Distribution of *Persea schiedeana* in Mexico and Potential for the Production of Fruits with High-quality Oil

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Abstract. The fruit of *Persea schiedeana* is consumed in various rural regions of Mexico and Central America and is mainly sold in local markets. Information regarding the ecological conditions where it grows and the potential for its distribution in Mexico has been little studied. The States of Chiapas, Hidalgo, Oaxaca, Puebla, Tabasco, and Veracruz in Mexico were explored to locate *P. schiedeana* trees. The ecological conditions of the places where *P. schiedeana* was found were characterized using thematic cartography and by evaluating the ecological niches to identify potential areas for its distribution. The trees were found in wide physiographic, geological, and edaphic conditions, but they were primarily located in semiwarm humid and warm humid climates. *Persea schiedeana* trees grow from almost sea level to 2000 m in altitude. Zones with the best developmental conditions for *P. schiedeana* were in the region of the high mountains in the center of Veracruz and the highland zone of northern Oaxaca. The oil obtained from the fruit of *P. schiedeana* trees growing at 1300 m had high oleic acid content. This wild fruit has the potential for obtaining new products for cosmetic and alimentary industries.

Persea schiedeana Nees., a fruit tree native to Mexico and Central America, belongs to the Lauraceae family (Galindo-Tovar et al., 2008). In Mexico it is called “chinene” or “chinin” and in Guatemala “chucte.” Trees can reach 25 m in height and the size and shape of the fruit resemble avocado (*Persea americana* Mill). It is attractive as a fresh product. In Mexico it is consumed by spreading the pulp of the fruit on maize tortillas and in Guatemala by adding the pulp to black bean soup. It is also a popular food in Honduras and El Salvador.

There are no commercial orchards of *P. schiedeana* in Mexico and Central America; however, in Oaxaca, Mexico, trees are artificially irrigated in home gardens during the dry season (Gómez-Pompa et al., 2010). *Persea schiedeana* grows wild mainly in the Mexican states of Oaxaca, Puebla, Tabasco, and Veracruz (GBIF, 2013; Joaquín-Martínez et al., 2007; Sánchez-Pérez, 1999). Fruit collected in the rainforest and/or home gardens can be found in regional markets of Veracruz, Mexico (Ibarra-Manríquez et al., 1997), and

Guatemala between June and September. In Cuetzalan del Progreso, Puebla, Mexico, the fruit is sold in the local market without its seed, and is called “chinene capado” (seedless chinene). Mammalian fauna in coffee plantations consume *P. schiedeana* fruit and the tree provides shelter and protection from predators (Gallina et al., 1996). In avocado production, ‘Martin Grande’, a hybrid between *P. schiedeana* and *P. americana*, has been tested as a rootstock to combat phytophthora root rot (Coffey et al., 1988).

Persea schiedeana trees are used for shade in coffee plantations in Veracruz, Puebla, and Oaxaca, Mexico (Bost, 2014; Del Angel-Coronel et al., 2010), and they have been determined satisfactory for carbon sequestration in the highlands of Veracruz, Mexico (Melchor-Marroquín et al., 2014). However, there is little information regarding the soil and climatic conditions where *P. schiedeana* grows, and the potential areas where *P. schiedeana* could achieve high fruit yield are unknown.

There are no registered cultivars of *P. schiedeana* for human consumption. An increase in the fruit production of *P. schiedeana* with selected trees has been recommended to improve food security, and the economy of local agriculture in the tropics of Mexico and Central America (Bost, 2014).

Persea schiedeana is a climacteric fruit with a postharvest life span of only 3–5 d

(Del-Angel-Coronel et al., 2010). Thus, processing the fruit pulp could be an option for extending its use and making it available for consumers. The fruit oil potential of *P. schiedeana* has been demonstrated in a few studies (Cruz-Castillo et al., 2007; Joaquín-Martínez et al., 2007), but the concentrations of the main fatty acids of the oil need to be confirmed.

The aims of the present study were to determine the environmental characteristics where *P. schiedeana* grows and its potential for distribution in Mexico, and to demonstrate the capacity of the tree for production of fruits with high-quality oil.

