

Morphological characterization of Maax pepper (*Capsicum annuum* var. *Glabriusculum*) and Pico Paloma pepper (*Capsicum frutescens*)

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ABSTRACT

Objective: To morphologically characterize two wild species of *Capsicum annuum* Var. *Glabriusculum* (Maax pepper) and *Capsicum frutescens* (Pico Paloma pepper).

Methodology: Two seed compounds were evaluated, one from Maax pepper and another from Pico Paloma pepper, collected in Campeche, Mexico. Both ecotypes were evaluated *ex situ* in the 2016 and 2017 cycles, under greenhouse conditions. The evaluation was carried out jointly with eight other ecotypes in a randomized block design with three repetitions. The morphological characterization was based on the *Capsicum* descriptor of the IPGRI. The ecotypes were characterized and compared based on descriptive statistics.

Results: The main differential characteristics were: shape, length, and width of the cotyledonous leaf; shape and margin of the leaf; number of flowers per axil; color and spot of corolla; number of fruit's locules, and seed surface.

Conclusions: The morphological characterization allowed to establish differences between the two genotypes; contributing to the knowledge of *ex situ* growth characteristics.

Keywords: Morphological characterization, wild chili peppers, *ex situ*.

INTRODUCTION

Mexico has a great diversity of plants, and it is one of the main centers of domestication worldwide. The genus *Capsicum* stands out as one of the first domesticated plants in the Americas. Specifically, more than 100 morphotypes of cultivated and wild chili peppers are known to be widely distributed in the national territory. This variation includes two types or species of pepper: Maax (*Capsicum annuum* Var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*), with different morphotypes depending on the region where they grow. In the Yucatan peninsula, these chili peppers are part of the Mayan gastronomic culture and have been a staple food since before the conquest.

The Mayans knew the fruit of *Capsicum annuum* Var.

Glabriusculum —a plant that generally is one meter

or less tall— as Maax Iik (Carnevali

et al., 2010). In this region, the

Maax pepper grows in “milpa” or

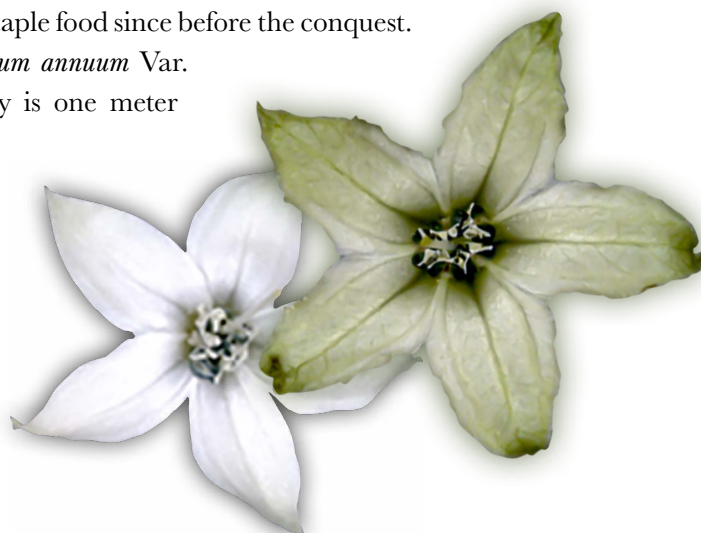
“solar” fields and jungles, where it

behaves as a perennial plant. This

chili pepper can be found mainly

from July to December, during

the rainy season. Immature



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fruits can be pale green to dark green, while ripe fruits are reddish orange to dark red. For its part, the Pico Paloma pepper is a wild chili pepper species found in the Mexican southeast, specifically in the states of Tabasco, Chiapas, and Campeche, and it has various morphotypes and populations (Pérez-Castañeda *et al.*, 2008). The wild chili peppers of *Capsicum frutescens* can be found all year round growing on the edges of roads, pastures, family vegetable gardens, banana plantations, and cocoa plantations (Castañón-Nájera *et al.*, 2008). They are used for local consumption and sale, as well as to garnish typical dishes of the local gastronomy (Pérez-Castañeda, Castañón-Nájera & Mayek-Pérez, 2008). As a result of the existing variation of the genus *Capsicum*, the morphological characterization is important, given the agroecological diversity of the chili pepper ecotypes, which represents a valuable collection of genes. Salinas *et al.* (2010), Moreno-Pérez (2011), Ramírez-Meraz *et al.* (2015), and Toledo-Aguilar *et al.* (2016) have carried out many characterization studies, while Alonso *et al.* (2008), Pérez-Castañón *et al.* (2008), Castañón-Nájera *et al.* (2008), Pérez Castañeda *et al.* (2015), Galvez *et al.* (2018), and Gutiérrez-Buron *et al.* (2020) have researched morphological diversity. However, a more detailed morphological description is required. Consequently, the objective of the research was the morphological description of the Maax pepper and the Pico Paloma pepper in *ex situ* conditions in the state of Campeche.

