

Review

A review on the geographical distribution, fruit production and concentration of capsaicinoids in *Capsicum annuum* var. *glabriusculum* in the northeastern region of Mexico

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Abstract: *Capsicum annuum* var. *glabriusculum*, is a variety of wild chili pepper belonging to the family Solanaceae and is considered as the origin for all cultivated chili species of the world. This species is an important genetic resource for agriculture and food, is widely distributed in northeastern Mexico in altitudes from 0 – 1200 m.a.s.l. This species grows mainly at low altitudes and its upper limit reaches 1000m., it prefers temperatures above 18.3°C and its production and harvest may occur at two seasons, one during the beginning of the summer and the main one occurring in the middle of the autumn in northeast México. It is estimated that the main production occurs in the state of Tamaulipas with 84 tons per year and is harvested from 23 municipalities. Concentration of capsaicins and dihydrocapsaicine from wild populations may vary considerably from one location to another in the municipalities, ecotypes and diverse climatic conditions from this wide geographic zone. The high demands of wild chili as well as the variability on concentration of capsaicins in fruits are considered as some of the main reasons why intensive cultivation of this species should be carried out in Northeastern Mexico.

Key words: distribution, species, wild chilli pepper, *Capsicum annuum* var. *glabriusculum*

1. Introduction

The genus *Capsicum* was originated in Southamerica [1], and it is believed that both Mexico y Central America could also be considered as a diversity spot for the taxa [2,3] and it is classified as an important genetic resource for agriculture and food [4,5]. *Capsicum annum* L., is one of the cultivated species that has more varieties, it has economical medical and industrial importance in order to obtain food, capsaicinoids, carotenoids and antioxidants [6].

Wild chili pepper populations have a wide geographic distribution in México, Central America and South of the United States of America [7]. Some studies have stated that the wild chili pepper *Capsicum annum* var. *glabriusculum* (also known as chile piquín, chiltepin or chile del monte) is the progenitor for all cultivated varieties in the world [1,8,9]. It is well known that the center of origin for this variety is restricted to two important zones in Mexico. The first one is located at the municipality of Ocampo in the state of Tamaulipas and the second is located Tehuacán, Puebla in the center south zone of Mexico. This since seeds have been found in some caves located in these two sites, and this comes to confirm the beginning of domestication for the species [10,11].

Although there are not official records regarding fruits production under a cultivation system, it is estimated that there are some small cultivation systems for *Capsicum annum* var. *glabriusculum* in the states of Tamaulipas and Sonora [12].

The high demand of fruits of this species has led to carry out studies of its morphology and phytochemistry in order to demonstrate the existence of a great diversity of shapes and colors and concentrations of capsaicine [12,13]. These concentrations are apparently related to precipitation ranges, type of soil, light intensity, temperatures and humidity rates during development of plants and fruit age [14,15].

Some studies states that pungency of red fruits is due to the synthesis and accumulation of capsaicinoids characteristics from the genus *Capsicum*. These are secondary metabolites originated in the seed testa [16], and capsaicine is the most important element including dihydrocapsaicine, nordihydrocapsaicine, homocapsaicine and homodihydrocapsaicine [12,13,17]. It has been confirmed that capsaicin and dihydrocapsaicin build up approximately 90% of the total content of capsaicinoides in chili [18,19].

According to the genetic studies carried out by [8,20,21], there are high levels of genetic variation in and out of the populations of wild chili peppers in Mexico. Also, there are high differences in the percentage of germination of seeds and a high resistance against the huasteco chili virus (PHV) [22].

This study had as a main aim to make a review on geographic distribution, fruits production and concentrations of capsaicins in *Capsicum annum* var. *glabriusculum* in wild populations from Northeastern Mexico.

2. Genus *Capsicum*

The genus *Capsicum* L. (family Solanaceae, subfamily Solanoideae) includes approximately 32 species originated in America [23,24]. Five of these varieties have been domesticated as food the next five: *C. annum* L., *C. frutescens* L., *C. baccatum* L., *C. pubescens* Ruiz. & Pav., y *C. chinense* Jacq. [25,26]. However, it is considered that *C. annum* is the species with higher economic importance and is the only one native from Mexico [27].