Materials and Methods

Localization of *P. schiedeana* in six states of Mexico. General indications about places where *P. schiedeana* has been reported were obtained from the herbarium of the National Institute of Ecology in Xalapa, in Veracruz, Mexico. Those places as well as nearby areas were explored. The trees found were localized using a GPS-12 Channel Garmin personal navigator, which gave the exact latitude (N), longitude (W), and altitude (m). *Persea schiedeana* trees (n. 146) were georeferenced in the states of Oaxaca, Veracruz, Tabasco, Puebla, Hidalgo, and Chiapas. A maximum of three trees per municipality are shown in Table 1.

Ecological characterization and zoning. The ecological conditions of the sites georeferenced for the presence of *P. schiedeana* trees were characterized using the cartographic analysis of thematic and digital maps obtained from the National Institute of Statistics and Geography (INEGI, 2002, 2004, 2006, 2014) and from the Autonomous University of Chapingo, Mexico (Gómez et al., 2006).

For each georeferenced tree, information regarding the physiographic province, type of rock, soil type and texture, mean monthly temperature, mean yearly temperature, average monthly and average annual precipitation, and climate was obtained using ArcMap® modified by Köppen. With this information, a geographic database was elaborated to describe the habitat of *P. schiedeana*.

A cluster analysis using climatic and soil data was performed using the Ward method (Di Rienzo et al., 2016), and groups with homogeneous distribution of *P. schiedeana* trees in zones of Mexico were identified (Núñez, 2010). With the records of precipitation and mean monthly temperatures in each cluster, a climograph was generated and the climatic classification was obtained according to the system of Köppen modified by García (1988).

Potential for distribution. The DIVA-GIS® software was used to develop a climatic model for the potential distribution of *P. schiedeana* in Mexico using georeferenced trees and the database of WorldClim with a spatial resolution of 2.5 min. The potential distribution of *P. schiedeana* was made on

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Table 1. Coordinates [latitude (N), longitude (W)] of *Persea schiedeana* trees (n. 88) located in municipalities of six Mexican states. A maximum of three trees per municipality are shown.

