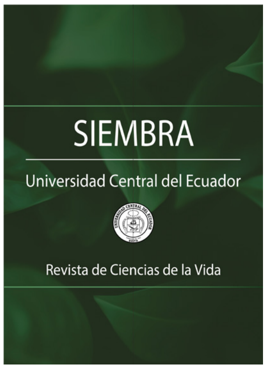
Management of native maize varieties in the Ch'ol milpa of Salto de Agua, Chiapas, Mexico

Manejo de maíces nativos en la milpa Ch'ol de Salto de Agua, Chiapas, México



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Abstract

The Choles, a Mayan group living in southern Mexico, base their economy on agricultural activities. Using traditional farming methods, they cultivate only native maize varieties that are adapted to the local environmental conditions and their consumption culture. To learn about the management system used by the indigenous people with their native seeds, the maize cultivation management system was characterized to determine the maize varieties cultivated in the municipality of Salto de Agua, Chiapas, Mexico. We interacted directly with farmers in nine localities of the municipality 12 months. Maize is grown in two seasonal cycles: spring/summer (March-September) known as *milpa de año*, which in some areas is cultivated according to Mesoamerican principles of slash-and-burn agriculture, and fall/winter (October-April), known as *tornamil*. The cultivation of the *milpa* is carried out by family labor, where mainly native maize varieties of the Vandeño, Tuxpeño, Tepecintle, Zapalote Grande, Olotillo, and Chiquito types are grown. Native maize varieties have specific parameters. Vandeño and Tuxpeño, the most widely cultivated varieties, have plant height, ear height, and leaf area of 3.30 and 3.36 m, 1.73 and 1.76 m, and 9250 and 8841 cm^2, respectively. Both varieties have medium green leaves, with many lateral branches on the ear. The ears are cylindrical and conical in shape; the kernels are semi-crystalline, opaque, and serrated, with creamy white, yellow, and red colors; average yields of both varieties are 2.0 t ha^{-1}. Promoting the *in situ* conservation of native maize varieties in the study area using an agroecological approach is a strategy that grants its sustainability.

Key words: traditional agriculture, indigenous, tropical maize, slash and burn.

Resumen

Los Choles, grupo mayense que habitan en el Sur de México, fundamentan su economía en las actividades agropecuarias. Bajo un enfoque de agricultura tradicional, cultivan únicamente maíces nativos adaptados a las condiciones ambientales y a su cultura de consumo. Para conocer el sistema de manejo que realizan los indígenas con sus semillas nativas, se realizó la caracterización del sistema de manejo del cultivo de maíz, determinándose las razas de maíces cultivados en el Municipio de Salto de Agua, Chiapas, México. Se interactuó de forma directa durante 12 meses con agricultores de nueve localidades de dicha municipalidad. El maíz se cultiva en dos ciclos agrícolas de temporal, primavera/verano conocido como milpa de año (marzo-septiembre), desarrollándose en algunos espacios bajo los principios de la roza-tumba-quema Mesoamericana, y otoño/invierno conocido como tornamil (octubre-abril). El cultivo de la milpa se desarrolla con mano de obra familiar, en donde se cultivan esencialmente maíces nativos de las razas vandeño, tuxpeño, tepecintle, zapalote grande, olotilllo y chiquito. Los maíces nativos presentan parámetros diferenciados, vandeño y tuxpeño, que son las razas más cultivadas, presentan altura de planta, mazorca y área foliar de 3,30 y 3,36 m, 1,73 y 1,76 m, 9250 y 8841 cm^2 respectivamente. Ambas razas tienen un color de la lámina de la hoja verde medio, con muy alta presencia de ramas laterales en la espiga. En cuanto a la forma de la mazorca, estás son cilíndricas y cónicas; el tipo de grano son semicristalinos, opacos y dentados, con colores blanco cremoso, amarillo y rojo; rendimientos medios de ambas razas de 2,0 t ha^{-1}. Promover la conservación *in situ* de los maíces nativos del área de estudio bajo un enfoque agroecológico, representa una estrategia que garantiza su sostenibilidad.

Palabras clave: agricultura tradicional, indígenas, maíces tropicales, roza-tumba-quema.

