w; frijol sarabanda negro mediano y breve; black short-cycle cowpea with médium long pods (*Vigna unguiculata*)

L3-vr Adhik tsokoy láb tsanak’w; frijol sarabanda café mediano y breve; brown-colored short-cycle cowpea with médium long pods (*Vigna unguiculata*)

L3-vr Káyúm dhakní’ láb tsanak’w; frijol sarabanda blanco mediano y tardío; white long-cycle cowpea with medium long pods (*Vigna unguiculata*)

L3-vr Káyúm pakdha’ t’unu’ láb tsanak’w; frijol sarabanda negro largo y tardío; black long-cycle cowpea with long pods (*Vigna unguiculata*)

L3-vr Káyúm pakdha’ t’unu’ láb tsanak’w ani morado an ot’ól; frijol sarabanda negro largo y tardío y de cáscara morada; black long-cycle cowpea with long purple pods (*Vigna unguiculata*)

L3-vr Káyúm tsokoy láb tsanak’w; frijol sarabando café mediano y tardío; brown-colored long-cycle cowpea with médium long pods (*Vigna unguiculata*)

L3-vr Káyúm t’unu’ láb tsanak; frijol sarabanda negro mediano y tardío; black long-cycle cowpea with médium long pods (*Vigna unguiculata*)

L1-lf Ts'ojol; hierba y planta pequeña; herb or weed

L2-gn Alte' tudhey an othodh; tomatillo de cáscara del monte; groundcherry

L3-sp Alte’ tudhey pakadh an othodh; tomatillo dulce del monte grande; smallflower groundcherry (*Physalis cinerascens*)

L3-sp Alte’ yax ts’akam tudhey an othodh; tomatillo verde chico de cáscara del monte; wild small green groundcherry (*Physalis* sp.)

L3-sp Alte’ yax tudhey an othodh; tomatillo verde de cáscara del monte; wild green groundcherry (*Physalis* aff. *tamayoi*)

L3-sp Ts’ik alte’ tudhey an othodh; tomatillo dulce de monte, tomatillo de zopilote; husk tomato (*Physalis pubescens*)

L2-gn Bombaj kapéj; café bomba/ bombóm; okra (*Abelmoschus esculentus*)

L2-gn Dhakpen; ajonjolí; sesame

L3-sp (Tének) dhakní’ dhakpen; ajonjolí criollo blanco; local white sesame (*Sesamum indicum*)

L3-sp (Tének) dhakpen tsokoy; ajonjolí criollo cafe; local coffee-colored sesame (*Sesamum indicum*)

L3-sp (Tének) t’unu’ dhakpen; ajonjolí criollo negro; local black sesame (*Sesamum indicum*)

L2-gn Chabcham; pina; pineapple

L3-sp Chabcham; piña commercial; commercial pineapple (*Ananas comosus*)
L3-sp Tének chabcham; piña criolla; local pineapple (*Ananas comosus*)
L2-gn Jilil tsojool; trébol; n.i. (*Oxalis latifolia*)
L2-gn Kakaw; cacahuate; peanut
L3-sp Dhak kakaw; cacahuate blanco (*Arachis hypogaea*)
L2-gn Lúm; n.i.; arrowleaf elephant ear
L3-sp Dhak lúm; lúm blanco; white arrowleaf elephant ear (*Xanthosoma sagittifolium*)
L3-sp Tsak lúm; lúm rojo; red arrowleaf elephant ear (*Xanthosoma sagittifolium*)
L2-gn n.i.; azafraan; turmeric (*Curcuma longa*)
L2-gn n.i.; jengibre; ginger (*Zingiber officinale*)
L2-gn n.i.; fresa; strawberry (*Fragaria* sp.)
L2-gn n.i.; frijol pica pica, frijol nescafé; velvet bean (*Mucuna pruriens* var. *utilis*)
L2-gn Wál palat’s; ojo de guajolote; creeping false holly (*Jaltomata procumbens*)
L2-gn Xuts’un padhum, xut’sun bex’e’; oreja de tigre, oreja de tejón; peperomia (*Peperomia maculosa*)
L1-lf **Ts’ojol k’apnel; verdura; vegetable**
L2-gn Alte’ jilil; jilil de monte; pinkfringe (*Arthrostemma ciliatum*)
L2-gn Chidh; quelite; edible leaves
L3-sp Dhak chidh; quelite blanco; edible white amaranth leaves (*Amaranthus hybridus*)
L3-sp Tsak chidh; quelite rojo; edible red amaranth leaves (*Amaranthus hybridus*)
L2-gn Dhuyu’; suyo; morning glory
L3-sp Kwexdha’ dhuyu’; dhakní’ dhuyu’; suyo hoja grande, suyo blanco; large-leafed morning glory, white morning glory (*Ipomoea dumosa*)
L3-sp Tsupdha dhuyu, tsakní’ dhuyu’; suyo de hoja anguda, suyo rojo; large-leave-shaped morning glory, red morning glory (*Ipomoea elongata*)
L2-gn Elbenax; hierba buena; mint (*Mentha* aff. *spicata*)
L2-gn Kulantuj; cilantro criollo; coriander
L3-sp Tének kulantuj; cilantro criollo; local coriander (*Coriandrum sativum*)
L3-sp Láb kulantuj, kulantuj an o'tol, cilantrón; long coriander (*Eryngium foetidum*)
L2-gn Lek’ ab pakax; lengua de vaca; curly dock (*Rumex crispus*)

