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Agrobiodiversity of cactus pear (*Opuntia*, Cactaceae) in the Meridional Highlands Plateau of Mexico

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Abstract

Mexico is characterized by a remarkable richness of *Opuntia*, mostly at the Meridional Highlands Plateau; it is also here where the greatest richness of *Opuntia* variants occurs. Most of these variants have been maintained in homegardens; however, the gathering process which originated these homegardens has been disrupted over the past decades, as a result of social change and the destruction of large wild nopaleras. If the variants still surviving in homegardens are lost, these will be hard to recover, that is, the millenary cultural heritage from the human groups that populated the Mexican Meridional Highland Plateau will be lost forever. This situation motivated the preparation of a catalogue that records the diversity of wild and cultivated *Opuntia* variants living in the meridional Highlands Plateau. To this end, 379 samples were obtained in 29 localities, between 1998 and 2003. The information was processed through Twinspan. All specimens were identified and preserved in herbaria. Botanical keys and descriptions were elaborated. The catalogue includes information on 126 variants comprising 18 species. There were species with only one variant (*Opuntia atropes*, *O. cochineria*, *O. jaliscana*, *O. leucotricha*, *O. rzedowskii* and *O. velutina*), two (*O. durangensis*, *O. lindheimeri*, *O. phaeacantha* and *O. robusta*), five (*O. joconostle* and *O. lasiacantha*), seven (*O. chavena*), 12 (*O. hyptiacantha* and *O. streptacantha*), 15 (*O. ficus-indica*), 22 (*O. albicarpa*), and up to 34 (*O. megacantha*). Additionally, 267 common cactus pear names were related to those variants.

Introduction

In Mexico there are 78 wild species of the genus *Opuntia* (*sensu stricto*) (Guzmán *et al.*, 2003), several of them prosper in Meridional Highland Plateau of Mexico (Reyes-Agüero and Aguirre, 2006) (Figure 1); relicts of the cactus shrubland, also known as nopaleras for the prevalence of *Opuntia* populations, still exist in this region (Rzedowski, 1978); furthermore, it is here where the greatest richness of *Opuntia* variants is found (Barbera, 1995). Many of these variants have become cultivars and have been preserved in homegardens (Figueroa *et al.*, 1980), and in Mexico only less than ten of them have been grown in over 51,112 ha for the production of cactus pear, and in over 10,200 ha to produce nopalito (Gallegos *et al.*, 2009).

Cactus pear cultivars have evolved from a long relationship between

Homo sapiens and *Opuntia*, and most of them are concentrated in homegarden nopaleras (Reyes-Agüero *et al.*, 2005a); however, the process that gave rise to peasant homegardens over the centuries is being lost steadily over the past decades as a result of either the destruction of the large nopaleras and abandonment after emigration of homegardens owners. Therefore, if the *Opuntia* cultivar richness of the homegardens is lost, it will be hard to recover, that is, this millenary cultural heritage of the human groups that inhabited Meridional Highland of Mexico will be lost forever. The above motivated the preparation of a catalogue to record the richness of wild and cultivated *Opuntia* variants.

Material and Methods

Field collections were carried out in 29 localities (Table 1) across the Meridional Highland (Figure 1). *Opuntia* specimens were collected: (1) if variant was valued and grown for the cladode, nopalito or fruit; (2) if the variant was given a clear and unmistakable common name; and (3) if the variant grew preferentially in a homegarden or commercial plantation, although specimens were also collected from wild populations and experimental plantations. A total of 379 variants were sampled, obtaining six replicates from each. Morphological features were recorded using a descriptor (Reyes-Agüero and Aguirre, 2000). One two-year cladode, one nopalito and one fruit were assessed from each replica, and information on 118 traits was recorded. Specimens were processed for preservation (Reyes-Agüero *et al.*, 2007) and deposited in the SLPM, MEXU and CHAP herbaria.

For the statistical analyses, a basic matrix was elaborated followed

by a multivariable analysis of classification, using Twinspan program (McCune & Mefford, 1999). All the specimens collected were previously identified based mostly on the keys by Britton & Rose (1919) and Bravo (1978). Afterwards, these identifications were matched to the Twinspan output. Both dichotomous keys and poly-keys were elaborated, based primarily on indicator traits revealed by the Twinspan. In most cases, the botanical descriptions comprised the 118 morphological traits. Each description was elaborated according to a standard sequence: starting with the life form and ending with seed characteristics; was described based on mean and modal values from the six replicates; in turn, the description of each species was prepared based on their variants, and the description of the genus was prepared based on its species.

