Technology in Horticulture

MINI REVIEW

Open Access

https://doi.org/10.48130/tihort-0025-0004

Technology in Horticulture **2025**, 5: e008

Regional importance and potential of *Passiflora:* the case of the Yucatan Peninsula and Chiapas, Mexico

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Abstract

According to Mexican herbaria, scientific databases, and literature, 91 *Passiflora* species are registered in Mexico; thus, worldwide, this country presents the fifth largest diversity for this genus. Among *Passiflora* species, the most important economic species include yellow and red passion fruit (*Passiflora edulis*). In southern Mexico, in Campeche, Chiapas, Quintana Roo, and Yucatán states, 50% of the countries *Passiflora* diversity are recorded. Fifty-five *Passiflora* species have been recorded, 50 in Chiapas, 23 in Quintana Roo, 22 in Campeche, and 17 in Yucatán. At the municipality level, Ocosingo, Chiapas, presented the highest number of *Passiflora* species of 21; followed by Othón P. Blanco, Quintana Roo, with 14; and Calakmul, Campeche, with 11. In its territory, Chiapas presents five biogeographical regions, explaining, at least in part, its richness in *Passiflora* species. The fruits of several species of this genus have been used in local communities as food, mainly beverages, and traditional medicine.

Citation: Franco-Mora O, Sánchez-Pale JR, Castañeda-Vildózola Á, Moreno-Jiménez JA. 2025. Regional importance and potential of *Passiflora:* the case of the Yucatan Peninsula and Chiapas, Mexico. *Technology in Horticulture* 5: e008 https://doi.org/10.48130/tihort-0025-0004

Introduction

Passiflora plants are lianas with axillar tendrils and nectaries; their sexual organs are merged into a structure named the androginophore[1]. *Passiflora* is a genus with nearly 600 species; 95% of them are American natives, mainly from South America and Mesoamerica (from Central Mexico to Panama)[2]. More than 60 species of *Passiflora* produce large edible fruits, and nearly 25 species are cultivated. The economically important edible juice producers are *Passiflora edulis*, *P. edulis* f. *flavicarpa*, *P. ligularis*, *P. quadrangularis,* and *P. tripartita* var. *mollissima*; moreover, the fruits of *P. tripartita*, *P. tarminiana*, *P. maliformis*, *P. alata*, *P. hannii*, *P. laurifolia*, *P. popenovii,* and *P. setacea* are consumed locally elsewhere[3]. Approximately 1.5 million tons of passion fruit (*Passiflora edulis*) are produced worldwide, with Brazil being the main producer and consumer[4].

Although most *Passiflora* species are American native, research on those species involved worldwide scientific groups. For example, due to their, actual and potential ecological and economic roles, in several world regions, such as China, projects for cropping and breeding *Passiflora* are being developed[5]. Medical researchers are determining the potential of *Passiflora* plant organs to recover physical and psychiatric human health[6,7].

In Mexico, 91 *Passiflora* species, native and introduced, have been reported, indicating that, for this genus, this country is the fifth in worldwide diversity ranking[8]. Within Mexico, one of the areas with greater *Passiflora* diversity are the areas belonging to the southern states of Campeche, Chiapas, Yucatán, and Quintana Roo[9]. In Chiapas state there are, at least, two endemic species, *P. pendens* and *P. tacanensis*[8].

The land area of those southern states is 215,047 km^2, representing approximately 10% of the total Mexican territory. Nowadays, its current inhabitants belong to different ethnic groups and mestizo people[10]. Nevertheless, before Spanish irruption in Mexico, this area was inhabited by several groups belonging to ancient Mayan culture, including *yucatecos* in the states of the Yucatan Peninsula (Campeche, Yucatán, and Quintana Roo), and *choles*, *tsetales*, *tsotsiles*, *tojolabanes*, and *lacandones* in Chiapas state[11,12].

As Mexico is one of the main land reserves for *Passiflora* plants, scientific efforts to claim further national studies on this plant genus must be performed. This review presents a list of the *Passiflora* species botanically recorded in four southern Mexican states. Then reports related to previous, actual, and potential uses for those species are briefly summarized. This review aims to point out the importance of the conservation of *Passiflora* genetic resources in southern Mexico.

