







Sociocultural and economic significance in the harvest of the pitaya sahuira (*Stenocereus montanus*) in Sinaloa, Mexico

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Abstract. Pitayas (*Stenocereus* spp.) are one of the most important wild plants in Mexico; however, there are few studies that evaluate the harvest value and commercialization of local species. This research records the sociocultural and economic importance of the harvest of pitaya sahuira (*Stenocereus montanus*) in two localities of the state of Sinaloa, Mexico: 1) San José del Llano, Badiraguato, and 2) several small communities in the municipality of Choix. Semi-structured surveys and participatory evaluation were carried out with different people who harvest and market the pitaya fruits during the production season to document the harvest method, productivity, commercial value, fruit destination, cultural perceptions, and the differences between both regions. In both localities, daily harvests are made, and it constitutes the main economic activity during the production season, about 40 to 50 days between May and July. In San José, the harvest is carried out by men and women, while in Choix, it is practically exclusive by men. Higher productivity was recorded in San José, reflected by a greater amount of daily fruit harvested in a workday; however, in Choix, the fruit has a higher sales value, which balances the estimated annual earnings of around 1,940 dollars per harvester (~40,000.00 Mexican pesos). Given its great commercial value, it is necessary to implement cultivation and domestication strategies at the local level, as a regional economic alternative and to reduce the pressure on native populations. This work incorporates additional evidence on the great cultural and economic importance of the genus *Stenocereus* in Mexico and motivates the design of better strategies for sustainable use and the revaluation of this biocultural heritage.

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Introduction

The genus *Stenocereus* (Cactaceae) comprises 22 species of columnar cacti from tropical America, distributed in dry forests and xeric scrublands (Arreola-Nava and Terrazas, 2013; Alvarado-Sizzo *et al.*, 2018; Powo, 2021). Mexico has 21 species from which 18 are endemic (Villaseñor, 2016; Alvarado-Sizzo *et al.*, 2018). The fruits of *Stenocereus*, mainly known as pitayas, constitute an important food source for local communities and native fauna in the driest season. In Mexico, pitayas are one of most valuable wild edible plants for rural communities (Pimienta-Barrios and Nobel, 1994; Yetman and Van Devender, 2002; Pío-León *et al.*, 2017a, 2017b; Quiroz-González *et al.*, 2018; Lázaro-Juárez *et al.*, 2020); however, although all

Stenocereus species produce edible fruit, not all produce fruit big enough nor the necessary amount to motivate harvest for sale. Among the most important *Stenocereus* species in Mexico are *S. dumortieri*, *S. fricci*, *S. huastecorum*, *S. montanus*, *S. pruinosus*, *S. queretaroensis*, *S. stellatus* and *S. thurberi* (Pío-León et al., 2017b; Alvarado-Sizzo et al., 2018; Quiroz-González et al., 2018).

Sinaloa is one of the Mexican states with the highest agricultural development, favoring food security. However, it has become one of the main causes of deforestation and loss of biodiversity (Monjardín-Armenta et al., 2017); moreover, is one of the states with the least number of ethnobotanical studies. The word *Sinaloa* derives from the Cahita (language of the former Cáhita, a local Indian tribe) *SINA* (pitaya or pitahaya), and *LOBOLA* (rounded), which means round pitaya, and is part of the state coat of arms (INAFED, 2008). However, despite the cultural significance for the state, there are no studies that analyze the sociocultural and economic value of its pitayas species and very few it's known about the commercialization process (Quiroz-González et al., 2018). There are seven species of *Stenocereus* in Sinaloa which, based on the author's experience, only three can be considered as pitahaya producers: *S. thurberi* in the north, *S. martinezii* in the center-south and *S. montanus* in the mountain region.

Stenocereus montanus belongs to the group of *Stenocereus* with brown areolas (Arreola-Nava and Terrazas, 2013) with candelabriform structure. It grows 6-9 m tall and is characterized by not having constrictions in the branches below the areoles, not clearly differentiated radial or central thorns, and yellow thorns in the fruit of variable intensity. It is the species of pitaya with the largest fruits in Sinaloa and one of the largest in the genus; blooms from April to May and the fruit can be harvested from May to June. It is distributed in the tropical deciduous forest of northwest Mexico at 200-500 m from sea level. In Sinaloa, like most *Stenocereus* species, it is known as *pitaya* or *pitaya de la sierra*, in contrast to the other species that are distributed along the coast; however, among the Mayo/Yoreme community of southern Sonora and northern Sinaloa, it is known as *sahuira* (Yetman and Van Devender, 2002).