L2-gn Midhidh; tepehua; Bolivian coriander (*Porophyllum ruderale*)
L2-gn n.i.; acelga; chard (*Beta vulgaris*)
L2-gn n.i.; cebolla; onion (*Allium cepa*)
L2-gn n.i.; lechuga; lettuce (*Lactuca sativa*)
L2-gn n.i.; menta; n.i. (*Mentha* aff. × *piperita* sp.)
L2-gn n.i.; puerro; broadleaf wild leek (*Allium ampeloprasum*)
L2-gn n.i.; romero; rosemary (*Rosmarinus officinalis*)
L2-gn n.i.; ruda; rue (*Ruta* sp.)
L2-gn Pitsits wal; verdolaga, purslane (*Portulaca oleracea*)
L2-gn Tijtson; epazote; jesuit’s tea (*Dysphania ambrosioides*)
L2-gn Tizón ts'ojol; albahaca; basil (*Ocimum basilicum*)
L2-gn Xunnakat; cebollín; onion leek
L3-sp (Tének) xunnakat; cebollín criollo; local onion leek (*Allium longifolium*)
L1-lf **Ts'ojól tom; pasto; grass**
L2-gn Limón tom; zacate limón; lemon grass (*Cymbopogon citratus*)
L1-gn **Utsun; papaya; papaya**
L2-sp Alte' utsun; papaya del monte; wild papaya (*Carica papaya*)
L2-sp Bolom it'adh utsun, mamey utsun; papaya mamey; mamey papaya (*Carica papaya*)
L2-sp Manu' utsun; papaya amarilla; yellow papaya (*Carica papaya*)
L2-sp Muldha’ utsun; papaya de bola; round-shaped papaya (*Carica papaya*)
L2-sp Melón utsun; papaya melón; melón papaya (*Carica papaya*)
L2-sp Nakadh utsun; papaya larga; long papaya (*Carica papaya*)
L2-sp Pakdha’ utsun; papaya grande grande; big papaya (*Carica papaya*)
L2-sp Ts’akam utsun, chuwda utsun; papaya chica; small papaya (*Carica papaya*)
L1-lf **Wayelom alte’; arbusto, árbolito; shrub**
L2-gn Ak; mala mujer; n.i. (*Cnidoscolus multilobus*)
L2-gn Chuk baim, chuc bai, chuc bem; capulin; n.i. (*Eugenia* sp.)
L2-gn n.i.; árbol de mora; black mulberry (*Morus nigra*)
L2-gn n.i.; chaya; n.i. (*Cnidoscolus aconitifolius*)

	L2-gn	n.i.; lenteja de árbol; pigeon pea	
		L3-sp	Mili’ lenteja; lenteja de árbol borrado; striped pigeon pea (*Cajanus cajan*)
		L3-sp	T’sokoy lenteja; lenteja de árbol café; brown pigeon pea (*Cajanus cajan*)
		L3-sp	T’unu’ lenteja; lenteja de árbol negro; black pigeon pea (*Cajanus cajan*)
	L2-gn	Úmu; n.i.; blackbead (*Pithecellobium dulce*)	
	L2-gn	T’inche’; yuca; cassava	
		L3-sp	Dhak t’inche’; yuca blanca; white cassava (*Manihot esculenta*)
		L3-sp	Tsak t’inche’; yuca roja; red cassava (*Manihot esculenta*)
	L2-gn	Tiyá; hoja santa; pepperleaf (*Piper* sp.)	
L1-gn	**Wey; agave; agave**		
	L2-sp	Tsi'iimm; wiich; maguey; agave (*Agave* aff. *americana*)	
L1-gn	**Wits; flor; flower**		
	L2-sp	Coxol huítz; flor de gallito; jack bean (*Canavalia villosa*)	
	L2-sp	Met'ol k'ichaj; girasol; sunflower (*Helianthus annuus*)	
	L2-sp	Wits jamaica; flor de Jamaica; roselle (*Hibiscus sabdariffa*)	

Notes: Hierarchical level: L1-L4; Ethnobiological category: lf = life form, gn = generics, sp = specifics, vr = varietal.

The plant names are presented in the following order: *Tének* name; local Spanish name; Common English name.

Tének names and local Spanish names are based on information provided by the key informants in the research area. Common English names are listed according to the information of Germplasm Resources Information Network (http://www.ars-grin.gov/). In some cases alternative sources were consulted. At varietal and speficic level names were often literally translated. Scientific names are provided according to ThePlantList (http://www.theplantlist.org/). Covert terms are shown in brackets and synonyms are separated with a dash. n.i. = no information on name

CHAPTER IV

General Discussion and Conclusions

Considerations for *In Situ* Conservation

The *Tének* in the Huasteca Potosina, as other indigenous cultures in Mexico and Mesoamerica, manage agrobiodiversity-rich agroecosystem complexes consisting of different land use systems (Toledo et. al. 2003). In this study three land use systems were included, *milpas*, home gardens and *te'loms*, simultaneously managed by the farmers from three localities along an altitudinal gradient. The aim was to inventory and describe the total, specific and intraspecific diversity of food crops of the agroecosystem complex of the *Tének*, and evidence its importance for future *in situ* conservation efforts.

In the following, after some key methodological considerations, the major findings of the previous chapters are discussed in a comprehensive manner, followed by conclusions. Overall, the breadth and depth of the rich agrobiodiversity managed by the *Tének*, as well as their knowledge about it as reflected by their practical yet complete edible-plant taxonomic system, are considered here in relation to both its conservation and its use in fulfilling their needs facing limited resources and heterogeneous environmental conditions.

The comparison of the food crop diversity of these land use systems to other similar studies is, however, hindered, since only limited information that fully considers intraspecific diversity exists on this topic. Detailed information on both inter- and intraspecific diversity is required to fully understand the dimension and relevance of agrobiodiversity in these and other traditional systems. Clearly, to know and understand what must be conserved, *in situ* and/or *ex situ*, should be seen as a prerequisite for its efficient conservation.

Methodological Considerations

These methodological considerations, a selected subset of all methods employed, are the result of the author's personal experience gained through the development of this research as well as through the systematic use of methods that were selected to obtain data with applicability to the conservation and use of plant genetic resources.

Although it is challenging and laborious to produce comparable data on intraspecific diversity, their importance is paramount to provide a complete overview, especially when working with traditional farming communities. A combination of surveys, participatory methods, key informants and intensive sampling of the plots accompanied by farmers is important to avoid over- and under-estimation of FVar+FSpe (farmer-recognized variants and farmer-recognized species with no variants, respectively) and to create comparable baseline data for the future.

As field methodologies, implemented during three years, were supported by an array of complementary botanical methods (such as species classification following herbarium protocols, a complete set of plant photographs to aid identification of species and variants, consultation with colleagues and of internet sources) and a meticulous processing of data, it is clear that the effort invested is proportional to the results that are being sought.

This overall description of the methodology, however strenuous it may be, should encourage other researchers to determine whether other indigenous localities in Mesoamerica and elsewhere grow a similar diversity of edible crops. To characterize at the proper level the richness of the managed world's crop genetic capital seems an unavoidable step, and its relevance for Mexico has been recently stated (Mastretta-Yanes et al. 2019).