ID	State	Municipality	Latitude	Longitude
1	Oaxaca	Chinantla	17°44'24.6"	-96°33'31.6"
2	Oaxaca	Chinantla	17°44'24.6"	-96°33'31.5"
3	Oaxaca	Chinantla	17°44'22.8"	-96°33'31.5"
4	Oaxaca	Santa Catarina Juquila	16°44'22.3"	-97°17'40.6"
5	Oaxaca	Candelaria Loxicha	15°57'16.2"	-96°28'46"
6	Oaxaca	Candelaria Loxicha	15°57'17.1"	-96°28'44.6"
7	Oaxaca	Pluma Hidalgo	15°56'40.7"	-96°24'5.3"
8	Oaxaca	Santiago Comaltepec	17°36'2.2"	-96°25'3"
9	Oaxaca	Santiago Comaltepec	17°37'55"	-96°20'33.1"
10	Oaxaca	Santiago Comaltepec	17°42'25"	-96°17'59"
11	Oaxaca	S. Juan Bautista Tuxtepec	17°45'18.8"	-96°19'9"
12	Oaxaca	S. Juan Bautista Tuxtepec	17°48'30"	-96°19'30"
13	Oaxaca	S. Juan Bautista Tuxtepec	17°49'50.7"	-96°19'51.5"
14	Oaxaca	Guevea de Humbolt	16°48'7.2"	-95°22'25.1"
15	Oaxaca	San Bartolomé Zoogocho	17°17'2"	-96°13'21"
16	Oaxaca	Tanetze de Zaragoza	17°22'6"	-96°17'54"
17	Oaxaca	Tanetze de Zaragoza	17°22'40"	-96°17'52"
18	Oaxaca	San Juan Yae	17°25'36"	-96°17'2"
19	Oaxaca	Villa Talea de Castro	17°23'3"	-96°16'8"
20	Oaxaca	Villa Talea de Castro	17°23'2"	-96°16'8"
21	Oaxaca	Santiago Lalopa	17°25'20"	-96°13'30"
22	Oaxaca	Santiago Lalopa	17°24'29"	-96°15'23"
23	Oaxaca	San Juan Lachao	16°10'9"	-97°5'43"
24	Oaxaca	San Gabriel Mixtepec	16°5'47"	-97°5'43"
25	Oaxaca	San Gabriel Mixtepec	16°4'29"	-97°4'8"
26	Oaxaca	San Gabriel Mixtepec	16°4'25"	-97°4'4"
27	Veracruz	Orizaba	18°51'26.6"	-97°4'22.4"
28	Veracruz	Orizaba	18°51'27.2"	-97°4'23.3"
29	Veracruz	Orizaba	18°51'20.1"	-97°4'24.3"
30	Veracruz	Cuichapa	18°46'24.5"	-96°52'15.3"
31	Veracruz	Cuichapa	18°46'17.3"	-96°52'16.2"
32	Veracruz	Cuichapa	18°46'15.2"	-96°52'12.3"
33	Veracruz	Amatlan de los Reyes	18°51'18.5"	-96°54'47.7"
34	Veracruz	Tezonapa	18°33'20.4"	-96°43'6.3"
35	Veracruz	Tezonapa	18°32'27.2"	-96°46'6.3"
36	Veracruz	Tezonapa	18°32'21"	-96°46'7.9"
37	Veracruz	Huayacocotla	20°33'44.4"	-98°26'36.2"
38	Veracruz	Huayacocotla	20°33'44"	-98°26'36.9"
39	Veracruz	Huayacocotla	20°33'43.8"	-98°26'36.9"
40	Veracruz	Ixhuatlán del Café	19°2'20.7"	-96°55'23.3"
41	Veracruz	Ixtaczoquitlan	18°52'23.8"	-97°1'42.9"
42	Veracruz	Ixtaczoquitlan	18°52'21.1"	-97°1'40.7"
43	Veracruz	Ixtaczoquitlan	18°52'21.6"	-97°1'44.3"
44	Veracruz	Huatusco	19°9'14.8"	-96°58'29.8"
45	Veracruz	Huatusco	19°9'15"	-96°58'30.6"
46	Veracruz	Huatusco	19°9'16.7"	-96°58'33.8"
47	Veracruz	Tlaltetela	19°18'57.5"	-96°54'26.8"
48	Veracruz	Omealca	18°45'46.1"	-96°49'31.6"
49	Veracruz	Omealca	18°45'42.1"	-96°49'26.4"
50	Veracruz	Omealca	18°45'36"	-96°49'7"
51	Veracruz	Juchique de Ferrer	19°49'48.4"	-96°41'6.4"
52	Veracruz	Juchique de Ferrer	19°47'39.2"	-96°40'49.2"
53	Veracruz	Juchique de Ferrer	19°47'22"	-96°41'30.8"
54	Veracruz	Chiconquiaco	19°43'47.2"	-96°43'30.4"
55	Veracruz	Chiconquiaco	19°43'44.5"	-96°43'35.3"
56	Veracruz	Chiconquiaco	19°43'39.5"	-96°43'29.4"
57	Tabasco	Nacajuca	18°7'9"	-93°22'1"
58	Puebla	Cuetzalan	20°2'9.3"	-97°32'12.2"
59	Puebla	Cuetzalan	20°2'27.2"	-97°32'10.8"
60	Puebla	Cuetzalan	20°3'18.6"	-97°32'13.9"
61	Puebla	Tlatlauquitepec	19°55'49"	-97°55'19.2"
62	Puebla	Tlatlauquitepec	19°55'5.3"	-97°27'1'24"
63	Puebla	Ahuacatlan	20°0'18.51"	-97°51'35.66"
64	Puebla	Jalapan	20°25'54.69"	-97°51'8.65"
65	Puebla	Jalapan	20°24'20.25"	-97°52'31.08"
66	Puebla	Xicotepec	20°16'2.15"	-97°57'32.02"
67	Puebla	Xicotepec	20°15'56.61"	-97°57'51.45"
68	Puebla	Zihuatehutla	20°15'33.97"	-97°51'15.8"
69	Puebla	Zihuatehutla	20°17'20.98"	-97°47'16.15"
70	Puebla	Zongozotla	19°59'14.16"	-97°43'55.08"
71	Chiapas	Ixtacomitan	17°27'34.3"	-93°6'4"
72	Chiapas	Ixtacomitan	17°25'37.3"	-93°6'13.8"
73	Chiapas	Ixtacomitan	17°22'8.4"	-93°6'35"

(Continued on next page)

the basis of the ecological niche method (Hijmans et al., 2005) and only data regarding precipitation and temperatures were used.