The fruits of *Stenocereus* are a source of several phytochemicals such as vitamin C, phenolics, and, mainly betalains (Beltrán-Orozco et al., 2009; Quiroz-González et al., 2018). Among higher plants, betalains are pigments restricted to the order Caryophyllales, which are safe for the human body with no upper limit (Delgado-Vargas et al., 2000). Therefore, pitayas might be a natural safe alternative source of pigments compared to some synthetic dyes.

The objective of this work was to evaluate the sociocultural and economic importance of the harvest of pitaya sahuira (*Stenocereus montanus*) in two localities of the state of Sinaloa, Mexico: 1) San José del Llano, Badiraguato, and 2) several small communities in the municipality of Choix, where there is an annual traditional harvest and sale of the pitaya fruits.

Material and Methods

Study area

The communities studied are shown in Figure 1. San José del Llano is in the municipality of Badiraguato, Sinaloa, in the area known as El Llano, a warm, lowland area surrounded by temperate mountain ranges of the Sierra Madre Occidental. Its population is around 1,000 inhabitants of mestizo origin and the main economic activities are seasonal agriculture and extensive cattle ranching. The closest meteorological station (Soyatita) registers an annual

average rainfall of 780 mm, an annual average temperature of 23.8 °C, a maximum average of 33.1 °C, and a minimum average of 17.6 °C. The study includes the Bajahui, Mochique, Santa Ana, San José de los Portillos, Tabucahui and Venecia communities around the municipal seat of Choix. These populations include both mestizo and indigenous Yoreme (Mayo) inhabitants, whose distribution includes northern Sinaloa and southern Sonora (INPI, 2017). The average annual rainfall in the municipality is 784 mm and the average temperature is 25 °C, with a maximum of 47 °C and a minimum of 15 °C (INAFED, 2008).

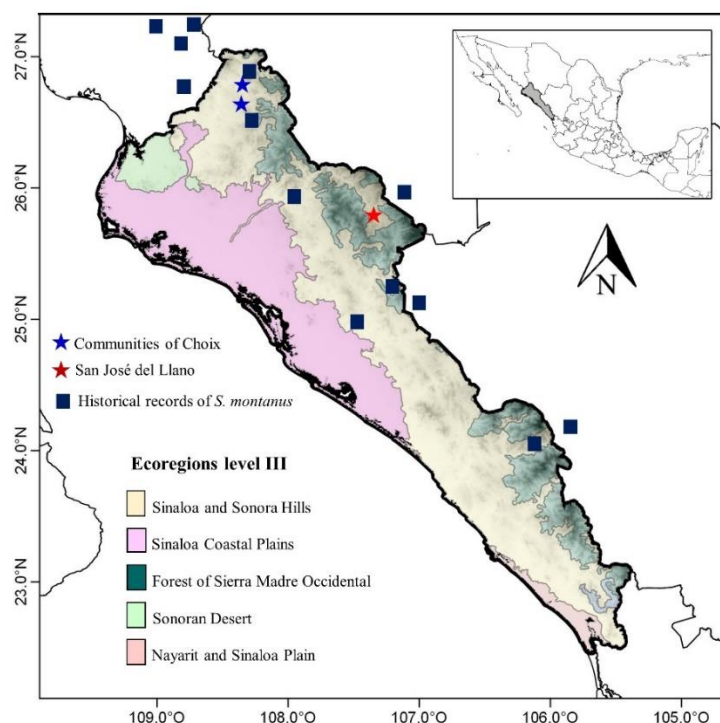


Figure 1. Geographic location of the study sites and historical records of *Stenocereus montanus* in Sinaloa and surrounding areas (records from Naturalista, 2021).

Both locations are within the ecoregion level III, Sinaloa and Sonora Hills with Low Deciduous Forest (Wiken *et al.*, 2011), corresponding to the Tropical Deciduous Forest of Rzedowski (2006). Common dominant species in both localities are tepehuaje (*Lysiloma acapulcensis*), Indian comb (*Pachycereus pecten-aboriginum*), Mexican logwood (*Haematoxylum brasiletto*), tree morning glory (*Ipomoea arborescens*), igualama (*Vitex mollis*) and papache (*Randia echinocarpa*); a distinctive element between both is the netleaf hackberry (*Celtis reticulata*) in San José del Llano and tempisque (*Sideroxylon tepicense*) in Choix.