MATERIALS AND METHODS

The Maax pepper and Pico Paloma pepper ecotypes were collected in 2016. The former was collected in Escárcega, while the latter were collected in Candelaria, both municipalities located in southern Campeche. Ripe red fruits were collected from different plants, forming a compound of ripe fruits for each ecotype. The fruits were washed with sterilized water and kept at low temperature before seed extraction. The seed was extracted through artisanal techniques, using water and macerating the pulp. The extracted seeds were dried on metal trays in a ventilated and shaded place for 8 to 10 days. Subsequently, the seeds were stored at 0 °C. The number of seeds was enough for the two cycles of morphological characterization of the ecotypes. Sowing was carried out under greenhouse conditions in May 2016 and 2017, in 200-cavity polystyrene trays. Canadian Peat Moos[®] was used as substrate. The seeds were covered with black plastic bags to encourage a rapid and uniform germination. After eight days, the trays were uncovered and placed on terraces where the seedlings grew until they were taken to the field. The plants were transplanted 45 days after sowing. The study included eight different types of chili pepper. Planting was carried out under protected agriculture conditions, with 0.25 m between plants and 1.5-m wide furrows. Two furrows were used per ecotype. The agronomic management of the plants followed the technical recommendations for the region (Soria *et al.*, 2002). The qualitative and quantitative morphological characterization was carried out using the varietal description guide of the International Plant Genetic Resources Institute (IPGRI, 1995). The variables or stages considered for the morphological description of the plants were: seedling, plant, flower, fruit, and seed. The analysis of the results of the morphological description was based on descriptive statistics, estimating the average and the coefficient of variation. This coefficient was used as a measure to explain the

contribution of morphological variables to the morphological diversity of the evaluated pepper ecotypes. The contribution of the qualitative morphological variables to the diversity of the morphological expression was determined by the different expressions of a specific characteristic of the Maax pepper and Pico Paloma pepper plants.

RESULTS AND DISCUSSION

Seedling

The Maax pepper had a staggered seedling emergence of five to eight days, while the Pico Paloma pepper had a more uniform seedling emergence. The cotyledonous leaf had a lanceolate shape, while Pico Paloma pepper had a deltoid shape and was greener (Table 1 and Figure 1). The cotyledonous leaf of the Pico Paloma pepper was longer and wider; however, the length and width of the cotyledonous leaf of the Maax pepper had a higher coefficient of variation (12.67% and 17.17%) than the Pico Paloma pepper (7.95% and 7.59%). This phenomenon is explained by the morphological variation of the ecotypes of wild chili peppers that can be found in the state of Campeche and the Yucatán peninsula (Gutiérrez-Burrón *et al.*, 2020). The value of the coefficients of variation determined that, for both types of pepper, the cotyledonous leaf can help to identify and differentiate the Maax and Pico Paloma peppers.

Table 1. Qualitative and quantitative *ex situ* characteristics of the seedling stage of the Maax (*Capsicum annum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes. CV Coefficient of variation.

Characteristics	Maax chili		Pico paloma chili	
Qualitative				
Hypocotyl colour	Green		Green	
Hypocotyl pubescence	Sparse		Sparse	
Cotyledonous leaf colour	green		green	
Cotyledonous leaf shape	Lanceolate		Ovate	
Quantitative	Average	CV	Average	CV
Cotyledonous leaf length (mm)	15.31	12.67	21.25	7.95
Cotyledonous leaf width (mm)	6.52	17.17	7.61	9.59



Figure 1. Leaf shape of the Maax (*Capsicum annum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Plant

The results found for the plant morphology indicate that the main qualitative differences between the Maax pepper and the Pico Paloma pepper were the presence of anthocyanins in the stem, leaf density, leaf color, leaf shape, and leaf blade margin (Table 2).

The Pico Paloma pepper plant had a more vigorous expression than the Maax pepper, judging by the size of the plant and the density of the branches and leaves, with deltoid-shaped leaves and undulate leaf margin (Table 2). The Maax pepper had lanceolate leaves and slightly undulated leaf margins. These characteristics provided the best explanation of the phenotypic variation, which matches the findings of De la Cruz-Lázaro *et al.* (2017), Gálvez-Muñoz *et al.* (2018), and Gutiérrez-Buron *et al.* (2020). Additionally, the presence of anthocyanins in the stem node of the Maax pepper was another characteristic that set it apart from the other ecotypes evaluated.