Fatty acid profile of the oil. The fatty acid composition of the oils from *P. schiedeana* pulp was evaluated in 2015 on oils extracted from fruit of three different trees growing wild in the central part of the state of Veracruz at an altitude of 1300 m. The trees were selected due to the good flavor of the pulp according to growers, and all the fruit had black skin. All the fruit was analyzed at consumption maturity. The fresh weight of the samples was between 190 and 267 g. The seedling trees were about 30 years old and 20–25 m high. A completely randomized design was conducted using each tree as a treatment with 10 fruits per tree as replications. Analysis of variance was performed and the comparison of means was carried out using the Tukey's test (0.05) (Di Rienzo et al., 2016).

The oil was extracted using chloroform and methanol following the methodology described by Joaquín-Martínez et al. (2007). The fatty acid composition of the oil was determined as in Portarena et al. (2015). Fatty acids were converted to methyl esters before analysis by shaking a solution of 0.2 g oil and 3 mL of hexane with 0.4 mL of 2 N methanolic potassium hydroxide. After separation through a 100% dimethyl-polysiloxane VF-wax Varian column (30 m length, 0.25 mm i.d., and 0.25 µm film thickness) with a split/splitless injector (1/10 ratio), the methyl esters were analyzed using a GC-FID detector. The temperatures of the injector and detector were held at 220 and 250 °C, respectively. The injection volume was 1 µL. Preliminary peak identification was carried out by comparison of retention times with known standards. Fatty acids were designated according to standard notation (total number of carbon atoms: number of double bonds, followed by the position of the double bond from the methyl end of the molecule) as described by Peacock et al. (2001).

Results and Discussion

Ecological characterization. The spatial distribution of *P. schiedeana* trees was positioned between the maximum coordinates 20°50'24" and 15°56'42" north latitude, and 98°37'4.8" and 92°59'49.2" west longitude in Mexico. The altitudinal range of the trees was between 4 m (Nacajuca, Tabasco) and 2147 m (Chinantla, Oaxaca). The distribution of *P. schiedeana* in Mexico had a greater range as compared with that indicated by Sánchez-Pérez (1999), who established the presence of *P. schiedeana* primarily in the states of Veracruz and Tabasco. With the system of global biodiversity information facility (GBIF, 2013), *P. schiedeana* was located in San Luis Potosí, northeastern Chiapas, and southern Quintana Roo, Mexico. Likewise, Joaquín-Martínez et al. (2007) recorded the presence of *P. schiedeana* in Tuxtla, Veracruz, Mexico, in plant communities of tall evergreen jungles,

Table 1. (Continued) Coordinates [latitude (N), longitude (W)] of *Persea schiedeana* trees (n. 88) located in municipalities of six Mexican states. A maximum of three trees per municipality are shown.

ID	State	Municipality	Latitude	Longitude
74	Chiapas	Chapultenango	17°19'16.2"	-93°9'31.3"
75	Chiapas	Chapultenango	17°18'31.8"	-93°9'56.2"
76	Chiapas	Chapultenango	17°18'31.9"	-93°10'55.8"
77	Chiapas	Francisco León	17°17'29.4"	-93°12'28.3"
78	Chiapas	Francisco León	17°17'25.1"	-93°12'31.7"
79	Chiapas	Francisco León	17°17'20.8"	-93°12'40.6"
80	Chiapas	Tecpatan	17°13'7.1"	-93°20'31.1"
81	Chiapas	Copainala	17°7'36.2"	-93°16'20.5"
82	Chiapas	Copainala	17°7'33.3"	-93°15'49.1"
83	Hidalgo	Xochicoatlán	20°50'23.4"	-98°36'56"
84	Hidalgo	Xochicoatlán	20°50'23.6"	-98°36'56.93"
85	Hidalgo	Xochicoatlán	20°50'23.2"	-98°36'56.3"
86	Hidalgo	Tiangustengo	20°50'6.2"	-98°35'32.1"
87	Hidalgo	Tiangustengo	20°50'12.7"	-98°35'22.9"
88	Hidalgo	Tiangustengo	20°50'13.02"	-98°35'22.4"