1. Introduction

The system of maize production constitutes for Mexican peasants the epicenter of a set of socioeconomic activities carried out mainly by the family, whose main purpose is producing staple foods; in addition, around this production process, other cultural activities develop that unify and identify the rural environment. The traditional maize cultivation agroecosystem in Mesoamerica is called *milpa*; this is a system of multiple crop sowing, where maize is the main cultivated plant, but other plants of socioeconomic importance also coexist, primarily intended for food (Damián-Huato, 2023). *Milpas* are unique as an anthropic response to the natural environment. In the tropics, they exhibit high natural and cultivated biodiversity, and their management involves the peasant family. Indigenous groups in southern Mexico base the production of staple crops on this a millenary nomadic agroecosystem, in which native seeds of maize, beans, squash, and chili peppers are mainly cultivated (Reza-Solis et al., 2024). Additionally, in Mesoamerican *milpas*, arable flora, that is often consumed as traditional food, emerges. Indigenous societies of Chiapas typically manage the *milpa* using only local resources, thus contributing to food-safe production, as no external inputs are introduced into the system. The ancestral *milpa* (a term derived from the Nahuatl *milli*: "cultivated land," and *pan*: "area of sowing, on or in," referring to the Mesoamerican region where maize is grown) (Comisión Nacional para el Conocimiento y Uso de la Biodiversidad [CONABIO], 2016) is known as *cho'lel* in the Ch'ol language; this native group bases the *milpa* on the slash-and-burn system.

Archaeological findings show that the slash-and-burn agricultural technique [s-b] for maize cultivation was the initial method of farming in Mesoamerican regions (Flannery, 1985). Charcoal remains, dating back more than 6,000 years, have been found in these tropical areas (Gliessman, 2002). Agriculture in the Americas developed independently, with no influence from the European-Asian-African continent. Although the plant species initially domesticated included amaranth and epazote, it was mainly maize, squash, and beans crops that became the essential food base of Mesoamerican civilizations (Rojas Rabiela, 1991). In this agricultural model, lands were cultivated for short periods (one or two sowing cycles), before opening new areas for cultivation; the fallow period lasted more than a decade, allowing the soils to regain their productive qualities. This practice of nomadic, or itinerant farming favored the extraordinary flourishing of the Mayan civilization in the south-southeast of Mexico.

Slash-and-burn constitutes a traditional agricultural system that serves as a starting point for the development of more advanced farming techniques in various types of ecosystems, from the wettest to the relatively dry. Researchers agree on four fundamental elements of this agricultural system: first, the complete removal of vegetation cover (trees, shrubs, and herbaceous plants); second, the use of fire after creating protective strips around the cultivated land (known as firebreaks) to prepare the area just before the rainy season begins; third, maintaining a prolonged fallow period after harvest to allow the soil to regenerate; and fourth, the rotation of sowing areas (Fonteyne et al., 2023; Jouault et al., 2018). The slash-and-burn agricultural system, widely spread and characteristic of tropical territories, reflects the limitations set by the natural environment. Although the foundations of this agricultural practice remain constant across various ecosystems, each region and community develop specific adaptations and variations. It is the conditions of the land, the geographic relief, the environment, along with the sociocultural and historical elements unique to each group, that are the factors defining the particularities of agricultural management.

Maize is the most important crop in Mesoamerica. Mexico ranks eighth in the world, with 6,436,119 hectares harvested and a total production of 27,549,917 tons. Chiapas ranks ninth nationally, with a harvested area of 688,085 ha and a volume of 1,327,894 tons; the Palenque Regional District has the largest harvested area in Chiapas, totaling 150,472 ha with a production of 190,042 tons; in the municipality of Salto de Agua, 23,307 ha are harvested, producing 31,936 tons (Servicio de Información Agroalimentario y Pesquero [SIAP], 2023). The management practices of this basic crop in indigenous societies are typically based on traditional agriculture, mainly cultivating native maize varieties that have been passed down from generation to generation. These native maize varieties represent a legacy of Mexico's millennial agricultural culture, making their *in situ* conservation by the farmers themselves, constitutes a process that must be recognized and is necessary for its sustainability.

Maize has uncertain ancestral origins, as its original wild variant has not been discovered by contemporary researchers. This, makes it impossible to determine precisely when it first appeared, although evidence suggests that it dates back at least five millennia (Jugenheimer, 1981). As to its geographic origin, this species comes from the south-central region of Mexico, extending into Central America, particularly in the Mesoamerican area of Mexican territory (Sierra-Macías et al., 2014). There is widespread agreement among specialists that it descends from its wild ancestor known as teosinte (*Zea mays* spp. mexicana) (Kato Yamakake et al., 2009). The process of domestication and historical evolution of maize was characterized by being discontinuous with a wide geographic distribution, developing simultaneously in various areas, with south-central Mexico being one of the main regions where it presumably took place, thus causing intraspecific diversity.