The total number of 347 FVar+FSpe inventoried for the three production systems in the three localities is remarkable considering that only 33 farmers were included in the study (a total of > 99 sample units considering the three production systems). The rarefaction analysis conducted evidenced that the taxa inventoried for the three systems and altitudes and in total were close to 100% of the hypothetical total taxa that could be found if the sample size of farmers were to be increased (Chpt. 2). For example, the total taxa inventoried (347) for the three systems and three localities with the 33 farmers considered here, represent 99.6% of the total taxa that could be found if sample size were to be substantially increased. This may imply that the depth of an agrobiodiversity inventory, such as the one presented here, is an important contributor towards achieving completeness of taxa that can be inventoried as part of a sampling effort.

Additionally, the prioritization exercise described in Chapter 1 for the study of *milpa* agrobiodiversity showed that there are many and variable elements that can be used to prioritize crops, sites, and farmers to fit goals and resources of future initiatives. Prioritization is important because resources are limited (Bellon and van Etten 2014, Pacicco et al. 2018) and, as shown, even a limited number of farmers as considered here can yield most of the taxa in need to be inventoried.

Moreover, prioritization serves as an entry point for further initiatives that may eventually expand number of crops, sites, and farmers as needed. The type of exercise described for the *milpas*, perhaps adding considerations about diversity indexes and population size (Chpt. 1), can be similarly applied to home gardens and *te'loms*, as well as for the complete agroecosystem complex.

A tool that proved valuable was regression analysis, simple and multiple. For example, the simple linear regression analysis, used in various occasions, showed that there are significant covariations between diversity parameters (Figures 6, 7 Chpt. 2). The number of *milpa* FVar is significantly and positively correlated to the overall number of FVar+FSpe in the agroecosystem complex managed by each farmer, and it can thus be selected as an indicator for the overall edible plant diversity that can be found in the complete complex (Figure 7, Chpt. 2).

However, to determine the factors that have a statistically significant influence on the number of *milpa* FVar via multiple regression was challenging. Different to other studies which demonstrate that socioeconomic factors such as age and family numbers have an influence on the number of crops (e.g., Salazar-Barrientos et al. 2016), in this study no significant correlations were found nor accepted in the multiple regression model for these factors as predicting variables. Nonetheless, three variables were identified which can be linked to the marginality of the *milpas* in terms of access (walking time to the *milpa* fields) and ecological constraints (slope gradient and rockiness). However, to explain the effect of each of these variables remains difficult.

This exercise, with limited success, on attempting to identify via multiple regression analysis the factors that determine diversity, coupled to the significant covariations in diversity between the different production systems established by simple linear regression, lead to consider that, as shown by Walter and Kantelhardt (2018), the mindset of farmers may be a key factor that must be taken into account. Multidisciplinary studies with focus on social and economic issues and methods that assess farmers' attitudes and viewpoints combined with biological and ecological data could contribute to fill this research gap.

Agrobiodiversity and the Need for *In Situ* Conservation

Though the *Tének* manage highly crop-diverse farming systems that are relevant for the use and conservation of a broad range of crop genetic resources, the persistence of those resources remains uncertain. Interdependent with other reasons like climate change and rural migration, the populations of many of the FVar and FSpe are rather small and are not evenly distributed. Thus, conservation measures are needed if these resources are to be preserved, *in situ* and/or *ex situ*, or promoted since they may be at risk.

Specific pools of edible plant genetic resources

The TWINSPAN classification (Fig. 5, Chpt. 1) formed eight *milpa* groups according to their altitudinal position. The application of this tool visualized the distinctiveness of the farmers' production strategies in the three research sites. Each *milpa* group serves as a specific pool of different assemblies of intraspecific diversity of certain crop species. These results also indicate that the *milpa* as a system can be considered the basic management unit for research, use, and *in situ* conservation efforts, including prioritization. A similar system-based approach can be extended for the whole agroecosystem complex as well.

The low similarity between and within the three land use systems of the agroecosystem complex and localities, as determined by SIMPER analysis, coupled to the fact that only a very small amount of the farmers' edible plant diversity is cultivated in all three systems (0.4; Table 4, Chpt. 2) and that only 19.3% of the total FVar+FSpe is shared among all the three systems of the different localities (Figure 4, Chpt. 2), supports the argument of favoring an agroecosystem-approach for the *in situ* conservation of plant genetic resources. This would also bring multiple benefits by fostering synergies of the different abiotic and biotic components which support the functionality of the farmers' productions systems and provide ecosystem services that contribute to the planet's health in general (Vandermeer et al. 1998, Girardello et al. 2019).

The individual farmers manage on average 48.7 FVar+FSpe in their agroecosystem complex. The farmers in the medium altitude locality (MedAlt) cultivate more FVar+FSpe with an average of 60, compared to the farmers in the other two sites (Table 2, Chpt. 2). The MedAlt is also the locality that shares most of the *milpa*, home garden and *te'lom* FVar+FSpe with the two other localities and hosts most of the exclusively distributed FVar+FSpe in the *milpa*, home gardens and *te'loms*. Hence, MedAlt in this study is the most important plant genetic reservoir and the proposed priority site for interventions in favor of crop diversity.

Almost three quarters of the FVar+Spe of the three systems are classified as rare and 24.8% are registered only once (Figure 3, Chpt. 2). Furthermore, diversity indexes (Table 1, Chpt. 2) demonstrate that most of the edible plant richness is unevenly distributed and only a small number of FVar+Spe (12.7%) show a high abundance, i.e. more than 1000 individuals (Figure 2, Chpt. 2), all of them belonging to groups of the most important crops of the *milpas*, or coffee plants and banana plants, which are mainly distributed in the *te'loms* and home gardens.

Small population numbers cannot assure the persistence of genetic diversity in the farmer's cropping systems (Bellón et al. 2018) and the edible plant diversity of the *Tének* agroecosystem complex should receive attention in terms of the promotion and use of their rich edible crop diversity, especially considering the fact that 68.6% of the total FVar+FSpe were identified as FVar, highlighting the role of this particular agroecosystem complex for on-farm conservation and use of intraspecific diversity. A crop group of specific concern would be fruit trees, due to the low number of individuals and the use of methods of asexual propagation, which decrease the existing gene pool of cultivated germplasm (Bisognin 2011) and could be investigated in more detail.