Passiflora species in southern Mexico

According to the herbaria MEXU[13], HERBANMEX[14], CICY[15], and CHAPA[16], thereafter confirmed in the specialized platform 'Plants of the word on line'[8], in the states under study, there are 55 *Passiflora* species (Table 1). Chiapas state accounts for 90% of those species, followed by Quintana Roo, Campeche, and Yucatán states[9].

Chiapas state presents five biogeographical provinces related to a specific natural area in relation to its endemic biota. Those five provinces are, the 'Gulf of Mexico lowland', 'Chiapas central plateau', 'Chiapas central depression', 'Madre mountain range', and 'coastal lowland'. In contrast, within the Campeche state area, there are two biographical provinces, the 'Gulf of Mexico lowland' and the 'Yucatán lowland'. Whereas Yucatán and Quintana Roo states belong only to the province named 'Yucatán lowland'[19]. Thus, the presence of different biogeographical provinces, implying different climates and ecological conditions, might influence *Passiflora* diversity. For example, in Mexico, Chiapas state is known to be the second state with a relatively high total plant diversity, with over 10,000 plant species[20].

For Chiapas state, there are botanical reports of *Passiflora* in 65 of the 126 municipalities, with a greater presence in Ocosingo (19 species), Unión Juárez (nine species), and Palenque (eight species). Including the four states under study, the municipality of Othón P. Blanco, Quintana Roo state (11 species), follows Ococingo, and then,

Table 1. *Passiflora* species botanically registered in the states of Chiapas, Campeche, Quintana Roo, and Yucatán, Mexico; and their names in Spanish (S), Yucatec Maya (Y), Lacandón Maya (L), Tseltal Maya (T), and English (E).