Fig. 1. Dendrogram by the method of Ward of 146 data of collected of *Persea schiedeana* Nees using variables of soil and climate.

mountainous mesophyll forests, and coniferous forests. The georeferenced sites were located in five physiographic provinces: Sierra Madre Oriental, Neo-Volcanic Axis, the

Coastal Plain of the Southern Gulf, Sierra Madre del Sur, and Sierras of Chiapas in Mexico and Guatemala. The largest presence of *P. schiedeana* was recorded in the

provinces of Sierra Madre del Sur and Sierra Madre Oriental in Mexico with 36.3% and 28.8% of the sites, respectively. The types of rock where *P. schiedeana* grew were the ancient rocks of sandy lutite that date from the Paleozoic era in Hidalgo and Puebla (Sierra Madre Oriental), and in Oaxaca (Sierra Madre del Sur). In contrast, the most recent geological records were positioned in the Sierras of Chiapas, Mexico, and Guatemala in the quaternary period on andesite rock in the physiographic provinces of Sierras de Chiapas and Guatemala in the State of Chiapas, Mexico, and in the volcanic tuff in the Neo-Volcanic Axis of the state of Veracruz. The trees were also found on alluvial deposits and palustres of the quaternary period, principally in the Province of Llanura Costera in the Southern Gulf of Mexico in the states of Veracruz and Tabasco. In general, the lower cretaceous calcareous rock type had the most sites referenced with 13% of the total; this geological unit is located in the Provinces of Sierra Madre Oriental in northern Puebla, Neo-Volcanic Axis in the central part of Veracruz, and in the Sierra Madre del Sur in northern Oaxaca.

The climate types (Köppen modified by García, 1988) where *P. schiedeana* trees were found were warm humid (31.5%), warm subhumid (7.5%), semiwarm temperate humid (56.2%), temperate humid (3.4%), and temperate subhumid (1.4%). The trees in semiwarm temperate humid climatic conditions were found in the windward zones of Sierra Madre Oriental (Hidalgo and Puebla), in the Neovolcanic axis (Veracruz), and in Sierra Madre del Sur (Oaxaca). With regard to precipitation, all of the *P. schiedeana* trees were distributed in areas that received between 900 mm (San Bartolomé Zoogocho, Oaxaca) and 5200 mm (Santiago Comaltepec, Oaxaca) of precipitation. Most of the trees (17.8%) received 2200–2400 mm of annual rainfall in the highland zones of eastern Hidalgo, the center of Veracruz, and north central Oaxaca. Only 11.6% of the trees received an annual rainfall between 2000 and 2199 mm. All the trees grew in areas that had a mean annual temperature between 15 and 27 °C, with 24.7% of the total growing in areas with temperatures 20–21 °C. They were found in the windward zone of Sierra Madre Oriental (Hidalgo, Veracruz, and Puebla), Neovolcanic Axis (center of Veracruz), and in Sierra Madre del Sur (northern Oaxaca). The monthly variation of the temperature in the georeferenced sites shows an average minimum monthly value of 12.7 °C in January and an average maximum monthly value of 29.1 °C in May.

Persea schiedeana trees were distributed from almost sea level to a little more than 2000 m in altitude. This species can adapt to various physiographic conditions, geological stratum, and soil types. The trees were primarily located in semiwarm and warm humid areas with a low presence in temperate climates. This suggests low resistance to heavy frost and extended periods of drought,

conditions that influenced the plant in the course of its evolution (Zunino and Zullini, 2003).