The number of shared FVar+FSpe between the different land use systems managed by each farmer is highest for home gardens and *te'loms* (Chpt. 2), probably because they share a lot of tree FVar+FSpe species. However, the *milpa* also shares an average of 2.3 FVar+Spe with home gardens. This indicates that home gardens are important sinks and sources of plant genetic resources for the farmers and serve as experimental sites for them to test plant diversity (Watson and Eyzaguirre 2002).

The Agroecosystem of the Tének as a unique reservoir for edible plant genetic resources

Comparing the data with selected studies, that documented a relatively high richness of edible food plants, it is shown that the agroecosystem of the *Tének* is a unique reservoir for edible plant genetic resources.

For the *milpas* 84 species were documented that include 191 FVar+FSpe with 140 farmer-recognized variants and 51 species with no intraspecific variants. These values are higher than reported in other studies about the *milpas* of indigenous people in and outside the research area (Chpt. 1). Especially staple crops have a high intraspecific richness (Table 2 of Appendix 2, Chpt. 1), which is in accordance with Jarvis et al. (2008), where it is shown that farming communities maintain a higher varietal richness of major staples than of non-staples. Jarvis et al. (2008) also provide data on the average varietal richness of 27 selected staple crops per farmer which ranges from 1.38–4.25. In this study the average value per *milpas* of each farmer is 16.4 FVar+FSpe out of 84 species of staples and non-staples. It is also shown that *Tének* farmers are important managers of squash and bean variants (examples of other studies are provided in Table 2 of Appendix 3, Chpt. 1). For these crops the varietal richness is higher than reported for other indigenous communities in Mexico (examples are provided in Table 3 of Appendix 3, Chpt. 1).

For home gardens, 243 different FVar+FSpe, including 120 botanical species, were documented. Toledo et al. (2003) provided a sum of 136 food plants that are used by a total of 10 different indigenous groups and other home garden studies showed a richness of 40, 42-50 and 60 edible plant species (Pulido-Salas et al. 2017, Chablé-Pascual et al. 2015 and Ortíz-Sánchez et al. 2015, respectively).

For the *te'loms* a total of 89 botanical species including 164 FVar+FSpe were registered. Toledo et al. (2003) documented 168 edible food plants from the secondary forests which are comparable to the *te'loms* of the *Tének* and Angel Martínez et al. (2007) provide information on 129 edible plant species in coffee-agroforestry systems in Mexico. Both numbers are higher than presented here. However, considering that the numbers provided by the authors represent the sum of numerous different studies that were undertaken in several different communities throughout Mexico, the richness of the edible plants reported in this study is unique and, until now, incomparable.

This study evidences the *Tének* agroecosystem as a unique reservoir for edible plant genetic resources with specific pools that might be relevant for conservation. The agroecosystem complex of the *Tének* in the Huasteca Potosina, in terms of diversity (understanding it as a relationship of richness and abundance), can be proposed here as an agrobiodiversity hotspot for edible plants in Mexico, and perhaps for the world. However, although the term “hotspot” has been used by different authors to highlight the importance of other regions for agrobiodiversity conservation (e.g., Kannaiyan 2009; Paccico et al. 2018; Prabhakaran et al. 2014), a thorough definition of agrobiodiversity hotspot, contrary to biodiversity hotspots for wild species (see Myers et al. 2000), is still pending and is recommended to be defined in the future.

Further Considerations

Systems in the natural and humanized environments are dynamic and a species or variant could be substituted for another one. The identification of loss, substitution, or change in crop diversity is even more complex than in a natural system. In addition to changing biotic and abiotic factors, a wide variety of human-induced pressures of socioeconomic, cultural, demographic origin, or private nature also have an impact on the crop diversity that is maintained in farmer’s fields (Brush 2000; Brush and Perales 2007).

It is considered that there is a decline in agrobiodiversity as traditional farming systems in Mexico are substituted by more modern cropping systems (Pérez-García and del Castillo 2016) and diversity has been related to economic stratum of farmers (Interián Kú and Duch Gary 2004). Due to a lack of historical baseline data in the region, and despite the work of Alcorn (1984), which is discussed below, no statements can be made about the diversity that has been lost in the past. This work remains as a description of the current diversity in different production systems of the *Tének* and changes may be evaluated in the future.

However, a comparison can be made with the work of Alcorn (1984), who documented more than 900 plant species (including 204 food plant species) in the *Tének* region of the Huasteca Potosina, though with a far higher recollection effort and the inclusion of more-land use systems as well as the natural environment. Out of the 149 plant species of this study, 107 coincide with those reported by Alcorn (1984). Interestingly, several plants classified by Alcorn (1984) as used for food were not mentioned by the farmers considered in this study as food plants and vice versa. This may indicate the dynamics in terms of plant use and knowledge related to it. Also, 45 food plant species, documented for this study were not reported by Alcorn (1984), most of them Old World plants, introduced more recently, demonstrating again the dynamic of crop diversity in agricultural landscapes over time.

A detailed characterization of heterogeneous agricultural systems, such as the one conducted here, is necessary to understand their complexity and guide use and conservation measures. However, the farmers are the decision-makers, and the whole farming community is eventually needed to obtain the complete inventory of crop genetic resources and of the ecosystem and socio-cultural services they provide.

Furthermore, the ability of farmers to manage such a high richness in the whole agroecosystem complex and specific diversity in the different land use systems also reveals the in-depth knowledge farming communities have, to simultaneously manage such an elevated number of crops. This knowledge about the management of the overall biotic and abiotic complexity of the agroecosystems, especially in terms of crop combination and planning of interventions deserves further investigation.

Tének Folk Taxonomy as a necessary tool for agrobiodiversity inventories

A sound understanding of how people classify and label their crops is required for complete and accurate agrobiodiversity inventories and to gain insights beyond just the listing of taxa. Contrary to the belief that an exhaustive inventory of natural species can never be achieved (see Hunn 1982), *Tének* farmers, managing a limited subset of species and variants, have an exhaustive inventory of existing agricultural species and variants. There is no edible plant species or variant without a name, due to the simple reason that every plant is used and needs to be recognized (Chpt. 3).