Collection of Information

The study was carried out between 2019 and 2021 in San José del Llano and in 2021 in Choix. Visits were made between the months of May and July to monitor the process of harvesting and selling pitayas and to carry out semi-structured surveys with harvesters and sellers. The participants were randomly selected at the harvest or sale points of the product. The total number of participants, gender, and age is shown in Table 1. The inclusion criteria were men and women older than 15 years who dedicated at least two years to harvesting pitayas; however, in the

communities of Choix, this activity is carried out almost exclusively by men, so women were not included in the study. The sampling was considered sufficient when increasing the number of surveys, no longer yielded different results.

Table 1. Age and number of the participants in the ethnobotanical surveys on *Stenocereus montanus* harvest and selling in the different communities of Sinaloa.

<u>Location</u>	Number of participants		Average age (max.-min.)	
	Men	Woman	Men	Woman
San José del Llano	23	26	37.26 (15-83)	42.9 (15-78)
Choix	29	0	34.55 (65-15)	-

Results and Discussion

Figure 2 shows specimens and representative populations of *Stenocereus montanus* in the localities studied. Table 2 shows the comparative variables in the pitaya harvest between San José del Llano and the communities of the municipality of Choix. The harvest is carried out traditionally year after year, and the main objective is the sale, then the surpluses are destined for personal consumption. The highest densities of wild plants in the state are in these communities, which allow their harvest to be profitable. The time invested in a workday, the distances traveled, and the sale price was higher and more variable in Choix. The harvest period was similar in both locations, approximately 40 to 50 days, beginning at the end of May and can extend until the beginning of July, with the maximum production in June. On average, about 8.5 dozen per person are collected in both communities, investing 2.5 hours of work in San José del Llano and 4.5 hours in Choix. The main point of sale in San José del Llano is a local company with the legal form of the Limited Responsibility Rural Production Society (S.P.R de R.L), called "Pitayas Golden", which freezes the pulp and makes various products such as sauces and jams. While in the communities around Choix, is the municipal seat of the same name and the neighboring roads near this. During the production season, harvests are carried out daily, which becomes the main economic activity; this phenomenon has also been reported in other pitaya regions of Mexico, such as in Baja California Sur with *Stenocereus thurberi* (Pío-León *et al.*, 2017b) and in south-central Sinaloa with *Stenocereus martinezii* (pers. comm.).

The higher cost of selling pitayas in Choix can be explained by the greater effort involved in their harvest, as well as going out to sell them on local roads or in the closest cities (Choix and El Fuerte). While in San José del Llano is carried out right in the town, directly with the local company or by visitors of Culiacan. Additionally, the productivity of the plants in San José del Llano is greater than in Choix, since the people surveyed reported a greater number of maximum fruits collected in a single plant per day, a greater number of dozens collected per day, and in one day of work lower than in Choix (Table 2). However, the approximate average annual earnings per person, considering a period of 45 days, range around 1,940 dollars/year (~\$40,000.00 Mexican pesos) for both communities, which justify the effort and encourage conservation, and cultivation. Furthermore, the pitaya season occurs during the driest season, when livestock and agriculture are less productive and there is greater economic need.



Figure 2. Specimens and representative populations of *Stenocereus montanus* in the study areas.

Table 2. Comparison of harvest attributes of *Stenocereus montanus* between the community of San José del Llano and communities of Choix.