The concept of "race" has been used in maize and other cultivated plant species with the purpose of classifying individuals or populations exhibiting similar traits, both in morphological, ecological, and genetic aspects, as well as in their cultivation history, all characteristics that enable their identification and distinction as a specific set. Races are organized into groups or racial complexes, which are associated with a relatively established geographic and climatic distribution, as well as with a shared evolutionary process (Sanchez et al., 2000). In Mexico, for maize, the naming of the races derives from various phenotypic characteristics (such as conical, due to the shape of the cob), the type of kernel (such as popping, because of the kernel's ability to expand and make popcorn), the site or area where they were initially collected or are significant (tuxpeño originating from Tuxpan, Veracruz; chalqueño, characteristic of the Valley of Chalco), or the name used by the indigenous or mestizo communities that cultivate them (zapalote chico in the Isthmus of Oaxaca or apachito in the Sierra Tarahumara).

Since the mid-20th century, 25 varieties of maize have been documented in Mexico, classified as ancient indigenous (4), pre-Columbian exotic (4), pre-Hispanic mixed (13), and incipient modern (4), in addition to seven varieties that are not clearly defined (Wellhausen et al., 1951). However, maize as a cropping system is dynamic and continuous, with open pollination and constant movement or exchange of seeds by farmers, whom conserve, exchange, and experiment with seeds from their own crops or from other farmers, both from the same area and from distant regions. In this way, out of the total 220 maize varieties existing in Latin America (Kato Yamakake et al., 2009), a total of 64 varieties (29%) have been identified and described mainly for Mexico. Of these varieties, 59 can be considered native, and five were originally described in other regions (Caribbean Yellow Cuban, and four Guatemalan varieties: Nal Tel de Altura, Serrano, Negro de Chimaltenango, and Quicheño), although they have also been collected or recorded in national territory (CONABIO, 2020a).

In the municipality of Salto de Agua, Chiapas, native maize has been systematically cultivated by farmers, who recognize them by common names, without having a technical identification of them. The aim of the research is to characterize the management process and identify the native tropical maize of this area, to systematize knowledge in traditional agroecosystems, and to determine the biological variability of the different maize races that are cultivated with a view to their conservation.

2. Materials and Methods

The native maize cultivated by the Choles indigenous people of the municipality of Salto de Agua, Chiapas, Mexico, as well as its management are characterized and described. The study area is known as the Tulijá Valley, a mountainous territory with flat areas along the banks of the Tulijá River, the main watercourse of the region. It is located in the northwest of the state, between 17°10’ and 17°30’ north latitude and 92°00’ and 92°25’ west longitude, with an average altitude of 100 m above sea level. The climate is warm and humid Af(m), with rainfall throughout the year, an average temperature of 27 °C, and annual precipitation of 3,500 mm (Figure 1). The socio-economic dynamics are characterized by agricultural and livestock activities, with cattle and small livestock being the most important in the region. For basic crops, native maize is cultivated in agricultural systems for the consumption of the household unit (Aguilar Jiménez, 2014).

The research approach was both qualitative and quantitative with an exploratory and descriptive scope. The description of the maize cultivation system is based on direct interaction with local farmers from nine locations, where three cooperating producers were identified to characterize the management of their maize production system, as well as the types of native seeds they cultivate. To understand the management of the maize production system, the inherent activities of the agroecosystem were monitored over the course of one year. In the same plots of the producers, sampling points of 10 plants each were randomly selected to collect vegetative variables (plant and cob height, stem diameter, leaf area, orientation and color of leaf blades, and ear branches); likewise, at harvest, representative cobs were collected to characterize productive parameters (cob shape, row arrangement, kernel type, kernel color, length and diameter of the ear, number of rows and kernels per row), the latter were identified according to the descriptor by Carballo and Benítez (2003). The maize varieties were identified according to the morphological characteristics of the ears (Wellhausen et al., 1951), relating the characteristics of the ears with the vegetative growth variables indicated.