Several similarities to other folk taxonomies were observed, as for example the absence of the unique beginner categories, and the higher number of subordinate folk taxa for culturally relevant crops like maize, beans, bananas, chayote, squash, coffee, but also peculiarities that are not comparable with other folk taxonomic studies. Different to other folk taxonomic studies (see

Berlin et al. 1974) which are often limited to botanical species level and folk generics are the core taxa (Berlin 1973), most of the 347 folk taxa inventoried here belong to the lower taxonomic categories. Only 19.6% belong to the terminal folk generics, thus are not the core taxa like in other studies (Berlin 1973). It also shows the greater knowledge the *Tének* have about the intraspecific diversity of edible plants which is related to access to and importance of such edible plant resources (Atran 1998, Begossi and Silvano 2008, Brown et al. 1985; de Haan et al. 2007).

Compared to scientists, farmers use less, but specific and practical descriptors, to identify their plants and variants correctly (de Haan et al. 2007; Mistura et al. 2016). The number of descriptor types used to distinguish inter- and intraspecific diversity is positively correlated to the number of subordinate taxa. Morphologic descriptors are more often used to distinguish folk taxa at intraspecific level (42%), meanwhile comparative descriptors are more used to distinguish folk taxa at interspecific level (33%) (Figure 3, Chpt. 3). However, some descriptors remain covert and are not explicitly used by the *Tének* in the name and labeling (i.e., information on origin), which is important to consider for agrobiodiversity inventories that are often used as a first entry point to obtain information on agrobiodiversity. Linguistic understanding is essential for working with indigenous communities (Martin 1995). The descriptor sets provided here are a useful reference for future investigators in the region in order to avoid over and underestimation in agrobiodiversity inventories.

Detailedness of classification and indigenous knowledge of edible plant diversity change over time, and the loss of local variants is intrinsically linked to the loss of human knowledge and linguistic diversity (Maffi 2002, Maffi 2014).

In retrospect, comparing these results with those from Alcorn (1984), obtained over 35 years ago with *Tének* communities in this same region, 107 edible plant species documented here coincide with the edible plant species reported by Alcorn. In terms of linguistic consistence, 22 folk generic *Tének* names are equally written in both studies. Alcorn (1984) did not include the local Spanish names for 36 plant species. In this study only five edible plant species have no local Spanish name, all of them coinciding with Alcorn (1984). This indicates that during the last four decades *Tének* people have not generated a local Spanish name for these five plant species. Examples are *puaam* (*Muntingia calabura*) and *k'oloní'* (*Phaselous coccineus*). It was also shown (Chpt. 3) that it could be that the incorporation of additional species into the *Tének* farming systems during these intervening decades, that are very similar to existing ones, leads to more specification in naming, thus, to changes in classification.

The correspondence rate of folk generics and botanical species from Linnaean taxonomy is high (62.6%, Table 2, Chpt. 3), and even higher (93.6%) when adding the correspondence of folk specifics of the polytypic generics with botanical species. High correspondence of folk taxa and scientific taxa has also been reported in other studies and demonstrates the strong relationship between the nature of folk science and Linnaean science (Berlin 1973, Soyolt et al. 2013).

Detailed studies on folk taxonomy of edible plants such as this, besides opening a window to human understanding and knowledge, provide a variety of opportunities and information that, complemented with scientific efforts, are essential to characterize and manage agrobiodiversity.

Overall Conclusions and Final Remarks

The results of this research lead to five overall main conclusions:

(1) The *Tének* in the Huasteca Potosina cultivate a high and (so far incomparable) diversity of different food-crops at both inter- and intraspecific levels, with the medium altitude site showing the highest diversity;

(2) The three different production systems serve as a specific pool for plant genetic resources and there is low similarity between and within systems and localities, making it necessary to prioritize depending on conservation and other efforts;

(3) The FVar in the *milpa* serve as a significant indicator of the total FVar+FSpe in the agroecosystem complex, evidencing that diversity covaries within and between production systems;

(4) The identification of variables that explain or predictors for crop diversity is challenging, yet marginal conditions (distance, slope and rockiness) seem to play a significant role; and,

(5) The *Tének* people have a deep and specific knowledge about their edible plant diversity, which they classify using a practical classification system based on utility and which has a high correspondence with Linnaean taxonomy.

Based on these conclusions, the very high diversity of edible crops managed by the *Tének*, when studied at the intraspecific level, represents for the three production systems a valuable pool of plant genetic resources, underutilized in a more general context perhaps because it has been to date under-characterized, i.e., poorly understood.

While diversity covaries within and between production systems, the *milpa* FVar is an adequate indicator for all the managed edible plant diversity. Yet, to explain *milpa* FVar via external factors, such as terrain conditions, only provided a partial explanation of the levels and variations encountered. This, supported by previous works (e.g., Altieri and Merrick 1987; Birol et al. 2009; Mastretta-Yanes et al. 2019; Perales et al. 2003), including those part of this study, lead to conclude that no matter specific variations due to terrain and other characteristics, the use of high diversity fulfills intrinsic and major requirements for both subsistence in marginal conditions and the personal choice of farmers and their families.

An interesting approach evidencing the need to consider diversity of mindsets of farmers, when trying to alter behavior that can contribute to a more stable environmental performance, has been presented by Walder and Kantelhardt (2018), arguing that in this manner the specifics of various farmer-groups can be approached with more accuracy.

To the extent that future works emphasize the characterization of intraspecific diversity, which has been shown to have a preponderant role in terms of *Tének* taxonomy and knowledge of their crops, and perhaps indigenous in general, different from the role modern agriculture gives to variants (Chpt. 1), a more complete understanding will be gained of both the level of richness being managed and its purpose. In terms of the need to maintain this richness, both for the benefit of the indigenous communities that own it and for the growing demand in food requirements in the context of population growth and adaptation to the climate emergency, identifying and mainstreaming crop genetic resources at the intraspecific level, well beyond the commonly used interspecific level or the development of improved varieties, becomes a necessity and opportunity.

The question remains, however, how to conserve *in situ* this biodiversity giving the changing times described earlier.

Recommendations

Besides the multiple strategies that can be implemented using *in situ* conservation measures, even in combination with *ex situ* strategies, e.g., communitarian seed banks, funding and promotion of biodiversity conservation (Barbier et al. 2018), including payments for agrobiodiversity conservation (e.g., Krishna et al. 2013; Narloch et al. 2011) remain crucial.