Harvest Information	Location	
	San José del Llano	Communities of Choix
Fruit harvested/ day (dozens)	14.87 ± 10.4	8.41 ± 3.7
Time invested (h)	2.51 ± 0.7	4.47 ± 1.8
Working hours (minimum-maximum)	4-9 am	2-9 am
Distance traveled (Km on average)	0.35 ± 0.16	4.75 ± 2.9
Number of fruits harvested per day, per plant	17	10
Sale price (Mexican pesos per average dozen):	58 ± 4.4 ^a	96.9 ± 16.7 ^b
Minimum	48	60
Maximum	60	130
Collection period	May-July	May-June
Maximum collection peak	June	June
Transport method (%):		
Walking	22.45	51.7
Motorcycle	69.4	31.0
Car	8.16	13.8
Bike	0	3.4
Sales place (%):		
Own house or town	4.08	6.9
local roads	0	51.7
Nearest city	81.6	41.4
local company	91.8	0
Perceives difference in flavor between fruits of different color (%):		

	Yes	87.75	93.1
	No	12.25	2.9
Color preference (%):	Red	42.85	79.3
	Orange or Yellow	0	17.2
	White	14.26	3.4
	Indistinct	42.85	0
It has fixed daily collection routes (%):	Yes	79.6	93.1
	No	20.4	6.9
There are conflicts to collect in the same areas as the neighbors (%):	Yes	2.05	10.3
	No	97.95	89.6
Additional uses of the plant (%):	Firewood	75.55	0
	Fence	16.32	0
	None	16.32	100

In both locations, pitaya fruits show pigmentation ranging from white, yellow, orange, and red (Figure 3). However, they are collected and sold indiscriminately. In general, the surveyed harvesters from both localities perceive a different flavor between fruits of different colors, with red being the most preferred; however, a significant percentage in San José del Llano prefers them indistinctly. Most harvesters in both communities use the same daily harvesting routes, which allow them to avoid competition conflicts with neighbors.



Figure 3. Different phenotypes and presentations of the *Stenocereus montanus* fruits for sale in the study areas: (A) fruits of different colors; (B) fruit pulp harvested without the shell for the elaboration of processed products in San José del Llano; (C) fruits in bags offered in the communities of Choix; (D) fruit with atypical flower production.

The main additional use of the pitaya plant, besides fruit production, was for firewood or construction in San José del Llano, while the communities of Choix did not report any additional use. Neither of the two communities reported medicinal uses of the plant, except for the fruits as a laxative if consumed in sufficient quantity. Yetman and Van Devender (2002) reported that among the Mayos, an Indian group of Sonora, its consumption is recommended for the gastrointestinal system, as well as to cure ulcers and the peels to heal hemorrhoids.

Table 3 shows a comparison of harvest efficiency between men and women in San José del Llano. Women spend more time harvesting, which results in more fruits harvested per day, but the net efficiency (fruits/ h) is similar for both genders.

Table 3. Comparison of the harvest efficiency of pitayas between men and women from San José del Llano.

	Men	Woman
Fruit per day	155 ± 63 ^a	198 ± 159 ^a
Time invested (h)	2.3 ± 0.47 ^a	2.69 ± 0.79 ^b
Fruits per h	69.6 ± 29.9 ^a	68.7 ± 34.3 ^a
Distance traveled	350 ± 129 ^a	361 ± 189 ^a

The instrument used for harvesting ripe fruit is called the *pitayero hook*, *pitayero* or *wichuta*, which is made from a 5 to 7 m reed (*Arundo donax*), to which a spatula or wooden bow is placed at the tip, and a tip to prick the fruit and collect it (Figure 4). The material used for the tip differs in both communities, metal in San José del Llano and wood in Choix. In addition, in San José del Llano, a *pitayero* was also observed, comprising five arched metal spikes, resembling a cup or container to collect pitaya without perforating it (Figure 4). This is because there is an incentive to use tools that do not perforate the fruit, which offers better postharvest quality. However, the use of *pitayero* with a point offers the advantage of being more selective and not damaging the fruits that are on one side.

In both localities, the harvesting sites are areas of land that are also used for extensive cattle ranching and have most of their forest components removed, preserving the pitaya plants. Unfortunately, there are no cultivated plantations in the study areas to increase their productivity, in order to exert less ecological and extractive pressure on wild populations, in contrast to what was reported in the central-southern regions of Mexico (Pimienta-Barrios *et al.*, 1997; Quiroz-González *et al.*, 2018), where it has been pointed out that, among the columnar cacti, the genus *Stenocereus* is the most advanced group in terms of domestication (Casas *et al.*, 2016). However, in San José del Llano, the first plantations have been started because of the demand and need of the local company.