To relate the physiological response of maize to the types of agricultural soils in the cropping systems of the study area, a representative characterization of the main agronomic characteristics of interest was carried out (Table 1), using the Norma Oficial Mexicana NOM-021-SEMARNAT-2000 (formerly NOM-021-RECNAT-2000) for its interpretation. Soil samples were taken at a depth of 0-20 cm, one from each participating locality; their analysis was conducted in the Soil Science Laboratory of the Agricultural Sciences Postgraduate College in. Shallow soils with outcrops of limestone, rich in organic matter that create a suitable structure, with high contents of macro and micronutrients, slightly acidic as typical of humid tropical environments. The annual management of these soils for maize cultivation in the study area results in good soil fertility, which leads to no dependence on synthetic fertilizers, and other organic bio-amendments for cereal fertilization. The main cultural practices used to maintain soil fertility are the recycling of organic matter, the use of green manure and cover crops, as well as crop rotation through fallow or resting periods.

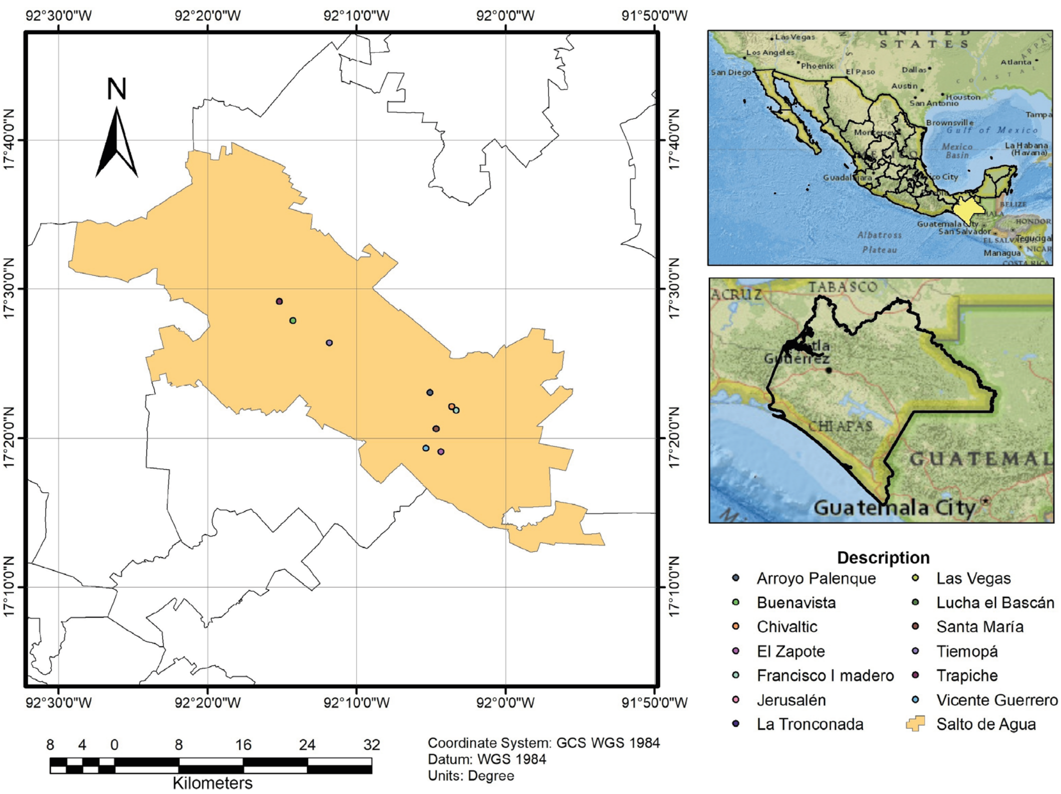

Figure 1. Location of the municipality of Salto de Agua, Chiapas, Mexico.

Table 1. Average physico-chemical characterization of representative soils for maize cultivation in Salto de Agua Chiapas, Mexico.

Parameter	Agricultural Cycle	
	Spring/Summer (*milpa*)	Fall/Winter (*tornamil*)
pH	6.8	6.02
O.M. (%)	8.1	7.1
N (%)	0.40	0.35
P (ppm)	7.10	6.33
K (NH_4OAc 1 N pH 7) meq/100g (cmoles+Kg^{-1})	0.90	0.80
Ca (NH_4OAc 1 N pH 7 meq/100g (cmoles+Kg^{-1})	38.12	33.08
Mg (NH_4OAc 1 N pH 7 meq/100g (cmoles+Kg^{-1})	5.80	6.72
CEC (meq/100g)	36.24	41.42
Fe (DTPA. ppm)	34.57	56.83
Cu (DTPA. ppm)	3.12	2.27
Zn (DTPA. ppm)	1.57	2.07
Mn (DTPA. ppm)	9.32	15.83
Horizon depth A (cm)	17	18
BD (g cm^{-3})	0.95	0.90