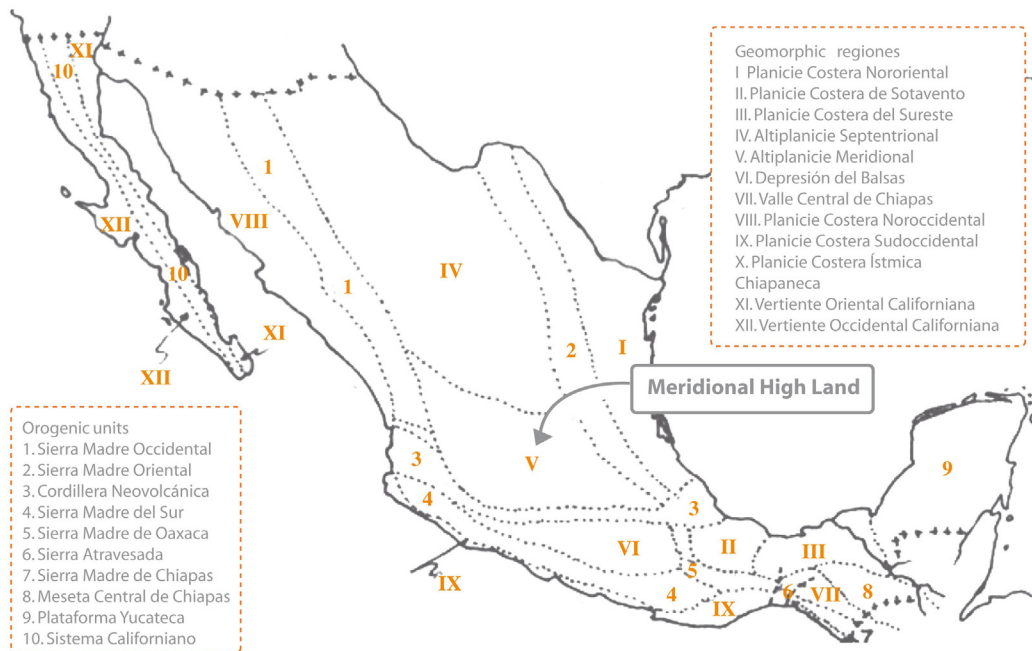


Figure 1. Orogenic units and geomorphic regions of Mexico. Highlighting the Meridional Highland Plateau (Tamayo 1988).

Results and Discussion

The information derived from the 379 samples was used to prepare a catalogue in a book format (Reyes-Agüero *et al.* 2009); into the catalog the arrangement of species and its cultivars (Table 2) reflect the Twinspan analysis; a complementary multivariate ordination analysis was made in order to review the relationship of morphological variation and process of domestication (Reyes-Agüero *et al.*, 2005a); the core of catalog consists of identification keys and botanical descriptions, including photographs for 126 resulted variants, most of them as cultivars. Almost fifty percent, 197 samples, were carried out from *in situ* and 182 from *ex situ* localities (Table 3). About *in situ*, is important to note that there are cultivars in wild environments and other few are in cropland as fences and/or on agricultural terraces,

to give them firmness. The most high percent of samples were from home gardens; this environment is a crucial space for the *in situ* conservation in order to protect and use the genetic diversity, but also for to develop new variants (Engels 2002; Galluzi *et al.* 2010), and in this process is important to maintain the link between home gardens and wild environment, from one side and the same time home gardens with commercial croplands, from the other side (Engels 2002). There are 18 *Opuntia* species with 126 cultivars appreciated for their cladodes, nopalitos or fruits. There were species with only one cultivar (*Opuntia atropes*, *O. cochinerana*, *O. jaliscana*, *O. leucotricha*, *O. rzedowskii* and *O. velutina*), two (*O. durangensis*, *O. lindheimeri*, *O. phaeacantha* and *O. robusta*), five (*O. joconostle* and *O. lasiacantha*),

seven (*O. chavena*), 12 (*O. hyptiacantha* and *O. streptacantha*), 15 (*O. ficus-indica*), 22 (*O. albicarpa*), and up to 34 (*O. megacantha*) (Table 2). This richness of cultivars is high if is comparable with *Zea mays*, with 59 landraces in Mexico (Bellón et al. 2008) and 52 in Peru (Tapia

2000) or *Persea americana* and its three landraces in Mexico (Bellón et al. 2008); but in comparison with *Solanum tuberosum* with its 1000 landraces also in Peru (Tapia 2000), the richness of *Opuntia* is very low.