There are notable differences in harvesting practices between the two communities studied, which can be attributed to geographical and cultural factors. The main difference is that, while in San José del Llano harvesting is carried out indistinctly or jointly by men and women, in Choix it is almost exclusively by men. Regardless of cultural factors, this can be explained by the dispersed population in San José del Llano, a lowland and relatively flat area between the high mountain ranges and forests of the Sierra Madre Occidental (Figure 2), where the community of San José is located, so the collection sites are very accessible. On the other hand, in the communities of Choix, the highly

productive populations are in more dispersed hills and farther away from the communities, which imply a greater effort to move and collect, so the work is mainly assigned to men; besides other reasons, such as social security, were also argued.

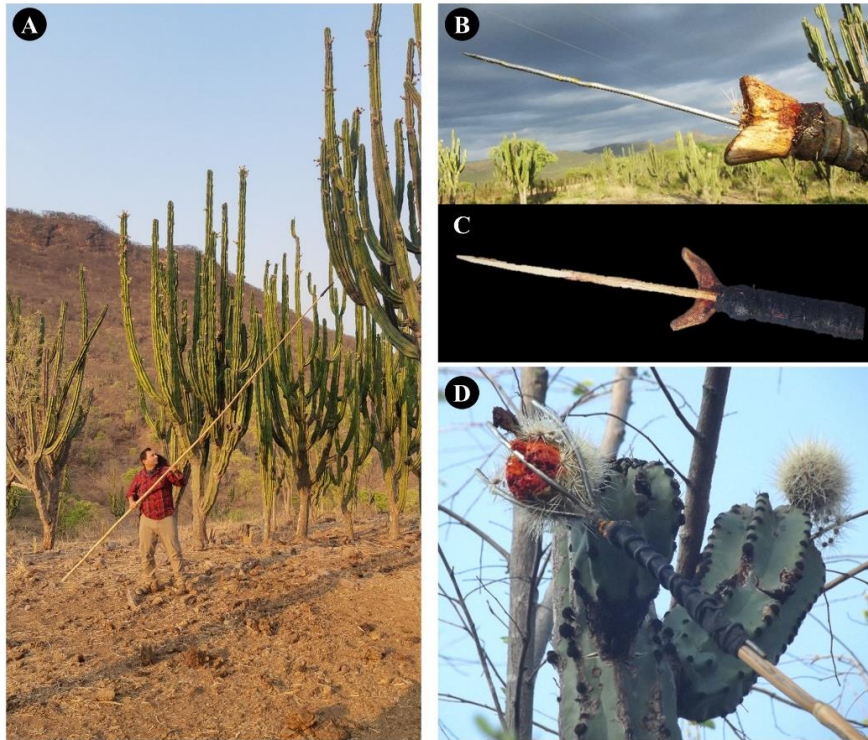


Figure 4. Tools used to collect *Stenocereus montanus* fruits in the communities studied: (A) complete *pitayero*; (B) *pitayero* with wooden tip in Choix; (C) *pitayero* with a metal tip in San José del Llano; (D) *pitayero* with a metal basket in San José del Llano.

The surveyed harvesters mentioned knowing other pitaya species that are harvested in neighboring municipalities, such as *Stenocereus thurberi* (pitaya marismeña) and *S. martinezii*; however, they all agreed that they prefer the pitayas they harvest, particularly because *S. montanus* is bigger than the other two. This is a cultural phenomenon that we are still documenting in the state, where local people always prefer the pitaya corresponding to the species of their locality.

Conclusions

Pitayas are one of the most important harvesting products in the state of Sinaloa and in Mexico. In the studied communities, its harvest represents an annual tradition that is motivated by the flavor of its fruits, but above all its high economic value in the dry season. Greater cultivation and domestication efforts should be encouraged in the species of northwestern Mexico that allow a greater sustainable use and exert less ecological pressure on wild populations.

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Consent for publication

All people in the figures were agreed to appear in this paper.

Data availability

Not applicable

Competing interests

The authors declare that they have no competing interests.

Author contributions

Conceptualization, B.S.M., R.C.C.A. and J.F.P.L.; methodology, B.S.M. and J.F.P.L.; investigation, B.S.M., P.Y.R.A., Y.R.L. and H.F.L.; data curation, P.Y.R.A., Y.R.L., H.F.L. and J.F.P.L.; writing—original draft preparation J.F.P.L.; writing—review and editing, B.S.M., R.C.C.A. and J.F.P.L.

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