3. Results and Discussion

3.1. Native maize management systems

The Tulijá Valley in the municipality of Salto de Agua, Chiapas is inhabited by Mayan indigenous people who speak the Ch'ol language, whose economy is based on agricultural and livestock activities. Maize *(Ixim*) constitutes the primary agricultural activity, and is mainly grown for self-consumption. The humid tropical environment allows for two agricultural cycles of the staple crop dependent on the rainy season: spring/summer (annual *milpa*) and fall/winter (*tornamil*) (Table 2). The management of maize production systems is carried out with the help of the peasant family under the principles of traditional agriculture. Only native maize varieties are grown, which have been millennia-old selected by the original communities and passed down from generation to generation. Pérez-García (2023) concludes that the cultivation of native maize by indigenous peoples is an undeniable element that ensures the sustainability of the biological wealth of this staple crop, which contributes to enriching the national biocultural heritage.

Table 2. Annual soil management calendar for maize production systems in the municipality of Salto de Agua, Chiapas, Mexico.

Month	Spring/summer Cycle (annual *milpa*)	Autumn/winter cycle (*tornamil*)
January	Fallow or rest	Management of weed flora, crop monitoring, sowing of nescafé beans
February	Fallow or rest	Crop monitoring, sowing of nescafé beans
March	Slash-clearing	Crop monitoring
April	Slash-burning and sowing	Fertilization, harvest
May	Sowing and weed management	Fallow or rest
June	Weed management, crop monitoring	Fallow or rest

Month	Spring/summer Cycle (annual *milpa*)	Autumn/winter cycle (*tornamil*)
July	Weed management, crop monitoring	Fallow or rest
August	Crop monitoring	Fallow or rest
September	Bending, harvest	Fallow or rest
October	Harvest, fallow or rest	Clearing and sowing
November	Fallow or rest	Sowing
December	Fallow or rest	Management of weed flora, crop monitoring

For the annual *milpa*, the original maize cultivation system in Mesoamerica, the Choles grow maize and other species of interest as a food source under the s-b system or with clearing only. The process takes place from March to September. The slash-and-sowing system signals that the slash-and-burn method has been eliminated. This is due to the fact that the fallow, or rest provided to the soils has been reduced and, therefore, there is no tree vegetation to cut down and burn. Similarly, generalized policies to avoid agricultural burning have contributed to this process of *milpa* sedentarization. Fonteyne et al. (2023), when conducting a review of scientific literature on agronomic knowledge of the *milpa* in Mesoamerica as well as its research priorities, conclude that the practice is decreasing due to socioeconomic changes and a lack of technical knowledge; they also point out that research is needed to understand and Improve their management under modern agricultural conditions, reducing workload, soil fertility, and weed management are research priorities.

In the lands where the typical millennial s-b is carried out, the itinerant system takes place in those areas where the vegetation, either original or in secondary succession, is well developed and contains trees over 10 meters high. When these trees are cut down with manual tools such as machetes or metal axes, their fall creates a strong impact, a sound characteristic of the clearing in the nomadic system. The procedure begins with slashing, which involves cutting the shrub and herbaceous vegetation and letting it dry for approximately 15 days. After that, the large trees are felled, and once they are chopped, the vegetation is left to dry again for about 30 days before burning. With the chopping of the felled trees, one could say that the system should be called slash-fell-chop-burn, since chopping the arboreal and shrub vegetation is an activity that occupies a significant number of labor days for the farmers firebreaks are typically created to prevent the fire from reaching surrounding lands, as the system, in this region of the Chiapas jungle, is implemented during the dry season (March-April). It is common that, during the drying of plant biomass, wood and firewood are obtained from the clearing, as the latter is the main source of energy for many indigenous families to prepare food in this part of the region. The collection of firewood depends on the distance of the *milpa* from the family unit. In many cases, the firewood is piled near the *milpa*, and then gradually taken to the family unit Leyva-Trinidad et al. (2020) when characterizing the *milpa* system of a Nahuatl community in the state of Veracruz in southern Mexico, conclude that this system is the backbone of the food system and the identity of indigenous groups, who use extensive knowledge and a worldview that connects them with lunar cycles and ancestral traditional practices to manage the system with local wisdom that allows for its social and cultural reproduction. In order to identify the reasons why farmers continue to carry out the r-t-q in southern Mexico, Elizalde López et al. (2024) conclude that the system is a means of livelihood for peasants, where food for the family and backyard livestock is produced, even though it does not cover the economic flow demanded by this agroecosystem.