Table 1. Locations where samples *Opuntia* variants were collected

Locality, county, state	LAT /LON	ALT(m)	Samples
Chapingo, Texcoco, Méx.*	19°30'/98°50'	2275	37
San Martín de Las Pirámides, Méx.	19°42'/98°50'	2280	9
San Bartolo, Axapusco, Méx.	19°42'/98 45'	2350	1
Camino a Sahagún, Axapusco, Méx.	19°43'/98 48'	2350	2
Milpa Alta, D. F.	19°60'/99°00'	2600	2
Real del Monte, Real del Monte, Hgo.	20 09'/98 40'	2853	2
Chicavasco, Actopan, Hgo.	20°12'/98°57'	2020	6
El Rincón, Actopan, Hgo.	20°16'/98°57'	2000	1
González, Santiago de Anaya, Hgo.	20°23'/98°58'	2040	8
El Nith, Ixmiquilpan, Hgo.	20°29'/99°11'	2060	1
San Andrés Daboxtha, Cardonal, Hgo.	20°31'/99°03'	2000	22
San Luis de la Paz, Gto.*	21°18'/100°31'	2020	90
Las Papas de Arriba, Ojuelos, Jal.	21°43'/101°39'	2280	18
Rancho El Palmar, Villa de Arriaga, SLP	21°54'/102°22'	2160	11
La Trinidad, Pinos, Zac.	22°02'/101°24'	2120	6
La Pila, San Luis Potosí, SLP	22°02'/100°52'	1870	18
La Monteza, Villa García, Zac.	22°03'/101°49'	2180	13
Villa de Pozos, San Luis Potosí, SLP	22°06'/100°46'	1900	13
San Luis Potosí, S.L.P.	22°09'/100°58'	1860	3
Palma de la Cruz, Soledad de Graciano, SLP*	22°11'/100°56'	1850	52
La Victoria, Pinos, Zac.	22°15'/101°40'	2310	1
Los Retes, Mexquitic, SLP	22°15' /101°04'	1950	20
San Elías, Armadillo de los Infante, SLP	22°18'/100°41'	1950	8
Loma Larga, Ahualulco, SLP	22°23' /101°09'	1850	8
La Mantequilla, San Luis Potosí, SLP	22°25'/100°52'	1850	11
Trancoso, Guadalupe, Zac.	22°44'/101°21'	2190	1
Charco del Lobo, Moctezuma, SLP	22°45'/101°05'	1720	8
Albercones, Dr. Arroyo, NL	23°24'/100°11'	1720	3
Potrero, Real de Catorce, SLP	23°42'/100°54'	1700	4
Total:			379

* Experimental plantation in scientific research institutions or *ex situ* localities

The automated classification enabled to confirm the great *Opuntia* variant richness previously documented by Figueroa et al. (1980) and Rodríguez and Nava (1998) for Meridional Highlands Plateau of Mexico, but at the same time confirmed the need to use multivariate methods to demonstrate this agrobiorichness in a formal way. This variant richness of wild and cultivated *Opuntia* valued by the Meridional Highlands inhabitants reveals that the cactus pear has been an important plant for both ancient and current populations. The continued and systematic gather of cactus pear favored that some plants with outstanding traits (fruit shape and size; flavor and texture of pulp or peel; seed hardness and amount; peel thickness and glochid density; and nopalitos shape, color, abundance, precocity, flavor, tenderness and fiber content) were subjected to different degrees of tolerance, favored or planting, and they began to be taken to the homegardens (Colunga et al. 1986, Figueroa et al. 1980). In homegardens, the cactus pear selected found the conditions needed to prosper. In this way, homegarden cactus pear plantations summarize the efforts by generations of collectors to gather the most useful traits out of the genetic diversity of *Opuntia* in their respective gathering territories, coupled with hundredths of years of care to preserve these cultivars (Reyes-Agüero et al., 2005a).