Persea schiedeana was found on 19 different types of soil: 20.5% of the trees were found on lithosol, 14.4% on haplic phaeozem, and 13% on chromic vertisol. Lithosol soil type was found in the municipalities of Cuetzalan del Progreso (Puebla), Ixtaczoquitlán (Veracruz), Francisco León (Chiapas), Cosolapa (Oaxaca), San Felipe Usila (Oaxaca), and Santa Catarina Juquila (Oaxaca); 53.4% of the soil texture was fine sand, and 46.6% medium sand in the upper 30 cm.

Zoning. Three different edapho-climatic clusters were identified (Fig. 1). Cluster 1 encompassed the northern zones of the states of Puebla, Oaxaca, and Chiapas (Fig. 2). Cluster 2 included the eastern part of Hidalgo and its boundaries with Veracruz, the center of Veracruz, and the region of north-central Oaxaca (Fig. 2). Cluster 3 included northern Puebla, Sierra de Zongolica in Veracruz, the north-central and southern parts of

Oaxaca, in Tabasco, and western Chiapas (Fig. 2).

The climograph obtained in each cluster (Fig. 3) shows that cluster 1 grouped 58 georeferenced sites with a mean annual precipitation of 2074 mm and a mean annual temperature of 19.5 °C. The mean minimum temperature was 15.9 °C in January, and the mean maximum temperature was of 22.4 °C in May. The rainiest month was September with 377.2 mm of precipitation.

Cluster 2 grouped 43 sites, with precipitation of 2287.9 mm and a mean annual temperature of 23.2 °C. The minimum temperature was 19.8 °C in January and the maximum was 25.9 °C in May. The rainiest month was September with 416.6 mm. Cluster 3 grouped 45 sites, with a mean annual precipitation of 22.1 °C and with the highest precipitation in comparison with the other clusters (4012.6 mm). As in the other clusters, September was the month with highest rainfall (623.3 mm). January was also the coldest month with 18.8 °C and May the hottest month with 24.9 °C.

Cluster 1 had a semiwarm temperate humid climate, whereas clusters 2 and 3 had a warm humid climate. A similar characteristic in all the clusters was the presence of slight dryness in August. The main types of soil in each of the three clusters were lithosol and rendzina (1), andosol humic and vertisol (2), and lithosol, chromic vertisol, and eutric regosol (3).

Potential distribution. The best potential areas for the development of *P. schiedeana* in Mexico, determined using DIVA-GIS® software, were the mountainous zone of the center of Veracruz (Fig. 4) (Municipalities of Zongolica, Amatlán de los Reyes, Córdoba, Tequila, Orizaba, and Ixhuatlán de Café), and the highland zones of medium altitude in the north of Oaxaca. A medium level of aptitude for *P. schiedeana* development was determined to be the zones surrounding the regions with maximum potential in the states of Veracruz and Oaxaca, as well as the northeastern part of the state of Chiapas and the areas where Hidalgo, Veracruz, and Puebla converge (Fig. 4). A low level of aptitude for *P. schiedeana* appears to be in warm conditions in the plain zones of the southern part of Veracruz, the east and west of Tabasco, and southern Campeche (Fig. 4). Avocados growing in warm tropical conditions produce less oil (Gómez-López, 1998); this may be similar for *P. schiedeana*. A fruit sample of *P. schiedeana* harvested in Tabasco had less oleic acid (%) than fruit from a highland area of Veracruz (Cruz-Castillo et al., 2007). *Persea schiedeana* trees are scattered in pastures of Tabasco and Chiapas (Nahed-Toral et al., 2013).

The present study provided useful information for specifying zones where *P. schiedeana* could adequately grow alone or in production systems. Furthermore, the clusters could serve as a tool for improving exploration to collect germplasm. For example, to search for rootstocks of *P. schiedeana* with tolerance to phytophthora root rot of avocado, it may be better to explore the high humid areas. Explorations to collect *P. schiedeana* have been carried out in Guatemala, El Salvador, Costa Rica, and Chiapas, Mexico (Schieber and Zentmyer, 1978). Future studies are aimed at evaluating the potential for *P. schiedeana* distribution in stages of climatic

Fig. 2. Spatial distribution of clusters of *Persea schiedeana* Nees in Mexico.