For the Choles, the *milpa* is identified as *cholel* (in Ch'ol), and, in recent times, it has been modified. The principles of r-t-q are maintained to a lesser extent; and, the elimination of burning is the main modification, so that the systems are managed only with clearing. The processes take place on land with poorly developed secondary succession (*acahuales*), where the traditional sowing method cannot be carried out; here, they simply clear and sow on dehydrated vegetation. This latter procedure has become more widespread in recent decades due to both official and non-governmental policies promoting the sedentarization of the *milpa*, that is, the suppression of fire use. The pressure on land use, due to population growth, has also forced indigenous farmers to use the land more intensively for maize cultivation, which further encourages avoiding burning, as it is also a strategy to accelerate the processes. and to mitigate the effects of water erosion that can occur on steep terrain. Likewise, in the municipality of Salto de Agua, there is a strong agricultural tradition of using Mucuna deeringiana Bort. (cajpe ac) as green manure, and a cover crop to improve soils. This agroecological practice has also played a decisive role in eliminating the use of fire (Figure 2). An important factor that has led to changes in the *milpa* processes in a timely manner is climate change. In this regard, Munguía-Aldama et al. (2016) point out that farmers in southern Mexico have implemented local innovation strategies to face this phenomenon caused by human activities, based on the reinterpretation of traditional knowledge. Prominent strategies include changing the sowing date, using short-cycle seeds, avoiding sowing in dry conditions, and implementing practices that increase soil moisture retention, improve nutrient availability, as well as performing rituals to request and give thanks for rain and a good harvest.

In the Tulijá Valley of the municipality of Salto de Agua, as in many other territories of the humid tropics of northern Chiapas, the *milpa* is a diversified production system, where, due to its noted importance, maize is the main crop; but many other species important for the food supply of peasant families are also planted and harvested there. The Ch'oles customarily plant in the *milpa* native maize seeds (*Zea mays L.*), bush and pole beans (*Phaseolus vulgaris L.*), hard- and soft-shelled squashes (*Cucurbita spp.*), native chili peppers (*Capsicum spp.*), leeks or chives (*Allium schoencoprasum L.*), cassava (*Manihot esculenta Crantz.*), taro, quexste or macal (*Xanthosoma sagittifolium L.*), cooking and dessert bananas (*Musa spp.*), oranges (*Citrus sinensis L.*), chaya (*Cnidoscolus chayamansa McVaugh*), sweet potatoes (*Ipomoea batata L.*), cilantro (*Coriandrum sativum L.*), yam (*Dioscorea bulbifera*), among others. In the *milpa*s managed by the Choles also endemic field flora that emerges naturally is consumed, notably the wild nightshade (*Solanum nigrescens M. Martens and Galeotti L.*), mustard (*Brassica juncea (L.)* Czern), and the tomatillo (*Physalis pubescens L.*). Serralta-Batun et al. (2024) when describing the milpa of southern Yucatán, Mexico, they identify the use of agrochemicals as a threat to the diversification of the system, which are also dangerous to human health and the environment. Linares Mazari and Bye Boettler (2015), when evaluating underutilized food-important species of the *milpa*, recognize the need for a national inventory, as there is a genetic erosion of these species.

Figure 2. Management of the traditional *milpa* system. Left: Sowing. Center: Development of the system. Right: Maize harvesting.

For its part, the *tornamil* (fall/winter cycle), known as *mol* in Ch'ol, takes place during the northern winds season of the region. This system works similarly to the annual milpa; however, burning is not carried out, because the environmental conditions involve frequent drizzles, thus making burning impossible. It could be defined as a milpa without burning, where maize is cultivated for the same purposes and principles, as its design integrates the natural and crop diversity appropriate for the annual milpa, and should, therefore, be recognized as a milpa. In this system, Mucuna deeringiana Bort. is used more intensively as green manure and cover crop. Aguilar-Jiménez et al. (2012) state that the maize-mucuna succession system in the study region significantly contributes to the biological fertility of agricultural soils. This is because the typical environmental conditions in fall/winter result in lower temperatures in this humid tropical territory, the maize yield per unit of area is typically higher than in the year-round milpa. Many farmers, due to climate change, assign more cultivated land during this seasonal agricultural cycle.