No.	Species	Location	Name
1	*P. adenopoda* DC.	Chiapas	(L): *k'um sek*; *ucumin sek*
2	*P. alata* Curtis	Chiapas	(E): winged-stem passion flower
3	*P. ambigua* Hemsl.	Chiapas, Quintana Roo & Yucatán	(S): granadilla de monte; ingo; jugito; jugo; (L): *ch'um ak'*
4	*P. apetala* Killip	Chiapas	No information
5	*P. bicornis* Mill.	Campeche, Chiapas, Quintana Roo & Yucatán	(S): ojo de luna; (Y): *poch k' aak' ; kasu' uk*; (E): wing-leaf passionfruit
6	*P. biflora* Lam.	Campeche, Chiapas, Quintana Roo & Yucatán	(S): calzón de niño; bejuco de guaco; hoja de murcielago; (Y): *poch aak'*; (L): *k'um sek (ah)*; (T): *mayil poch*; (E): twoflower passion-flower
7	*P. bryonioides* Kunth	Chiapas	(S): granada cimarrona; (E): cupped passion flower
8	*P. capsularis* L.	Quintana Roo	No information
9	*P. ciliata* Aiton	Campeche, Chiapas, Quintana Roo & Yucatán	(S): maracuyá; sipolan; (Y): *poch k' aak' ; poch kaki; xpoch aki*; (E): fringed passion flower
10	*P. clypeophylla* Mast. ex Don.Sm.	Chiapas	No information
11	*P. cobanensis* Killip	Campeche, Chiapas & Quintana Roo	No information
12	*P. conzattiana* Killip	Campeche, Chiapas & Quintana Roo	(S): hoja de vampiro
13	*P. dolichocarpa* Killip	Chiapas	No information
14	*P. edulis* Sims	Campeche, Chiapas & Yucatán	(S): maracuyá; flor de pasión; maracuyá morado; (Y): *xton kee jil*; (E): yellow passion fruit, purple passion fruit
15	*P. exsudans* Zucc.	Campeche	(S): bolsa de gato; té de insomnio
16	*P. filipes* Benth	Chiapas	(S): frijolillo; granadilla (E): slender passion flower
17	*P. foetida* L.	Campeche, Chiapas, Quintana Roo & Yucatán	(S): amapola; maracuyá silvestre; granadillo; cinco llagas (Y): *poch; túubok; poch' aak' ; poch' iil* (E): stinking passion fruit; fetid passion flower; rambusa
18	*P. hahnii* (E.Fourn.) Mast.	Chiapas	(S): granadilla chos
19	*P. helleri* Peyr.	Chiapas, Quintana Roo & Yucatán	No information
20	*P. holosericea* L.	Chiapas	No information
21	*P. itzensis* (J.M.MacDougal) Port.-Ult.	Chiapas, Quintana Roo & Yucatán	(Y): *maak xikin soots'*
22	*P. jorullensis* Kunth	Chiapas	(S): golondrina; tijerilla
23	*P. lancearia* Mast.	Chiapas	No information
24	*P. ligularis* Juss.	Chiapas	(S): granadilla; granada de moco; (E): sweet granadilla
25	*P. mayarum* J.M.MacDougal	Campeche, Chiapas & Quintana Roo	(S): granadillo; (Y): *toon ts' iimim; poch aak'*; (E): wild passion flower
26	*P. membranacea* Benth.	Chiapas	(S): granadilla; granada; (T): *karanotozak; karanato rak'*
27	*P. mexicana* Juss.	Chiapas	No information
28	*P. morifolia* Mast.	Chiapas	(E): woodland passion flower
29	*P. obovata* Killip	Campeche, Chiapas, Quintana Roo & Yucatán	No information
30	*P. oerstedii* Mast.	Chiapas	(S): granadilla chos
31	*P. ornithoura* Mast.	Campeche, Chiapas & Quintana Roo	No information
32	*P. pallida* L.	Campeche, Chiapas, Quintana Roo & Yucatán	(Y): *sak aak' ; soots' aak' ; ts' unyajil*
33	*P. pavonis* Mast.	Chiapas	No information
34	*P. pedata* L.	Campeche, Quintana Roo & Yucatàn	(Y): *toom ts' iimin; tontotzimin*
35	*P. pendens* J.M.MacDougal	Chiapas	No information
36	*P. pilosa* Ruiz & Pav. ex DC.	Chiapas	(S): granadilla; granada de zorro
37	*P. platyloba* Killip	Chiapas & Quintana Roo	(S): granadilla de monte
38	*P. porphyretica* Mast.	Chiapas	(T): *schelchikin chinzak*
39	*P. prolata* Mast.	Campeche, Chiapas & Quintana Roo	(S): granadilla de monte
40	*P. quetzal* J.M.MacDougal	Chiapas	No information
41	*P. rovirosae* Killip	Campeche, Chiapas & Quintana Roo	No information
42	*P. sanctae-mariae* J.M.MacDougal	Chiapas	No information
43	*P. seemannii* Griseb	Chiapas	No information
44	*P. serratifolia* L.	Campeche, Chiapas, Quintana Roo & Yucatán	(S): amapola; jujito amarillo; maracuyá de monte; pasionaria; granada de ratón; (Y): *pooch aak' ; ya' ax pooch*; (L): *poochin*; (E): broken ridge granadillo
45	*P. sexflora* Juss.	Chiapas & Campeche	(S): granadilla chos; (T): *schelchikinchinak; shel chikin chinzak; shel chikin*
46	*P. sexocellata* Schltdl.	Campeche, Chiapas & Yucatàn	(S) ala de murciélago; granada de ratón; (Y): *xikin sots' ; xiik' sots'*
47	*P. sicyoides* Schltdl. & Cham.	Chiapas	(S) granadilla
48	*P. standleyi* Killip	Chiapas	No information
49	*P. suberosa* L.	Campeche, Chiapas, Quintana Roo & Yucatán	(S): granadilla roja; granadita de ratón; pata de pollo; (Y): *kansel-ak; zal-kansel-ak*; (I): cork-barked passion-flower, corky passion fruit
50	*P. sublanceolata* (Killip) J.M.MacDougal	Campeche, Quintana Roo & Yucatán	(S) jujo; (Y): *pooch k' aak'*
51	*P. subpeltata* Ortega	Campeche & Chiapas	(S) pasionaria, granadina, aretitos, granada de zorra, jujo
52	*P. tacanensis* Port.-Utl.	Chiapas	No information