Seventy six percent of cultivars most of them are related to eight species of the series or section *Streptacanthae*, with rise to 88% if the *O. ficus-indica* cultivars are added. This richness of the section *Streptacanthae* makes of it the likely source of numerous "... horticultural varieties and forms" (Bravo 1978). *O. megacantha* stands out as the species with the largest amount of variants. There are only 15 *O. ficus-indica* cultivars which, along with another 22 for *O. albicarpa*, are the most extensively cultivated in commercial plantations and home gardens; from this two species only *O. ficus-indica* is absent in wild populations (Bravo 1978; Reyes-Agüero et al. 2004, 2005a, b)

and only one sample of *O. albicarpa* was located in wild environment.

From the cultivars, 31 were obtained only in one *in situ* locality, without representatives samples in *ex situ* localities; on the contrary, 32 were only in *ex situ* localities without representatives samples in *in situ* localities and 63 were in both kinds of spaces. About this 63, 71.4 % are in one or two *in situ* localities, 25.4 % are from three to five localities and only 3.17 % are in six or seven localities. During the development of this work, live samples of several cultivars were sent to the three *ex situ* localities and also to one fourth scientific collection in the Centro Regional Universitario Centro Norte, from the Universidad Autónoma Chapingo in El Orito, Zacatecas, where is the national official depository of the *Opuntia* cultivars.

As regards the cladode, the Twinspan revealed indicator traits included: shape, length, width, thickness and texture; for areoles: width and length, amount in each cladode side, and the number of areoles with spines, distance between areoles, distribution of spiny areoles in the cladode, and amount of areole rows in each cladode side; for spines: color, texture and form, length of the largest and smallest spine in each areole, average number of erect, radial or diffuse spines per areole, mean number of spines < 1.0 cm, between 1.0 and 3.0 cm and > 3.0 cm per areole. For the fruit, the indicator traits were weight, shape, width and length, depth and diameter of the floral scar; as regards peel: color, weight, diameter and amount of areoles; for the pulp: dimensions (length and diameter), weight, color and sweetness in Brix degrees; for the seed: number of normal and sterile seeds, weight of sterile seeds, width, thickness and hardness of normal seeds. The supplementary indicator traits were tepal apex shape, perianth color at flowering and pericarpel length; and, last nopalito leaf length and its number of spines per areole.

Table 2. Check-list of the agrobiodiversity of *Opuntia* in Meridional High Land Plateau of Mexico

Scientific name	Common names
Cultivars	
<i>O. albicarpa</i> Scheinvar	
<i>O. albicarpa</i> cv. Mango	B7 INIFAP & Mango
<i>O. albicarpa</i> cv. Burro	Copena 18K & Burro
<i>O. albicarpa</i> cv. Cristalino	Cristalino, Cascarón, Blanca papa, San migueleño & Nopal calabaza
<i>O. albicarpa</i> cv. Reina	Chapeada, Reina & Cristalina
<i>O. albicarpa</i> cv. Blanca	Blanco manso, Cristalino, Cañatierra & Blanca.
<i>O. albicarpa</i> cv. Reinita	Reinita
<i>O. albicarpa</i> cv. Fafayuco	Fafayuco, Blanco & Reina
<i>O. albicarpa</i> cv. Blanca chapeada	B6 INIFAP, Blanca chapeada & Clavijudo
<i>O. albicarpa</i> cv. Amarillo pera	Chapeada, Amarilla, Plátano, Amarillo tardío & Amarillo pera
<i>O. albicarpa</i> cv. Anaranjado	Anaranjado & Fafayuco
<i>O. albicarpa</i> cv. Amarilla olorosa	Sandía, 153 INIFAP & Amarilla olorosa
<i>O. albicarpa</i> cv. Copa de oro	Copa de oro, Fafayuco & Blanco
<i>O. albicarpa</i> cv. Gavia	Mango, Esmeralda, Burróna & Gavia
<i>O. albicarpa</i> cv. Bola de masa	Bola de masa & Chapeada