Prior to the maize cultivation process, the Choles carry out a religious activity known as Thanksgiving festival, praying for the good development of the production system. The ceremonies are participatory (women are more involved in this activity), and families make economic contributions as well as in-kind offerings. They invite families from nearby communities, who in turn will reciprocate this gesture. These celebrations take up part of the day in the Christian church, concluding with a meal where maize-based foods are present. Similar activities of other Mayan-origin groups are reported by Torres (2007), who argues that most peasant communities continue to celebrate agricultural festivals in one form or another, involving both pre-Hispanic and modern elements.

In both cycles, once the soil has been prepared through manual weeding, and when environmental conditions allow, maize is planted using a dibble stick or sowing stick. The Choles plant at an approximate distance of 1.2 m between rows and plants, placing an average of 4 to 5 seeds per sowing spot. The crops associated with maize are sown in the milpa according to their phenology and use. Within the local culture, there are different designs and/or topological arrangements of these crops. Crop management generally involves performing two phases of weeding of the arable flora (growing) in the milpa, primarily using a short machete manually. Some farmers have begun to incorporate the use of synthetic herbicides for weed management. In some cases, when maize has reached physiological maturity (R6), it is bent to accelerate drying and prevent ear damage from rain. Once the mature ears are harvested, they are stored in a space known as a *troje*, (large barn/storage structure) which is a rustic structure used to store dry maize ears in the field. For this purpose, plant-based materials present in the agroecosystem are used, and in some cases, nails and zinc sheets are added. The largest ears are selected from the pile as seeds and stored with husks (*joloche*) in the *troje*, usually hung up for identification. As the kernel is used, it is transported to the family unit. All the activities of the milpa agroecosystem are carried out with the participation of the family, and in some cases, local labor is hired. The culture of mutual aid is preserved, although precarious. Bastida-Francisca et al. (2024) indicate that in the management of the milpa, the family plays a leading role that promotes community work.

3.2 The native maize's grown

Table 3 lists in order of importance the varieties of native maize grown in the Tulijá Valley, Chiapas, Mexico. The Choles identify maize according to the color of the kernels: the white ones are called *SΛk waj*, the yellow ones *k'añal*, and the red and black ones *chΛchΛc*. The most widely grown varieties by farmers are Vandeño and Tuxpeño. To a lesser extent, Tepecintle, Zapalote Grande, Olotillo, and Chiquito are also planted. The main reasons for sowing the Vandeño and Tuxpeño varieties are: their large cobs and the fact that they are resistant to wind, and weevils (they do not suffer when stored in the granary). Both varieties are tall, with plant and cob heights exceeding 3.30 m and 1.70 m, respectively. The stem diameter is more than 0.7 cm, with an approximate leaf area of 9,000 cm^2, slightly curved leaves, and a high presence of branches on the ear. CONABIO (2020b) reports seven racial groups or complexes: conical, Sierra de Chihuahua, eight rows, chapalote, early tropicals, tropical dentates, and late-maturing; the main races identified in the study area are grouped in the tropical dentate group. Kato Yamakake et al. (2009) indicate that the racial distribution of native maize across the national geography can be grouped into five complexes. The Tuxpeño complex, which includes Vandeño and Tepecintle, originated in western Mexico and the southern territory of Mesoamerica (Oaxaca, Chiapas, Guatemala up to Sonora). Montejo et al. (2021), when characterizing the agrobiodiversity of the Ch'ol *milpa* in a community in northern Chiapas, concluded that the most cultivated races are Tepecintle, Tuxpeño, and Comiteco, with white, yellow, red, and purple colors identified. The Vandeño, Tuxpeño, Tepecintle, Zapalote Grande, and Olotillo maize races are grouped in the pre-Hispanic mestizo race group Coutiño Estrada et al. (2021); (Wellhausen et al., 1951), when carrying out a characterization of the phenotypic diversity of maize varieties grown in Chiapas, they identified that 18 varieties are cultivated in the state, highlighting for temperate climates [Cw] Olotón, for semicold [A(c)w] Comiteco, and for warm climates [Aw] Tuxpeño and Vandeño; of this total reported in the municipality of Salto de Agua, they are planted the 33.33% (6).

Table 3. Mean vegetative parameters of native maize varieties from Salto de Agua, Chiapas, Mexico.