(to be continued)

Table 1. (continued)

No.	Species	Location	Name
53	*P. tarminiana* Coppens & V.E.Barney	Chiapas	No information
54	*P. xiikzodz* J.M.MacDougal	Campeche, Chiapas, Quintana Roo & Yucatán	(Y): *maak xikin soots'*
55	*P. yucatanensis* Killip ex Standl.	Campeche, Quintana Roo & Yucatán	(S): flor de la pasión de Yucatán; (E): Yucatan passion flower

References[5,6,8,9,13–18].

the list continues with Calakmul, Campeche State (11 species). For Yucatán state, a greater *Passiflora* presence has been reported in Progreso (five species) (Fig. 1).

The number of *Passiflora* species recorded in Ocosingo is greater than the number of *Passiflora* species reported in each of the other 18 states in Mexico[9]. Additionally, Unión Juárez must be valorized for its *Passiflora* richness, as the municipality area is only 62 km^2[10].

Passiflora species grow mainly in family orchards and jungle systems[12,21]; the latter system is very sensitive to overexploitation of natural resources, pollution, and climatic change. Moreover, it is very responsive to demographic changes, public policies, and local technological projects[22].

Former and actual uses

To our knowledge, there are no reports of the use of *Passiflora* plants by ancient Mayan culture. However, ethnobotanical reports, written in the last three decades, indicate that in the Lacandón forest, native people eat the fruits of '*ch'um ak*" (*P. ambigua*), '*ch'ink ak'il*' (*Passiflora* sp.) '*poochin*' (*P. serratifolia*) and *P. hahnii*[12,13]. A recent review confirmed the consumption of *P. ambigua*, *P. bicornis*, *P. ciliata*, *P. foetida*, *P. hahnii*, *P. ligularis*, *P. mayarum*, *P. serratifolia,* and *P. yucatensis* fruits in communities of Chiapas and the Yucatan Peninsula[23].

In Yucatán state, the *P. ciliata* plant is used to treat hysteria, sleeplessness, and child convulsion; local people assign this species narcotic and sedative properties[24]. In the Chiapas High Valleys, *P. membranacea* liana is used as a rope to tie tools or help build rudimentary houses[21].

In the municipality of Solidaridad, Quintana Roo State, the staff of the butterfly pavilion of a theme park, crop at least two *Passiflora* species, one allegedly to be *P. lobata* ('pata de gallo' in Spanish), to raise butterfly larvae. The information within the park, mentions that they raise the butterflies *Agraulis vanillae*, *Dryas iulias*, *Heliconius erato*, and *H. charithonia*. Scientific literature supports the preference of butterfly larvae for *P. lobata*[25].

Potential uses

For centuries, some effects on the human body have been assigned to *Passiflora* plants. Moreover, in the Spanish language, the name of passion fruit was misunderstood, and many people have given aphrodisiac properties to *Passiflora* species, instead of relating its name to the passion of Christ[1]. Moreover, in plants of this genus, several molecules with spasmolytic, sedative, anxiolytic, and blood pressure modulation properties have been identified. One of those molecules is passicol, which has antibacterial properties. *P. foetida* leaf extracts reduce the growth of *Pseudomonas putida*, *Vidrio cholerae*, *Shigella flexneri,* and *Streptococcus pyogenes*, supporting the use of this plant in ethnopharmacology to treat fiber, diarrhea, stomach and throat pains, and ear and skin infections[26].