C. annum includes a high variety of shapes, colors and fruits both wild and cultivated [15]. This condition has propitiated a complication on the taxonomy of the species [26]. Studies on these subjects have been carried out throughout the time by different authors [26,28-33].

Although the center of origin of *Capsicum* is generally recognized from Southamerica [34], studies on isoenzymes indicate that the east of Mexico is the first domestication center of *C. annum*, including the state of Tamaulipas [27]. In general, most researchers agree that the progenitor for the

cultivated *C. annuum* var. *annuum*, originated from the wild *C. annuum* var. *glabriusculum* [35]. Even if the genetic variation of wild populations of *C. annuum* has been shown to be high, there is evidence of genetic fluxes occurring between them [36].

Also, the nomenclature used for identifications of wild chillies i.e. *C. annuum* is variable as e.g. *C. annuum* var. *minus* (Fingerh.) Shinnars, *C. annuum* var. *minimum* (Mill.) Heiser, *C. annuum* var. *aviculare* (Dierb.) D'Arcy & Eshbaugh, y *C. annuum* var. *glabriusculum* (Dunal) Heiser & Pickersgill. *C. annuum* var. *glabrisuculum* is currently the most commonly accepted variety [37], but recent studies have proposed the use of *C. hispidum* Dunal var. *glabriusculum* Dunal [38].

In this study wild chili peppers are recognized as *C. annuum* var. *glabriusculum* [39]. They are perennials herbaceous plants, subfrutescents, erected of 0.5 to 2 m tall; with simple leaves, lanceolate to ovate, of 2-8 cm long; with solitary flowers and a rotated campanulate white corolla; the fruit is a berry, ovoid to globose, of 8 to 10 mm long, green brilliant color changing to orange or red color at maturity; seeds are compressed, pale yellow of 2.5 mm long [40].

2.1. Traditional uses

Chili is considered as one of the first cultivated plants from Mesoamerica and its continued use is confirmed from 7000 to 5000 years A.C [41,42]. The wild chili pepper also known as chile piquín (*Capsicum annuum* var. *glabriusculum*) is very important in the Mexican culture and was used as food since prehispanic times [43]. It is used daily in the Mexican diet, either fresh green or red or dried, in dust, in brine, sauces, salads, moles, stuffed chili, sweet candies and many other presentations [44,45]. Among the main uses of the chili in México are: *Ceremonial*: Used by curanderos in different ceremonies, such as “cleaning” referring to avoid the bad vibes and is commonly used as cure for evil eye [42]. It is used in ceremonial foods, rituals, and special parties, as for example with the Huicholes [46]. *Medicinal*: it is known that they were used by prehispanic ethnic groups e.g. Aztecs used them to heal tooth ache, ear infections, constipation and labor pains [42], and these types of use were appreciated by the first Spaniards in America [47]. It is used for the digestive system against dyspepsia, is also used for toothache, diarrhea, ear pain, cough and to lower fever, since the capsaicin activates blood circulation. There are some medicines that have been obtained from oleoresins from *Capsicum* spp., they act at the mucosa’s alleviating respiratory ailments [42]. May be the most popular remedy using chili in food for hangover [48]. It was also used as punishment by the Aztecs as depicted at the Mendocino Code, they would make bad boys or children to inhale smoke from burning dried chilies. It is still used to stop children from sucking their fingers or to stop them from using the pacifier [25]. Chili is also used mixed up with soap, onions and garlic as repellent against aphids in cultivated plants [42]. *Ornamental*: Chili is considered as an emblematic plant from the Mexican culture and it is used as ornament in dishes, altars, religious parties and amulets amongst others [42]. *Gastronomic*: May be this is the most common and important use in Mexico. There are many recipes using wild chili peppers and is considered as an important part of the gastronomy from different regions from Mexico such as the semi-desertic areas and the Sierra Gorda de Querétaro and San Luis Potosí [48-50].