Breed	Plant height (cm)	Cob height (cm)	Stem diameter (cm)	Leaf area (cm^2)	Leaf orientation	Spike branches
Vandeño	3,30	1,73	0,76	9250	Slightly curved	Very tal
Tuxpeño	3,36	1,76	0,79	8841	Slightly curved	Very tal
Tepecintle	3,10	1,65	0,71	8460	Slightly curved	Very tal
Zapalote Grande	2,95	1,51	0,68	7350	Slightly curved	Very tal
Olotillo	2,75	1,38	0,61	6520	Slightly curved	Very tal
Chiquito	2,78	1,40	0,65	7120	Slightly curved	Very tal

Regarding the morphological characteristics of the cob, Vandeño and Tuxpeño have cylindrical and conical cobs (Figure 3), with straight row arrangement, semi-crystalline, opaque, and dented kernels, in creamy white, medium yellow, red, and pinto colors. The cobs of Vandeño measure on average 15.3 cm in length and 4.5 cm in diameter, with an average of 14.6 rows per cob and 35.3 kernels per row (Table 4). Tuxpeño shows similar parameters with slightly longer cobs but with smaller diameter. The Tepecintle race presents similar accessions, but with smaller cobs. For Zapalote Grande, only medium yellow maize was identified, the same as in the Olotillo race, with the particularity of having longer cobs and better diameter. For the Chiquito race, only cobs with black and pinto kernels, measuring smaller, were identified. Martínez-Sánchez et al. (2017), when characterizing the morphological variation of native maize grown in the central region of Chiapas, an area where native maize was mixed with improved genetic materials, reported that for plant and ear height, ear length, diameter, and number of rows per ear, the averages are lower than those found in the municipality of Salto de Agua, Chiapas, therefore indicating that the races identified within the study area retain their original characteristics to a greater extent.

Figure 3. Native maize varieties from Salto de Agua, Chiapas. Left: Vandeño variety. Center: Tuxpeño variety. Right: Representative accessions.

Table 4. Average production parameters for native maize varieties from Salto de Agua, Chiapas, Mexico.

Breed	Cob shape	Row arrangement	Kernel type	Kernel color	Cob length (cm)	Cob diameter (cm)	Number of rows	Kernels per row
Vandeño	Cylindrical, conical	Straight	Semicrystal-line, opaque, serrated	Creamy white, medium yellow, red, and pinto	15.3	4.5	14.6	35.3
Tuxpeño	Cylindrical, conical	Straight	Semicrystal-line, serrated, opaque	Creamy white, medium yellow, red, pinto	16.5	4.2	14	32
Tepecintle	Conical, cylindrical	Straight	Crystalline, semicrystal-line, opaque	Creamy white, black, purple, pinto	14	4.3	14	33
Zapalote Grande	Conical, cylindrical	Straight, slightly spiral	Semicrystal-line, serrated	Medium yellow	13.5	4.3	12	33
Olotillo	Conical, cylindrical	Straight	Semicrystal-line, serrated	Medium yellow	17	4.1	12	41
Chiquito	Conical, cylindrical	Straight	Semicrystal-line, serrated	Black, pinto	14	4.1	12	30

4. Conclusions

In the municipality of Salto de Agua, Chiapas, Mexico, mainly native maize of the Vandeño, Tuxpeño, Tepecintle, Zapalote Grande, Olotillo, and Chiquito races are planted, with the first two being the most cultivated due to the morphological characteristics of the ear. Both races have an average plant height of 3.3 m and an average yield of 2.0 t ha^{-1}. The ears are conical and cylindrical, with straight kernel arrangement, which are semi-crystalline, opaque, and dented, in creamy white, medium yellow, red, and mottled colors. These heirloom maize varieties are planted during two agricultural cycles dependent on the rainy season: spring/summer, known as *milpa de año*, and fall/winter, usually called *tornamil*. The production systems are based on traditional agriculture, with very low external input added to the production system.

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Contributor roles

- Carlos Ernesto Aguilar Jiménez: conceptualization, methodology, formal analysis, investigation, resources, project administration, supervision, writing – original draft, writing – review & editing.
- Franklin B. Martínez Aguilar: conceptualization, formal analysis, visualization, writing – review & editing.
- Héctor Vázquez Solís: conceptualization, formal analysis, writing – original draft, writing – review & editing.
- Jaime Llaven Martínez: investigation, methodology, supervision.
- Eraclio Gómez Padilla: investigation, methodology, supervision.
- José Galdámez Galdámez: research, methodology, supervision.

Ethical implications

The authors state that during the interaction with indigenous farmers of the Ch'ol language, there were no conflicts or situations of ethical concern, since the participants did so voluntarily and no personal data was collected. The conversations focused on the importance of conserving the native maize of their territory.

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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