It has been suggested that the anthocyanin present in the peel of *P. biflora* might be used as an additive to increase color and

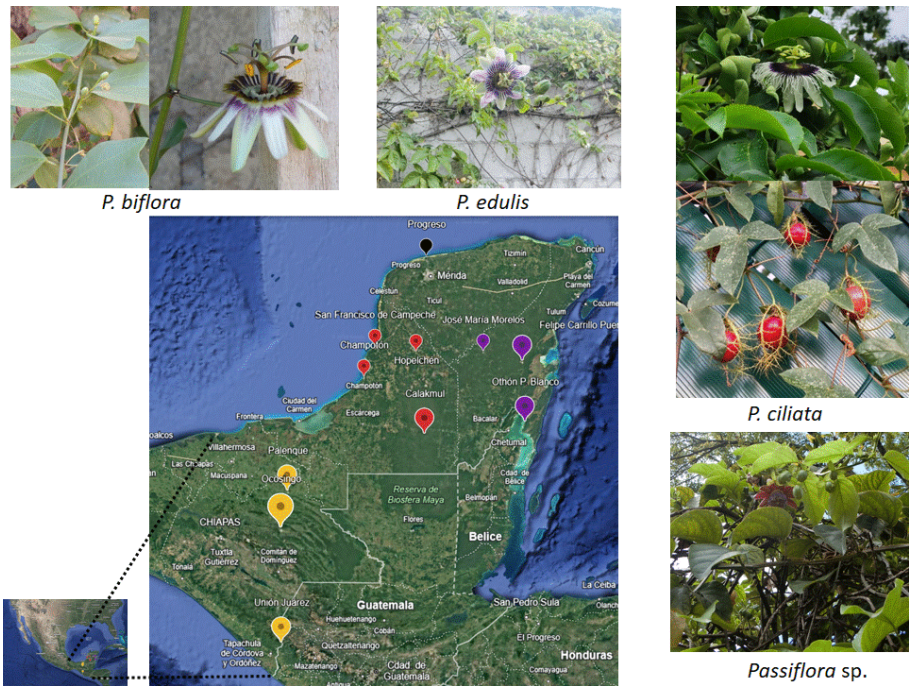

Fig. 1 Municipalities within Peninsula de Yucatán and Chiapas, Mexico, with greater botanical reports of *Passiflora* species. Chiapas (yellow) [Ococingo (19), Unión Juárez (9), and Palenque (8)], Campeche (red) [Calakmul (11), Holpechén (6), Campeche (5), and Champotón (5)], Yucatán (black) [Progreso (5)], and Quintana Roo (purple) [Othón P. Blanco (11), Felipe Carrillo Puerto (8), and José María Morelos (5)]. Four *Passiflora* species illustrate this genus diversity. Data of present work were marked on a map sourced from Google Earth.

antioxidant capacity in some human foods[27]. Additionally, pectin can be extracted from the *Passiflora* peel for human consumption[28], and it has been proposed to transform peel into biofuels[29]. As Brazil is a high yellow passion fruit producer, it has been proposed to produce passion fruit seed oil there. The oil might be used in human foods or transformed into creams, shampoos, and pharmacology products[30]. In addition, among the seed components, there are stilbenes, which are excellent antioxidants, enhance human skin conditions, and present hypoglycemic properties[31].

Conservation

In the Yucatan Peninsula, *Passiflora* is among the top five plant genera with relatively high diversity[17]. This richness might be used to breed, aiming for genotypes producing high-quality fruits and suitable for cropping in new areas[5,32]. Nevertheless, land use change represents one of the greatest risks to conserving actual biodiversity; this factor also contributes to increasing the rate of climatic change and affects ecosystem sustainability[33].

Quintana Roo state is one of the main tourist region's in Mexico, Cancun resort area is located there, and further luxury resorts are still planned. Mexican environmental law protects approximately 30% of the land of the municipality of Othón P. Blanco, Quintana Roo state[34]; and this municipality started policy programs for sustainable bay management, keeping its vegetation, including several medicinal plants[35]. In this sense, recently, the Mexican government involved some institutes in flora conservation. In the municipality of Solidaridad, Quintana Roo state, the Botanical Garden 'Dr. Alfredo Barrera Marín' belonging to the 'Centro de Investigaciones de Quintana Roo' is the repository of the flora native of the section North 5 of the project Maya Railway.