Another very important use of chili is in cosmetics, paints and foods and at the industry it is used to obtain oleoresins, and from them Capsaicin is obtained, and used in human and animal food e.g. birds and even in personal defense [12,51,52].

2.2. Geographic distribution and ecology

Capsicum annuum var. *glabriusculum* is widely distributed in Mexico, south of the United States of America, Central America, Colombia and down up to many regions in Perú [1,7]. In Mexico, this species is registered from all states and is widely found at the coastal zone of the country from Sonora to Chiapas over the Pacific and from Tamaulipas to Yucatán and Quintana Roo by the Gulf of Mexico [12,53]. At Northeastern Mexico is commonly found from the sea level up to about 1200m [12] (**Figure 1**), is particularly found in disturbed zones in low deciduous forest and thornscrubs [54]. Apparently the main limitant for its growth is altitude and is rarely found at 1000 masl [7], although there are records of some places where it has been found at 1500 masl in the states of Nuevo Leon, Coahuila, Querétaro and Oaxaca [1,53,54]. However, a recent study under investigation regarding modelling of potential distribution Martínez-Ávalos and Venegas-Barrera [55], shows that temperature could be one of the main environmental variables controlling its distribution from 18.3 °C on (**Figure 2**).

Figure 1. Geographic distribution of *Capsicum annuum* var. *glabriusculum* in Mexico.

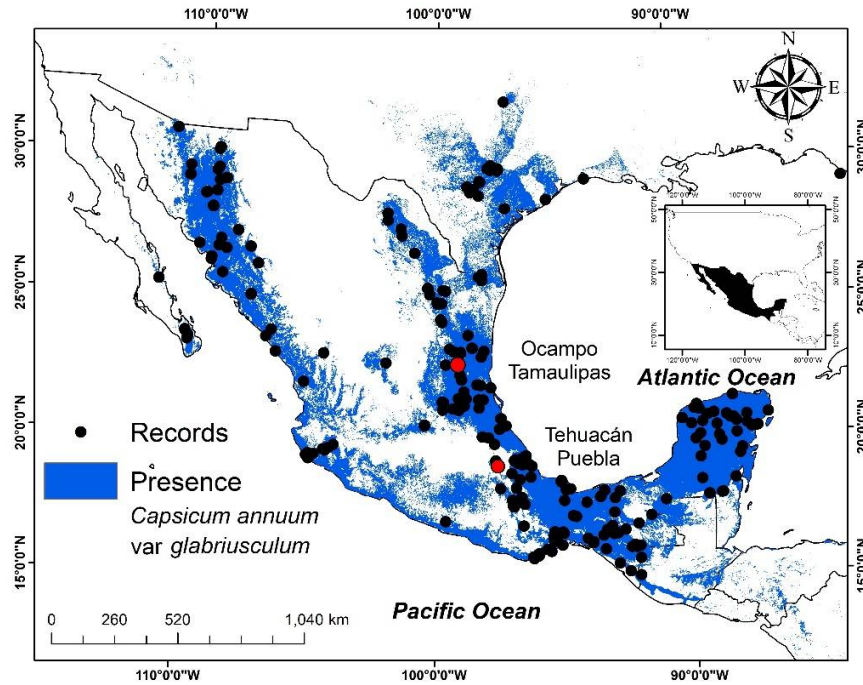
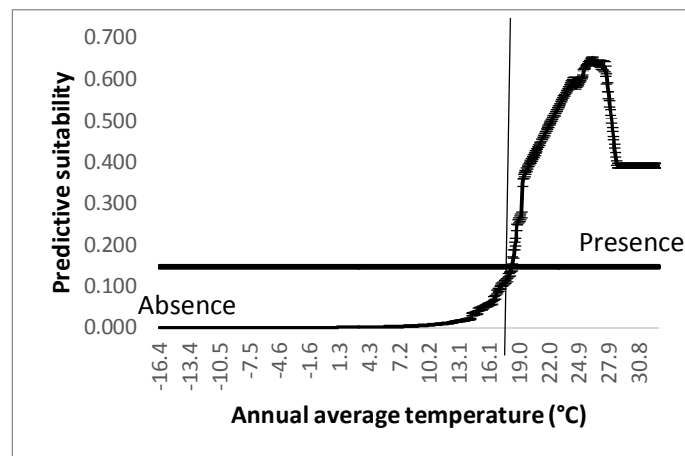


Figure 2. Mean annual temperature contributing to the geographic distribution of *Capsicum annuum* var. *galbriusculum* in México [55].