Fig. 3. Climographs of the three different clusters as potential ecological zones of distribution of *Persea schiedeana* Nees in Mexico.

Fig. 4. Potential distribution of *Persea schiedeana* Nees in Mexico using the WorldClim database.

Table 2. Fatty acids (%) found in the oil of *Persea schiedeana* fruits in three different trees. Means of ten fruits for each tree.

Trees	Palmitic	Palmitoleic	Estearic	Oleic	Linoleic	Linolenic
1	19.92 a	4.65 a	1.55 b	64.66 b	5.90 a	0.58 b
2	17.40 b	4.70 a	1.71 a	67.10 b	4.51 b	0.48 c
3	15.45 c	0.74 b	1.25 c	76.25 a	3.99 c	0.75 a

Means followed by different letters within each column are significantly different at $P \leq 0.05$ by Tukey's method.

change, due to the impact that climatic variability can exert on the phenology and distribution of the species (Monterroso et al., 2012; Tinoco et al., 2011). It is also recommended to carry out ethnobotanic explorations to identify the different uses of *P. schiedeana* in the local communities.

Fatty acid profile of oil of *P. schiedeana* fruit. It has been reported that the fruit has a percentage of oil between 20% and 27% (Joaquín-Martínez et al., 2007). Use of other methods for oil extraction could increase these values. The palmitic, palmitoleic, stearic, oleic, linoleic, and linolenic acids in the fruit oils from three different trees were significantly different ($P \leq 0.05$) (Table 2). Oleic acid ranged from 64.66% to 76.25% ($P \leq 0.05$), indicating significant differences due to the tree/genotype from which the fruits were collected. The tree with the highest value of oleic acid had the lowest values of all the other fatty acids, with the exception of linolenic acid (Table 2). According to Goldschmidt (2013), *P. schiedeana* is at an intermediate stage of domestication because although it is grown in home gardens it still remains wide in several tropical zones of Mexico and Central America. The large variability found in the fatty acid composition of the three tree samples indicates that through a selection procedure it could be

possible to select genotypes which could produce oils with very high values of oleic acid, which is known to have positive effects on the nutritional value of the oil (Inglese et al., 2011). Indeed, the values were comparable to those of extra-virgin olive oils, for which the Trade Standard of the International Olive Council prescribes that oleic acid must range from 55% to 83%; values higher than 73% significantly contribute to the nutritional value of the oil (Inglese et al., 2011). However, in olive oils, the composition of fatty acids can be very different depending on the environmental conditions, cultivar, and ripening stage of the fruit (Chehade et al., 2016; Inglese et al., 2011; Jbara et al., 2010). Also in avocado, the content and the composition of the fatty acids of the oil depend on different factors, such as the cultivar, time of harvest, and postharvest maturation period. Avocados growing in warm tropical conditions produce less oil (Gómez-López, 1998); this may be similar for *P. schiedeana*. A fruit sample of *P. schiedeana* harvested in Tabasco had less oleic acid (%) than fruit from a highland area of Veracruz (Cruz-Castillo et al., 2007). The effects of these factors on the oil of *P. schiedeana* are not known. However, in this study, the trees were in the same area and the fruits appeared to be at a similar stage of ripening; therefore, it is

likely that, as stated above, the differences in the fatty acid composition of the oils are due to the tree/genotype.

Conclusions

Persea schiedeana trees were found throughout the Mexican states of Oaxaca, Veracruz, Tabasco, Puebla, Hidalgo, and Chiapas. Three groups of distribution of *P. schiedeana* in Mexico were identified on the basis of temperature and rainfall. These were characterized by semiwarm temperate humid and warm humid climates. The best places for growing *P. schiedeana* are in the mountains of the center of Veracruz and northern Oaxaca. Fruit of *P. schiedeana*, besides being consumed directly, could be used for processed products because it contains a high amount of oleic acid. In future prospectations of *P. schiedeana*, the information shown in this article could be considered.

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