Traditional farmers often cultivate unique food plant diversity which is not offered in conventional markets. The promotion of markets that focus on local products can contribute to agricultural biodiversity on farms (Lamers et al. 2016). Three farmers participate in the Macuilli organic market in San Luis Potosí (http://mercadomacuilli.com/), which promotes local products and has a participatory certification system (Bara et al. 2017). Even though this initiative is a great step forward to promote local products of farmers and gives them the opportunity to receive fair payments for their products, farmers in the Huasteca and other areas often lack transport which hinders access to such markets (personal observation).

Therefore, investments and funding in infrastructure and transport are needed to provide more economic opportunities farmers should receive for their role in the *in situ* conservation of their plant genetic resources. Besides, there are other options that can be considered. In 2018, Aquismón was named “Pueblo Mágico” in San Luis Potosí, which is a designation of towns and villages that are particularly interesting sites for tourists, because they offer natural beauty, history and cultural identity (see also http://www.sectur.gob.mx/gobmx/pueblos-magicos/). Developing alternative tourist activities and events (agrobiodiversity and gastronomic fairs, routes to *milpas*, home gardens and *te'loms*, besides the mainstream activities, are further options (Ramírez 2001; see also de Boef 2013) to provide additional income options for the farmers and by this adding complementary value to the farmers to maintain local crop variants and their agroecosystem complexes. At the same time this enhances public awareness of consumers regarding the role of the farmers in the conservation of plant genetic resources, resulting in a virtuous cycle.

Overall, agrobiodiversity conservation is not just a matter of ensuring the continuous survival of traditional varieties for their eventual use in, e.g., breeding efforts. It is also and perhaps mainly a question of contributing to sustain and enhance the incomes and survival strategies of the rural people with whom crop genetic resources are entwined to the point that they and their ancestors shaped and now guard this agrobiodiversity. The challenge will be to help sustain traditional cultivation systems in a synergy between what is good for the farmers and what will benefit *in situ* conservation of biological diversity and the ecosystem services it provides for the whole of society.

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ANNEX

Olga Costa y la fiesta de la diversidad frutícola de México

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Título corto: *La vendedora de frutas*

Palabras clave: Frutas de México, pintora de fruta, marchante

Resumen

En *La vendedora de frutas* Olga Costa representó una parte de la diversidad frutícola de México, 69 especies y variantes. Las frutas proceden de distintas regiones: son mesoamericanas (46 %), le siguen las de oriente lejano (30 %) y oriente cercano (13 %), menor cantidad son las de origen sudamericano (6.0 %) y el más bajo (4.5 %) a África, pero de aquí procede nuestra especie *Homo sapiens*.

Olga Costa y La vendedora de frutas

En algún día de 1925, la niña de 12 años Olga Kostakowsky Fabricant descendió del *Espagne* en el puerto de Veracruz con sus papás y su pequeña hermana Lya. El casi imperceptible rocío de las flores, la diversidad de colores que contrastaba con el gris-guerra de Europa, los tonos morenos de la gente y los aromas de la brisa marina empezaron a diluir la nacionalidad germana y la ascendencia rusa de Olga. A la niña le encantaron las voces de los vendedores callejeros, el novedoso idioma español y el ambiente del hotel donde se hospedaron, pues tuvieron que esperar en vano en el puerto por sus equipajes perdidos. Esas impresiones y muchísimas más moldearon aquella niña ruso-germana para convertirla en Olga Costa (1913-1993), la pintora mexicana de renombre, Premio Nacional de Bellas Artes en 1990. A contracorriente de los muralistas mexicanos, Olga se alejó de los dogmas estéticos que impusieron, y evitó discriminar tendencias y valores en el arte. En su iconografía de personas, paisajes, flores, plantas y frutas, Olga buscó captar los símbolos y asuntos populares desde una perspectiva etnográfica, superando el folclorismo.

El pintor Fernando Gamboa, subdirector del Instituto Nacional de Bellas Artes en 1950, sabía del gusto pictórico de Olga por los frutos de México, y le solicitó que hiciera un cuadro con todos ellos. La petición fue para incluirlo en la "Exposición de Arte Antiguo y Moderno Mexicano" que se presentaría un año después en el Museo de Arte Moderno de París. En ese entonces, el gobierno estaba empeñado en exhibir el "Milagro Mexicano", acorde con la modernidad de la posguerra, pero a la vez, pretendía destacar el orgullo por las raíces prehispánicas y la amalgama mestiza de la nación.

Ya puesta a cumplir el encargo, muy probablemente Olga evitó pintar una naturaleza muerta, pues quería representar algo palpitante, muy vivo. Tampoco fue opción pintar un bodegón, que siempre tiene un tufillo medieval, y evadió el convencional cuerno de la abundancia, por su fuerte carga de lugar común para simbolizar la riqueza. Entonces, más fiel a su estilo, prefirió pintar la fiesta de la agrodiversidad frutícola que danza por los mercados de México, un cuadro que mostrara la alegría de los puestos de fruta, en cierta forma, una cornucopia *sui generis*. Así, 26 años después de su arribo a Veracruz concluyó su pintura *La vendedora de frutas* (1951, óleo sobre lienzo, 2.7 × 1.5 m, Museo de Arte Moderno, Ciudad de México) en la que plasmó sus impresiones que comenzaron cuando llegó a México.

Las frutas de *La vendedora*

El local de fruta que Olga pintó corresponde a un puesto semipermanente, que en México suelen establecerse alrededor de los mercados. La fruta está acomodada en el piso, otra sobre lo que parece ser paja y algunas esteras azules, y también dispuesta sobre huacales de huejote (*Salix oxylepis*), cestos y canastos de mimbre (*Salix chilensis* y *Taxodium mucronatum*), carrizo (*Arundo donax*) y sobre cajones de tablas (*Pinus* sp.). Los canastos están adornados con pliegos de colores (que en México se llama papel de China) y con hojas de palma camedor (*Chamaedorea* sp.).

Si bien la encomienda de Gamboa fueron las frutas como actoras de la pintura, Olga colocó a la vendedora como lo sustantivo del cuadro, por eso domina el centro de la imagen, representa a *Homo sapiens*, la especie que hace posible la domesticación y con ello, la generación de la agrodiversidad exhibida. A diferencia de algunas pinturas de caballete de Diego Rivera, aquí la mujer no está recogiendo flores, ni está de espaldas, está de frente dominando la parte central de la imagen, con una mirada serena y una sonrisa que muestra orgullo, fuerza y poder. Olga coloca a *La vendedora* como una mujer dueña de su espacio, con fuerza de espíritu y dignidad. Su personalidad y carisma afloran al contacto visual del posible comprador de fruta, y está vestida de manera simple y práctica, con elegantes aretes de forma de escudo o *chimalli*.