Table 2 continuation. Check-list of the agrobiodiversity of *Opuntia* in Meridional High Land Plateau of Mexico

Scientific name	Common names
Cultivars	
<i>O. albicarpa</i> cv. Octubreña	Octubreña, Virginia & Fafayuco
<i>O. albicarpa</i> cv. Pepino	Pepino & Chapeada SJZ
<i>O. albicarpa</i> cv. Esmeralda	Esmeralda, Forrajera, Tuna blanca, Blanca tipo & Alfajayucan
<i>O. albicarpa</i> cv. Copena T12	Copena T12 & Tuna blanca
<i>O. albicarpa</i> cv. Burróna	Alfajayucan, Amarillo aguado, Blanco de Castilla, Burróna & Copena T15
<i>O. albicarpa</i> cv. Papantón	Papantón, Reina, Copena 12, Copena 1-A, Calabazona tardía, Copena G14, Copena 2-B, Pepino, Burróna & Fafayuco
<i>O. albicarpa</i> cv. Cristalina	Burróna, Cristalina, Blanca suave & Promotora 3
<i>O. albicarpa</i> cv. Dadokjä	Blanca E Z, Dadokjä & Promotora 8
<i>O. atropes</i> Rose	
<i>O. atropes</i> cv. Blanco espinoso	Blanco espinoso
<i>O. chavena</i> Griffiths	
<i>O. chavena</i> cv. Cascarón	Cascarón & Rebusco
<i>O. chavena</i> cv. Cimarrón	Cimarrón, Güeras & Mión
<i>O. chavena</i> cv. Forrajera	Forrajera S
<i>O. chavena</i> cv. Pachona	Pachona
<i>O. chavena</i> cv. Hartón	Hartón & Cascarón
<i>O. chavena</i> cv. Chiquihuitillo	Cochinillo, Chiquihuitillo, Tempranillo, Pachoncilla, Pachón, Negrito, Camueso con espinas & Galarzo
<i>O. chavena</i> cv. Negrito	Negrito
<i>O. cochintera</i> Griffiths	
<i>O. cochintera</i> cv. Cacalote	Cacalote
<i>O. durangensis</i> Britton & Rose	
<i>O. durangensis</i> cv. Xoconostle moro	Xoconostle, Xoconostle chivo & Xoconostle moro
<i>O. durangensis</i> cv. Iskjä	Iskjä & Coconoixtle
<i>O. ficus-indica</i> (L.) Mill.	
<i>O. ficus-indica</i> cv. Copena V1	Copena V1 & Telokjä
<i>O. ficus-indica</i> cv. Copena F1	Copena F1, Milpa Alta & ACNF-INIFAP
<i>O. ficus-indica</i> cv. Amarillo huevo	Amarillo huevo & 33 INIFAP
<i>O. ficus-indica</i> cv. Liso blanco	Liso blanco
<i>O. ficus-indica</i> cv. Atlixco	Amarillo (Tipo Atlixco)
<i>O. ficus-indica</i> cv. Tlaxcalancingo	Tlaxcalancingo & A3 INIFAP
<i>O. ficus-indica</i> cv. Camuesa	Lisa-34 & Camuesa 58
<i>O. ficus-indica</i> cv. Amarilla Milpa Alta	Amarilla Milpa Alta, Atlixco, Plátano & Verdulero de Don Erasmo
<i>O. ficus-indica</i> cv. Doctor Mora	Doctor Mora, Amarillo grande, RDR-INIFAP & Cristalino
<i>O. ficus-indica</i> cv. Liso	Rojo vigor, Copena V1, Liso & Liso de Milpa Alta
<i>O. ficus-indica</i> cv. Telokjä	Telokjä, Verdulero de María Durán, B10 INIFAP, Copena F1, Amarilla UACH, Atlixco, Celaya, Forrajero & Copo de nieve
<i>O. ficus-indica</i> cv. Solferino	Amarilla, Solferino, RSB-INIFAP, Roja, Pelón & Rojo 8

Most of the indicator traits are related to the *Opuntia* general domestication process (Colunga et al. 1986; Reyes et al. 2005a); these include fruit color and length, and pulp weight, followed by areole and spine traits (Reyes et al. 2005a). However, in cultivars characterized by large fruits, spine abundance displays three modalities: total absence, reduced or minimal presence, and persistence of the normal

number per areole, that is, the amount of spines normally present in wild species, in dependence of domestication environment. The variants described in the catalog (Reyes-Agüero et al. 2009) represent only a fraction of the *Opuntia* richness in Mexico. This effort is only a first approximation. Further in depth botanical exploration is required, both in the Meridional Plateau Highland and in the rest of the country.