2.3. Fruits production

Mexico is one of the main producers of chili fruits in the world with ca. 2.2 million of tons per year [56,57], from a surface planted of 149,000 ha. and 12,000 producers participate every year in the process [58]. Considering these data chili has a great economic and social importance as an export product with more than 600,000 tons of green chili a year, and its consumption is increasing every year in the world [59,60].

Consumption of chili *Capsicum annum* var. *glabriusculum* is higher in the north of Mexico and people from nine cities in the states of Coahuila, Nuevo León y Tamaulipas [61] prefer the varieties jalapeño chili (37.3 %), piquín (29.6 %) and serrano (24.0 %), and the cities of Linares and Ciudad Victoria are the main consumers of the variety “piquín”. In the last decades the studies on the variety piquín have been increasing due to the attribution of medicinal properties [62,63] and its demand is increasing every year [64,65]. Harvest of fruits of wild chili *Capsicum annum* var. *glabriusculum* by people living in rural conditions is an important activity in some Northeastern states (Coahuila, Nuevo León, San Luis Potosí y Tamaulipas) and Northwestern (Baja California Sur, Sonora, Chihuahua and Sinaloa) in Mexico, as the price is always high and they are commercialized both in Mexico and the United States of America [12,20]. In the north of Mexico 65% of the harvest is used for local consumption and 35% for commerce [12]. According to Montes Hernández [44], the legal harvest in Mexico may reach a surface of 1,035 ha with an approximate production of 667.40 tons a year with a value of \$1,735.00 USD. However, it is estimated that illegal harvest might be three times higher than the reported amount by SAGARPA, highlighting the north states: Coahuila, Nuevo León, Baja California Sur, Sonora, Sinaloa y Tamaulipas [12,61,65,66]. According to Martínez-Ávalos and Venegas-Barrera [55], show that the production in 23 municipalities in the state of Tamaulipas reached 84 tons a year corresponding to \$641,000 U.S.D [12] and the main municipalities involved are San Carlos, Villagrán, Soto la Marina, Hidalgo, Abasolo and Victoria (**Table 1**).

Table 1. Production of *Capsicum annum* var. *glabriusculum* in Tamaulipas, México [55].

	Municipality	N/Communities	Production/Tons	Costs (M.N)	U.S Dollar
1	San Carlos	31	9.3	\$1,395,000.00	\$71,538.46
2	Villagrán	29	8.7	\$1,305,000.00	\$66,923.08
3	Soto la Marina	25	7.5	\$1,125,000.00	\$57,692.31
4	Hidalgo	18	5.4	\$810,000.00	\$41,538.46
5	Abasolo	15	4.5	\$615,000.00	\$31,538.46
6	Victoria	14	4.2	\$630,000.00	\$32,307.69
7	Méndez	14	4.2	\$630,000.00	32307.6923
8	Aldama	13	3.9	\$585,000.00	\$30,000.00
9	Guémez	13	3.9	\$585,000.00	\$30,000.00
10	Mainero	12	3.6	\$540,000.00	\$27,692.31
11	San Nicolás	11	3.3	\$495,000.00	\$25,384.62
12	San Fernando	11	3.3	\$495,000.00	25384.6154
13	Casas	10	3	\$450,000.00	\$23,076.92
14	Jiménez	9	2.7	\$405,000.00	\$20,769.23
15	Burgos	9	2.7	\$405,000.00	20769.2308
16	González	8	2.4	\$360,000.00	\$18,461.54