Era muy difícil que Olga pudiera incluir las cerca de 200 especies de frutas nativas de México, pero usó el lienzo con maestría para lograr representar la riqueza frutícola más conocida en el centro del país. Dominan los colores amarillos, contrastándolos con rojos y cobrizos. La perspectiva de profundidad la logró con piñas, cocos, calabazas y papayas puestas en la parte inferior de la pintura, en contraste con las frutas pequeñas en la parte media del puesto; luego, una diadema de cañas, plátanos, guayas, guajes y pirules provoca que *La vendedora* destaque aún más. El crítico de arte Goodkin (2013) percibió lo salvaje e indómito en la fruta pintada, pero el cuadro representa exactamente lo contrario. *La vendedora* muestra el poder de la humanización de la biota al sostener con elegancia, en su mano izquierda, una pitaya orejona, como una muestra de lo que el humano ha transformado. El arreglo de la fruta en el puesto lo dispuso para atraer y provocar el gusto, la vista, el olfato, la añoranza y el sentido estético de las marchantes, motivadas seguramente con un ondulante ¡Pásele! ¿Qué va a llevar? ¿Qué se le ofrece?

Olga recibió unos cinco mil pesos de pago (58 mil pesos actuales, eliminando los tres ceros de 1993). El cuadro le maravilló a Gamboa, quien le pidió dos pinturas más en ese estilo, una que plasmara la riqueza de los panes mexicanos y otra de dulces tradicionales, pero Olga se negó a hacerlas.

Olga registró en su cuadro una riqueza biológica de 58 especies de frutas (Figura 1, Cuadro 1). Algunas se repiten como variantes. Por ejemplo, se aprecian cuatro de plátano (costillón, hembra, macho y morado), tres de caña (morada, blanca y piñatera), dos de manzana (roja y amarilla), dos de mango (criollo y manila), dos de aguacate (tierra media y alta), dos de pera (común y verde), dos de ciruela mesoamericana (amarilla y roja) y dos de guayaba (blanca y rosa). Al sumar las especies y sus variantes la riqueza es de 69 frutas diferentes.

La jícama y la caña aunque se incluyen como frutas, botánicamente son raíz tuberizada y tallo, respectivamente, y los tetetzos de Mezcala son botones florales. De algunas frutas hay varias formas de presentación por ejemplo, el coco que Olga pintó cubierto con su fibra, despojado de ella y en porciones listas para comer; de la piña presenta diferentes grados de madurez, además de piña mondada o pelada y rebanada; la jícama también la pintó con cáscara y en rebanadas. Varias frutas están abiertas parcial o totalmente, para despertar el apetito del comprador; tales como la pitaya orejona en la mano de *La vendedora*, también el mamey, la chirimoya la guanábana, la granada china, la papaya, el coco, el pomelo, los xoconostle, el zapote blanco, la tuna naranjona y allá, en el último rincón, junto a la firma de Olga, una guayaba rosa.

Aunque Goodkin (2013) afirma que todas las frutas ilustradas son "…típicas de Latinoamérica, productos tradicionales sin influencia europea…", no es así, pues hay representantes de varios centros en donde se originó agricultura y civilización en el mundo. Aunque predominan las frutas de origen mesoamericano (46 %) como tuna, guanábana, papaya, zapote y pitaya, le siguen en importancia las frutas que algún día llegaron de oriente lejano (30 %) como limón, naranja, mango, plátano, caña y del oriente cercano (13 %) melón, higo, manzana, uva y durazno. El porcentaje de ambas regiones orientales (43.3 %) es tan importante como la cantidad de fruta de origen mesoamericano y es muy superior a la cantidad de fruta de origen en Sudamérica (6.0 %) como la piña, cacahuate y fresa. El porcentaje más bajo (4.5 %) corresponde a especies de África, como la sandía y el tamarindo, y a este origen se agrega *Homo sapiens*, nuestra especie, representada en la pintura por *La vendedora*.

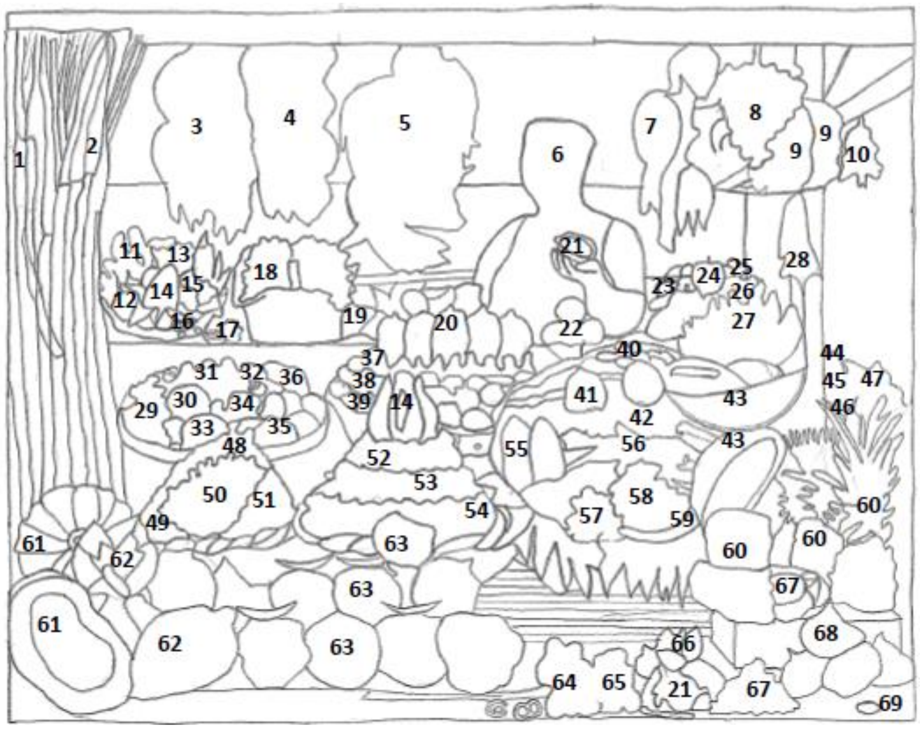
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Figura 1. *La Vendedora de frutas* (1951, óleo sobre lienzo, 2.7 × 1.5 m, Museo de Arte Moderno, Ciudad de México). De acuerdo con el MAM no se ha localizado al propietario de los derechos de la pintura [12/07/2019].