Table 2 continuation. Check-list of the agrobiodiversity of *Opuntia* in Meridional High Land Plateau of Mexico

Scientific name	Common names
Cultivars	
<i>O. ficus-indica</i> cv. Promotora	Promotora & Promotora 6
<i>O. ficus-indica</i> cv. Telokäjä rojo	Amarilla Milpa Alta, Copena CE, Tuna roja lisa & Telokäjä rojo
<i>O. ficus-indica</i> cv. Liso forrajero	Liso forrajero, Promotora 7, RSA-INIFAP, Rojo liso, Rojo 72, Telokäjä, Rojo pelón, Guanajuato, Rojo pelón de Zacatecas, Rojo 3509 & Liso-V, Tlaconopal
<i>O. hyptiacantha</i> A. Web.	
<i>O. hyptiacantha</i> cv. Ladrillo	Ladrillo
<i>O. hyptiacantha</i> cv. Jaqueña	Granada roja, RCH-INIFAP, Nopal blanco, Jaqueña-29 & Morado
<i>O. hyptiacantha</i> cv. Camueso	Cardón & Camueso
<i>O. hyptiacantha</i> cv. Amarilla 24	Amarilla 24
<i>O. hyptiacantha</i> cv. Pachón	Tempranillo, Charol, Pachón, Camueso & Cardón
<i>O. hyptiacantha</i> cv. Cardón de Las Papas	Cardón de Las Papas
<i>O. hyptiacantha</i> cv. Roja rubí	Roja rubí
<i>O. hyptiacantha</i> cv. Jokjä	Jokjä
<i>O. hyptiacantha</i> cv. Cardón blanco	Rojo 9, 79 INIFAP & Cardón blanco
<i>O. hyptiacantha</i> cv. Blanca Victoria	Blanca Victoria
<i>O. hyptiacantha</i> cv. Nistokäjä	Nistokäjä & RSD-INIFAP
<i>O. jaliscana</i> Bravo	
<i>O. jaliscana</i> cv. Chamacuero	Chamacuero
<i>O. joconostle</i> A. Web.	
<i>O. joconostle</i> cv. Xoconostle colorado	Xoconostle colorado
<i>O. joconostle</i> cv. Xoconostle de Las Pirámides	Xoconostle de San Martín de Las Pirámides & Iskjä de burro.
<i>O. joconostle</i> cv. Xoconostle blanco	Xoconostle blanco
<i>O. joconostle</i> cv. Xoconostle agrio	Xoconostle agrio
<i>O. joconostle</i> cv. Huevo de gato	Huevo de gato rojo, Huevo de gato rojo blanco, Duraznillo & Xoconostle
<i>O. joconostle</i> cv. Xoconostle blanco	Xoconostle blanco, Coyoconostle & Xoconostle
<i>O. lasiacantha</i> Pfeiff	
<i>O. lasiacantha</i> cv. Sanjuanero	Sanjuanero
<i>O. lasiacantha</i> cv. Blanca cristalina	Blanca cristalina or Cuero de rata
<i>O. lasiacantha</i> cv. Nopal del Real	Nopal del Real
<i>O. lasiacantha</i> cv. Madokäjä	Madokäjä
<i>O. lasiacantha</i> cv. Tuna Iris	Tuna Iris
<i>O. leucotricha</i> DC.	
<i>O. leucotricha</i> cv. Duraznillo	Duraznillo & Duraznillo-xoconostle
<i>O. lindheimeri</i> Engelm.	
<i>O. lindheimeri</i> cv. Oreja de elefante	Oreja de elefante
<i>O. lindheimeri</i> cv. Guilanchi	Guilanchi or Arrastrerilla
<i>O. megacantha</i> Salm-Dyck	
<i>O. megacantha</i> cv. Cuervo tuna	Cuervo tuna & Hartón
<i>O. megacantha</i> cv. Jarrilla	Piniche & Tuna jarrilla
<i>O. megacantha</i> cv. Sgt-INIFAP	Sgt-INIFAP
<i>O. megacantha</i> cv. Juanita käjä	Juanita käjä
<i>O. megacantha</i> cv. Chirriona	Chirriona, Revilla & Pastosa
<i>O. megacantha</i> cv. Chamacuero Monteza	Chamacuero Monteza
<i>O. megacantha</i> cv. Naranjona	Mango, Naranjona & Promotora 2
<i>O. megacantha</i> cv. Sangre de toro	Sangre de toro