In general, in the four states under study herein, there are important archeological and touristic venues; thus, *Passiflora* conservation in southern Mexico might involve ethno-tourism, ecotourism, and other local developmental projects. Moreover, in the Yucatan Peninsula and Chiapas there are almost 17 areas named Nature Reserves. They are: 'Pantanos de Centla', 'Río Celestum', 'Río Lagartos', 'Sian Ka'an' 'Chinchorro', 'Caribe Mexicano', 'Tiburón ballena', 'El triunfo', 'La Encrucijada', 'La Sepultura', 'Lacan tún', 'Montes azules', 'Selva El Ocote', 'Volcán Tacaná', 'Calakmul', 'Balam ku', and 'Los Peténes'. Therefore, according to UNESCO, in nature reserves, effective fauna and flora protection policies might be observed[36].

The role of *Passiflora* plant species in conserving local fauna, and, by a consequence, help to keep the ecosystem balance, must be carefully understood. Several *Passiflora* species included in Table 1 have been reported to be good feed sources for animals. For example, *P. biflora* may play a role in conserving bats in the Lacandón forest[9]. For *Passiflora* species being bat-pollinated, it has been observed that their flowers are well adapted to bat behavior, as their flowers secrete nectar at night[37]. Moreover, it has been reported that some years after introducing *Passiflora* plants, the population of butterflies and bees was increased[9]. Some studies have revealed that *P. suberosa* is a good feed source for *A. vanillae maculosa* larvae, although less preferred by *D. iulia* caterpillar, who prefers leaves of *P. misera*[38,39].

Although tropical forest regeneration is possible, the predicted growth of urban areas is a risk factor[33] in reducing *Passiflora* diversity. On the other hand, some researchers have suggested that rural families contribute strongly to maintaining plant species[40]. Thus, reducing the poverty factor might be included in national, state, and municipality politics to recognize the importance of native and original communities in conserving plant genetic resources. For example, within the three municipalities with the greatest presence of *Passiflora* species, only Othón P. Blanco has less than 45% of its population living in poverty, whereas over 80% of the populations of Ocosingo and Calakmul live in poverty. In five of the six municipalities with a greater presence of *Passiflora*, the human population living in poverty is greater than 70%[41].

Although some countries offer payments to conserve plant genetic resources, they are limited to plant species presenting economic importance[42]. Thus, to involve local people in plant genetic conservation, projects aimed at sustainability, environment conservation, prosperity, and human welfare must be offered. The municipality, state, and national governments must establish laws and regulations to save jungles and mangroves. Further efforts to keep flora and fauna, in this case *Passiflora* species, in the areas with a higher presence of this genus, are expected to keep its holistic value and diversity.

Conclusions

The high diversity of *Passiflora* plants in Chiapas state seems to be related to the presence of five biographical provinces: 'Gulf of Mexico lowland', 'Chiapas central plateau', 'Chiapas central depression', 'Madre mountain range', and 'coastal lowland'. Within Chiapas state, Ococingo is the municipality with the highest *Passiflora* diversity.

Although there are no reports of the use of *Passiflora* in ancient Maya culture living in Chiapas, Campeche, Yucatán, or Quintana Roo states, the actual use of *Passiflora* suggests inherited knowledge. On the other hand, the agro-industrial and pharmacological potential of this plant genus might help promote sustainable regional development. The rescue of traditional fruit species and their ancient knowledge might enhance the local economy and maintain ecological balance.

Author contributions

The authors confirm contribution to the paper as follows: study conception and design: Franco-Mora O; data collection: Franco-Mora O, Moreno-Jiménez A; analysis and interpretation of results: Franco-Mora O, Sánchez-Pale JR; draft manuscript preparation: Franco-Mora O, Castañeda-Vildózola Á. All authors reviewed the results and approved the final version of the manuscript.

Data availability

The herbarium MEXU, HERBANMEX, and CICY offers free access to their on line database; they are cited in the References section[13–15]. Data from herbaria CHAPA (16) is available at the Institute.

Acknowledgement

The herbaria exemplars, consulted herein, represent the work of several botanists. The picture of *Passiflora ciliata* was kindly donated by Prof. Elia Ballesteros-Rodríguez (CICY, Yucatán, Mexico).

Conflict of interest

The authors declare that they have no conflict of interest.

Dates

Received 25 October 2024; Revised 21 January 2025; Accepted 24 January 2025; Published online 4 March 2025

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