Cuadro 1. Las especies en *La vendedora de frutas* de Olga Costa.

Núm.	Nombres*		Región de origen (Harlan, 1992)
	Común	Científico	
1.-	Caña blanca	*Saccharum officinarum* L.	Oriente lejano
2.-	Caña morada	*Saccharum officinarum* L.	Oriente lejano
3.-	Plátano costillón	*Musa paradisiaca* L.	Oriente lejano
4.-	Plátano hembra	*Musa paradisiaca* L.	Oriente lejano
5.-	Plátano macho	*Musa paradisiaca* L.	Oriente lejano
6.-	Humana	*Homo sapiens* ssp. *sapiens*	África
7.-	Banana	*Musa acuminata* Colla	Oriente lejano
8.-	Coyol	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	Mesoamérica
9.-	Pirúl	*Schinus molle* L.	Sudamérica
10.-	Guaya	*Melicoccus bijugatus* Jacq.	Mesoamérica
11.-	Mango	*Mangifera indica* L.	Oriente lejano
12.-	Pera verde	*Pyrus communis* L.	Oriente lejano
13.-	Capulín	*Prunus serotina* Ehrh.	Mesoamérica
14.-	Mamey	*Pouteria sapota* Moore & Stearn	Mesoamérica
15.-	Tamarindo	*Tamarindus indica* L.	África
16.-	Tetetzo de Mezcala	*Neobuxbaumia mezcalaensis* Backeb.	Mesoamérica
17.-	Guamúchil	*Pithecellobium dulce* Benth.	Mesoamérica
18.-	Uva	*Vitis vinifera* L.	Oriente cercano
19.-	Pitaya	*Stenocereus pruinosus* Buxb.	Mesoamérica
20.-	Cidra	*Citrus medica* L.	Oriente lejano
21.-	Pitaya orejona	*Hylocereus undatus* Britton & Rose	Mesoamérica
22.-	Naranja	*Citrus sinensis* Osbeck	Oriente lejano
23.-	Higo	*Ficus carica* L.	Oriente cercano
24.-	Chirimoya	*Annona cherimola* Mill.	Mesoamérica
25.-	Guayaba fresa	*Psidium littorale* Raddi	Mesoamérica
26.-	Durazno	*Prunus persica* Batsch	Oriente cercano
27.-	Plátano morado	*Musa paradisiaca* L.	Oriente lejano

Núm.	Nombres*		Región de origen (Harlan, 1992)
28.-	Guaje	*Leucaena esculenta* Benth.	Mesoamérica
29.-	Kumquat	*Fortunella margarita* Swingle	Oriente lejano
30.-	Pomelo	*Citrus maxima* Merr.	Oriente lejano
31.-	Aguacate de tierra media	*Persea americana* L.	Mesoamérica
32.-	Aguacate de tierra alta	*Persea americana* L.	Mesoamérica
33.-	Melón	*Cucumis melo* L.	Oriente cercano
34.-	Caqui	*Diospyros kaki* L.	Oriente lejano
35.-	Zapote negro	*Diospyros nigra* Perrier	Mesoamérica
36.-	Mango manila	*Mangifera indica* L.	Mesoamérica
37.-	Pera	*Pyrus communis* L.	Oriente cercano
38.-	Manzana roja	*Malus domestica* Borkh.	Oriente cercano
39.-	Manzana amarilla	*Malus domestica* Borkh.	Oriente cercano
40.-	Limón mexicano	*Citrus aurantifolia* Swingle	Oriente lejano
41.-	Saromuyo	*Annona squamosa* L.	Mesoamérica
42.-	Tejocote	*Crataegus mexicana* Moc. & Sessé	Mesoamérica
43	Sandía	*Citrullus lanatus* Matsum. & Nakai	África
44.-	Ciruela amarilla	*Spondias purpurea* L.	Mesoamérica
45.-	Zapote blanco	*Casimiroa edulis* La Llave	Mesoamérica
46.-	Ciruela roja	*Spondias purpurea* L.	Mesoamérica
47.-	Granada	*Punica granatum* L.	Oriente cercano
48.-	Ciruela europea	*Prunus domestica* L.	Oriente cercano
49.-	Zarzamora	*Rubus leibmanii* Focke	Mesoamérica
50.-	Níspero	*Eriobotrya japonica* Lindl.	Oriente lejano
51.-	Fresa	*Fragaria ananassa* Duchesne	Sudamérica
52.-	Guayaba blanca	*Psidium guajava* L.	Mesoamérica
53.-	Mandarina	*Citrus reticulata* Blanco	Oriente lejano
54.-	Lima chichona	*Citrus* sp.	Oriente lejano
55.-	Guanábana	*Annona muricata* L.	Mesoamérica
56.-	Caña piñatera	*Saccharum officinarum* L.	Oriente lejano
57.-	Chicozapote	*Manilkara zapota* P. Royen	Mesoamérica
58.-	Granada china	*Passiflora ligularis* Juss.	Mesoamérica
59.-	Jinicuil	*Inga edulis* Mart.	Mesoamérica
60.-	Piña	*Ananas comosus* Merr.	Sudamérica
61.-	Calabaza	*Cucurbita moshata* Duchesne	Mesoamérica
62.-	Papaya	*Carica papaya* L.	Mesoamérica
63.-	Coco	*Cocos nucifera* L.	Oriente lejano
64.-	Xoconostle	*Opuntia joconostle* A. Web.	Mesoamérica

Núm.	Nombres*		Región de origen (Harlan, 1992)
65.-	Tuna blanca	*Opuntia albicarpa* Scheinvar	Mesoamérica
66.-	Tuna naranjona	*Opuntia megacantha* Salm-Dyck	Mesoamérica
67.-	Cacahuate	*Arachis* hypogaea L.	Sudamérica
68.-	Jícama	*Pachyrhizus erosus* Urban	Mesoamérica
69.-	Guayaba rosa	*Psidium guajava* L.	Mesoamérica

*La asignación de los nombres comunes y científicos ha sido un reto y se hicieron los esfuerzos por asignar los correctos. Sólo se asignó un nombre común de los varios que cada fruta tiene.

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