Table 2 continuation. Check-list of the agrobiodiversity of *Opuntia* in Meridional High Land Plateau of Mexico

Scientific name	Common names
Cultivars	
<i>O. megacantha</i> cv. Manso apastillada	Anaranjada, Amarilla, Manso apastillada & Anaranjada 33
<i>O. megacantha</i> cv. Mieluda	Mieluda & Tuna perra
<i>O. megacantha</i> cv. Ushikäjä	Ushikäjä
<i>O. megacantha</i> cv. Reventón	Morado, Sangre de toro, Apastillada, Nopal chiva, Reventón, Morada, Trompa de cochino, Tazaja, Nopal duro & Jarrillo.
<i>O. megacantha</i> cv. Jagüeño	Amarillo de tuna chica, Jagüeño, Camueso & Mieludo
<i>O. megacantha</i> cv. Bola de masa	Bola de masa, Redonda, Chapeada, Nopal ligero, Morado & Nopal loco
<i>O. megacantha</i> cv. Amarilla raleña	Camuesa Matancillas, Amarilla raleña
<i>O. megacantha</i> cv. Apastillada anaranjada	Apastillada anaranjada
<i>O. megacantha</i> cv. Tzebekäjä	Tzebekäjä & Jarrillo
<i>O. megacantha</i> cv. Roja saeta	Roja saeta
<i>O. megacantha</i> cv. Pico chulo	Tuna sabina, Amarilla, Morada, Morado, Pico chulo & Naranja
<i>O. megacantha</i> cv. Torreoja	Torreoja
<i>O. megacantha</i> cv. Naranjona dulce	Naranjona dulce
<i>O. megacantha</i> cv. Amarilla Monteza	Amarillo Monteza o Huesos, Amarillo de Tuna grande & Amarilla Monteza
<i>O. megacantha</i> cv. Sangrita	Sangrita
<i>O. megacantha</i> cv. Amarilla naranjona	Amarilla naranjona & Amarilla redonda
<i>O. megacantha</i> cv. Rojo 10	Naranjona, 25 INIFAP & Rojo 10.
<i>O. megacantha</i> cv. Naranjona Helia	Naranjona Helia, 26 INIFAP & 25 INIFAP
<i>O. megacantha</i> cv. Astikäjä	Astikäjä
<i>O. megacantha</i> cv. Rubí reina	Amarillo con espinas, Colorada, Monteza & Rubí reina
<i>O. megacantha</i> cv. Amarilla mansa	Amarilla mansa
<i>O. megacantha</i> cv. Amarilla china	Amarilla china
<i>O. megacantha</i> cv. Jarrilla grande	Juanita kajä, Pico chulo, Amarilla, Jarrilla grande & Jokjä
<i>O. megacantha</i> cv. Sangre	Sangre
<i>O. megacantha</i> cv. Tenikäjä	Tenikäjä, Apastillada & Amarilla
<i>O. megacantha</i> cv. Morada de San Martín	Solferino, Morada de San Martín & Tuna roja
<i>O. phaeacantha</i> Engelm.	
<i>O. phaeacantha</i> cv. Pintadera	Pintadera
<i>O. phaeacantha</i> cv. Pintadera de Daboxtha	Pintadera de Daboxtha
<i>O. robusta</i> Wendl.	
<i>O. robusta</i> cv. Tapón	Bonda, Tapon de mayo, Tapón macho, Tapón (macho), Tapón hembra & Tapona
<i>O. robusta</i> cv. Tapón pelón	Tapón pelón
<i>O. rzedowskii</i> Scheinvar	
<i>O. rzedowskii</i> cv. Cenizo	Cenizo & Cuatroalbo
<i>O. streptacantha</i> Lem.	
<i>O. streptacantha</i> cv. Cardoncillo	Cardoncillo & 66 INIFAP
<i>O. streptacantha</i> cv. Burra	Burra & Masona
<i>O. streptacantha</i> cv. Sandía	Sandía & Pachón rojo.
<i>O. streptacantha</i> cv. Amarilla Cardona	Amarilla cardona
<i>O. streptacantha</i> cv. Isbini	Isbini, Madokäjä & Cardón
<i>O. streptacantha</i> cv. Dojä	Dojä, Tomatillo & Redondilla
<i>O. streptacantha</i> cv. Santo Tomás	Jarrillo, Cardón & Santo Tomás
<i>O. streptacantha</i> cv. Cardón potosino	Cardón potosino