17	Cruillas	8	2.4	\$360,000.00	18461.5385
18	Ocampo	7	2.1	\$315,000.00	16153.8462
19	Mante	6	1.8	\$270,000.00	13846.1538
20	Antigua Morelos	5	1.5	\$225,000.00	11538.4615
21	Altamira	4	1.2	\$180,000.00	9230.76923
22	Xicotencatl	4	1.2	\$180,000.00	9230.76923
23	Nuevo Morelos	3	0.9	\$135,000.00	6923.07692
	TOTAL	279	83.7	\$12,495,000.00	\$640,769.23

2.4. Concentrations of capsaicines

Capsaicinoids are alkaloids characteristics from *Capsicum*, they are a complex of structural related compounds and are responsible for the hot sensation and other bioactive properties. There are 22 known compounds for *Capsicum annuum*, capsaicin [(6E) -N- (4-hidroxi-3-metoxibencil) -8-metilnon-6-enamid] representing 69%, the dihydrocapsaicine [6,7-Dihydrocapsaicine] 22% and the nordihydrocapsaicine [7-metil nordihydrocapsaicine] with ca. 7% (**Figure 3**); the rest corresponding to capsaicinoids (homocapsaicina, norcapsaicina, homodihydrocapsaicina, nonivamida, and others) [67]; and their content may vary considerably and are responsible for the pungency and these characteristics allows the classification of some varieties as hot and some others as sweet [68]; and is mainly due to their genetic characteristics and the selection during the domestication process [69,70]. The wild chili pepper *Capsicum annuum* var. *glabriusculum* is very important genetically because it contains many of the desired characteristics such as the hot properties. This variety has a wide distribution and has contrasting levels of capsaicine and dihydrocapsaicine in wild populations from the south and north regions with 0.5 mg de capsaicine /g DW for south populations (21), while populations from the north have levels of up to 56.6 mg de capsaicine/g of dry weight [71]. In the state of Tamaulipas there are reports of studies regarding the capsaicinoids content of wild chili populatins in 15 sites from 9 municipalities in the center zone of the state i.e. Burgos, Güémez, Hidalgo, Llera, Méndez, San Carlos, Soto La Marina, Casas y Villagrán. There are many different environmental conditions in these sites and conditions for the production may include agricultural sites, thronscrubs, mezquital, tropical desciduous forests and coastal plains [55] It is believed that the variability in environmental conditions from these sites might be responsible for the capsaicinoids content variation found in the municipalities with capsaicine contents of 0.3 mg / g DW and ca. 0.1 mg of dihydrocapsaicine / g DW for ecotype from the municipality Méndez, up to 18.6 mg of capsaicine / g DW and 8.6 mg of dihydrocapsaicine / g DW for ecotype from the municipality Llera with a capsaicine dihydrocapsaicine content of 1.4: 1 up to 2.5: 1 [12,13]. These wide variations are due to the genetic and physiological conditions of the wild variety, and it represents an important phylogenetic resource to be used in genetic improvements strategies for cultivated varieties. Levels of capsaicine and dihydrocapsaicine are the main characteristics inducing the hot properties and might be related to environmental conditions from each site and other companion capsaicinoids are also important and are little known.