Table 2 continuation. Check-list of the agrobiodiversity of *Opuntia* in Meridional High Land Plateau of Mexico

Scientific name	Common names
Cultivars	
<i>O. streptacantha</i> cv. Jocoquillo	Cardón, Cardona, Color de rosa, Chino & Jocoquillo
<i>O. streptacantha</i> cv. Cardón	Cardón
<i>O. streptacantha</i> cv. Trompa de cochino	Trompa de cochino
<i>O. streptacantha</i> cv. Demshikjä	Cayahual, Isbini, Tomatillo o Demshikjä, Cardón, Colorada & Cardón blanco
<i>O. streptacantha</i> ssp. <i>aguirrana</i> Scheinvar & Rodr.	Apalillo, Chiquihuitillo, Nopal del monte, Zarco & Charola
<i>O. velutina</i> Scheinvar	
<i>O. velutina</i> cv. Ukäjä	Ukäjä

Table 3. Number of *in situ* and *ex situ* localities of the samples of *Opuntia* cultivars in Meridional High Land Plateau of Mexico

Scientific name	<i>In situ</i>					<i>Ex situ</i>		Total	%	
	Wild	Fences and/or terraces	Home garden	CP*	Sub Total	%	EP**			%
<i>O. albicarpa</i>	1	2	22	9	34	9.0	54	14.2	88	23.2
<i>O. atropes</i>							1	0.2	1	0.2
<i>O. cochineria</i>	1				1	0.2			1	0.2
<i>O. chavena</i>	5		9		14	4.0	5	1.3	19	5.3
<i>O. durangensis</i>	2		3		5	1.3			5	1.3
<i>O. ficus-indica</i>			12	6	18	4.7	41	10.8	59	15.1
<i>O. hyptiacantha</i>	3	3	8		14	3.7	11	2.9	25	6.6
<i>O. jaliscana</i>			1		1	0.2			1	0.2
<i>O. joconostle</i>	3	1	6	3	13	3.4			13	3.4
<i>O. lasiacantha</i>			4	1	5	1.3	3	0.8	8	2.1
<i>O. leucotricha</i>		1	2		3	1.2			3	1.2
<i>O. lindheimeri</i>			1		1	0.2	2	0.5	3	0.7
<i>O. megacantha</i>	5	2	34	5	46	12.1	58	15.3	104	27.4
<i>O. phaeacantha</i>	1		1		2	0.5			2	0.5
<i>O. robusta</i>	4		5		9	2.3	1	0.2	10	2.5
<i>O. rzedowskii</i>			2		2	0.5			2	0.5
<i>O. streptacantha</i>	8	3	17		28	7.4	6	1.6	34	9.0
<i>O. velutina</i>			1		1	0.2			1	0.3
Total	33	12	128	24	197		182		379	
%	8.71	3.17	33.77	6.33		52.0		48.0		100.0

*CP = Commercial plantations

** EP = Experimental plantation in Scientific Research Institutions

Conclusion

A total of 126 variants were identified in association with 18 species of cactus pear; most of them preserved in homegardens, but several are also present in wild populations and commercial plantations. Seventy six percent of variants are associated with eight species of the series *Streptacanthae*, rising to 88% if the *O. ficus-indica* cultivars are also considered. *O. megacantha* stands out as the species with

the largest number of cultivars and for being the most broadly distributed species in the study area (wild populations, homegardens and plantations). Most of the morphological characteristics that turn out to be indicator traits are related to the *Opuntia* domestication process.

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