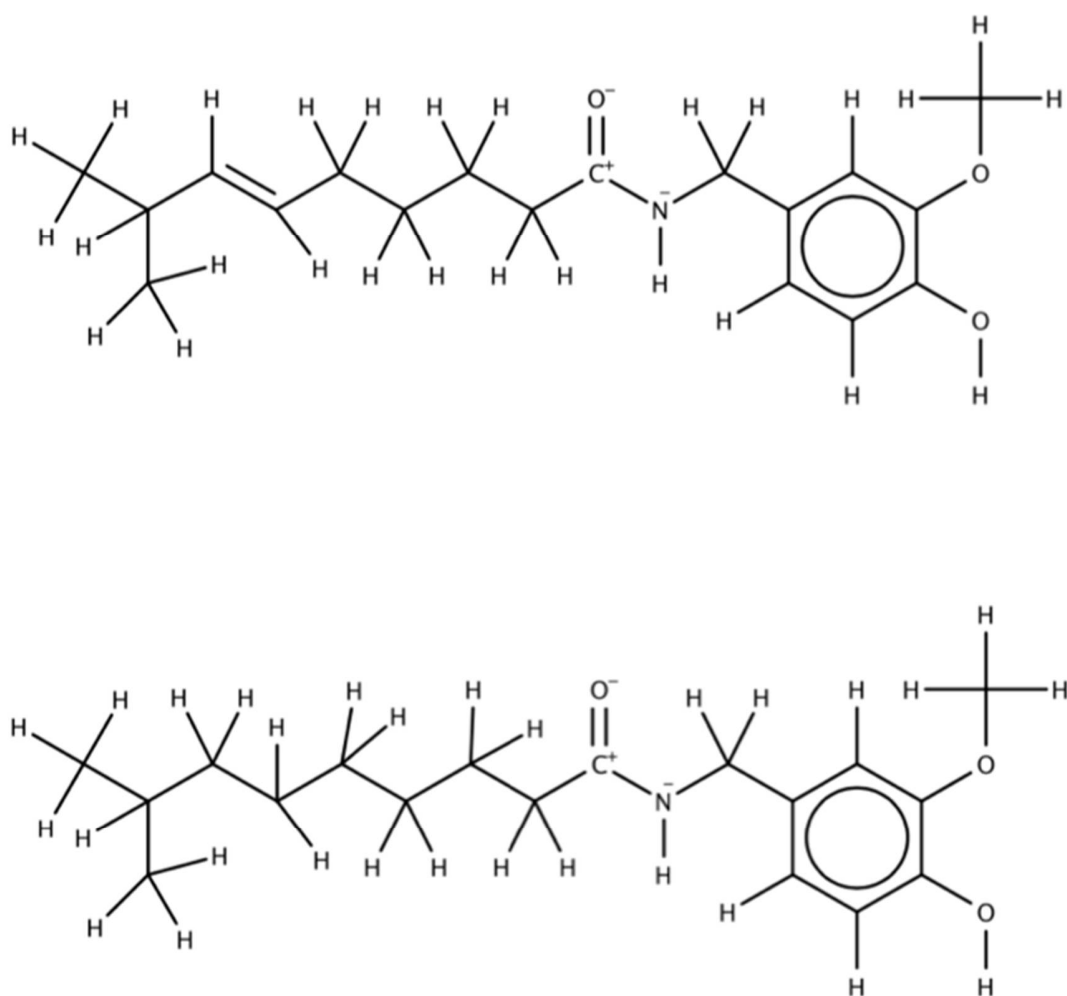


Figure 3. Capsaicine (top) and dihydrocapsaicine (below) are structurally very similar.

5. Conclusions

Capsicum annuum var. *glabriusculum* is an economically important species in Northeastern Mexico, their fruits are consumed and sold representing an important income for many families living in rural conditions during the production at two seasons of the year. Geographic distribution is apparently limited by altitude and temperature conditions and it prefer thomscrubs and thorny bushy low forests for its growth in northeastern Mexico. Results indicate that from the states of Coahuila, Nuevo León and Tamaulipas major production occurs in the last one with 84 tons a year. The contrasting environmental conditions occurring in these zones account for the variation found in capsaicin variation both in the municipalities and ecotypes. The high demand of this product and the varied amount of capsaicinoids in fruits *Capsicum annuum* var. *glabriusculum*, are the main reasons

for the need to increase the cultivation of this variety in intensive production systems in northeastern Mexico.

Author Contributions: J.G.M.A; C.S.V.B; R.M.G; F.E.O.S, A.M.O and A.G.P contributed to the conception of the review; J.A.T; L.U.A and F.G.O contributed with constructive discussions and translation; all authors have read and approved the manuscript.

Funding: This research received no external funding.

Acknowledgments: Authors thank the academic bodies: Ecología y Conservación de Ecosistemas (UATAM-CA-71), Ecosistemas Terrestres y Acuáticos (ITCVIC) and Manejo de Recursos Naturales y Sustentabilidad (UANL-CA-262) for the support obtained from their researchers to carry out this investigation.

Conflicts of Interest: The authors declare no conflict of interest

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