Quantitative differences could be observed in the morphology of the plants. The Maax pepper had an average plant height of 1.86 m. This result falls within the plant height range (0.77-2.35 m) established by Estrada *et al.* (2010). These findings were different from those reported by Domínguez-Orta and Herrera-Martínez (2019) under natural conditions (≤ 1 m). These differences can be attributed to the conditions of the place of growth with greater or lesser humidity and soil fertility. According to De la Cruz-Lázaro *et al.* (2017),

Table 2. Qualitative and quantitative *ex situ* characteristics of the plant of the Maax (*Capsicum annuum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Qualitative characteristics	Maax chili		Pico paloma chilli	
Steam colour	Green		Green	
Nodal anthocyanin	Light purple		Green	
Stem shape	Angled		Angled	
Steam pubescence	Sparse		Sparse	
Plant growth habit	Erect		Erect	
Branching habit	Dense		Dense	
Tillering	Dense		Dense	
Leaf density	Intermediate		Dense	
Leaf colour	Dark green		Green	
Leaf shape	Lanceolate		Ovate	
Lamina margin	Undulate		Undulate	
Leaf pubescence	Sparse		Sparse	
Quantitative characteristics	Maax chili		Pico Paloma chilli	
	Average	CV (%)	Average	CV (%)
Plant height (cm)	173.82	8.47	1.85	5.54
Steam height (cm)	69.33	17.45	50.67	14.0
Plant width (cm)	119.00	5.86	144.67	31.11
Mature leaf length (cm)	12.40	12.90	14.43	4.72
Mature leaf width (cm)	4.83	1.84	4.53	9.95
Pedicle length (cm)	2.39	6.25	8.23	10.33

CV=Coefficient of variation.



Figure 2. *Ex situ* characteristics of plants of the Maax (*Capsicum annum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

plant height is a major morphological characteristic in characterization and diversification studies, because its variation depends on environmental conditions.

Flower

Regarding its qualitative characteristics, the Maax pepper had two flowers per axil, white corolla, pale blue anther, white filament, and intermediate calyx margin. These characteristics coincide with the findings of Alonso *et al.* (2008) who reported two flowers per axil (Table 3). Meanwhile, the Pico Paloma pepper had yellowish flowers, greenish corolla spot, and two flowers per axil. These characteristics should be considered for the morphological description and differentiation of pepper morphotypes (Table 3). These results match the findings of the diversity studies of Alonso *et al.* (2008).

Fruit

The Maax pepper had an intermediate fruit set, a red fruit, and an intermediate persistence of the fruit on the stem, which made it qualitatively different from the Pico Paloma pepper. For its part, the Pico Paloma pepper had a low fruit set, intense red fruit during the ripe state, and persistence of the pedicel with the stem (Table 5). These results match the findings of Gutiérrez-Burrón *et al.* (2020), who considered that color, pigmentation, and fruit size are differential morphological characteristics of Maax pepper.

The Maax pepper was smaller and lighter than the Pico Paloma pepper. These results can be compared with different *in situ* conditions. Salinas-Hernández *et al.* (2010) recorded a fruit weight and fruit diameter of 0.21 g and 0.51 cm and 0.31 g and 0.57 cm for

Table 3. Morphological ex situ characteristics of the flower of the Maax (*Capsicum annum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Qualitative characteristics	Maax chili		Pico Paloma chili	
Number of flowers per axil	From one to two		Two	
Flower position	Erect		Erect	
Corolla colour	White		Light yellow	
Corolla spot colour	White		Green	
Corolla length (cm)	<1.5		<1.5	
Corolla shape	Rotate		Rotate	
Anther colour	Light blue		Blue	
Filament colour	White		Purple	
Stigma exertion	Excert		Excert	
Calyx pigmentation	Absent		Absent	
Calyx margin	Intermediate		Dentate	
Quantitative characteristics	Average	CV	Average	CV
Anther length (cm)	1.94	4.37	1.98	12.54
Filament length (cm)	1.05	1.02	1.29	3.43

CV=Coefficient of variation.

**Figure 3.** Ex situ characteristics of the flower of the Maax (*Capsicum annum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Maax pepper and for Pico Paloma pepper, respectively. For their part, Alonso *et al.* (2008) indicates a fruit weight of 0.41 g for Pico Paloma pepper and a variable weight for Maax pepper.

The Pico Paloma pepper had longer fruits (1.72 cm) and two locules, while the Maax pepper had 1.15-cm long fruits and three locules. These characteristics were considered to explain the morphological variation, following the conclusions of Gálvez-Muñoz *et al.* (2018).

Table 4. Qualitative and quantitative *ex situ* characteristics of the fruit of the Maax (*Capsicum annuum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Qualitative characteristics	Maax chili		Pico paloma chili	
Fruit set	Intermediate		Intermediate	
Fruit colour at mature stage	Red		Dark red	
Fruit shape	Triangular		Triangular	
Fruit shape at pedicel attachment	Obtuse		Obtuse	
Fruit shape at blossom end	Pointed		Pointed	
Fruit blossom end appendage	Absent		Absent	
Fruit cross-sectional corrugation	Slightly corrugated		Slightly corrugated	
Fruit surface	Semiwrinkled		Semiwrinkled	
Pedicel with fruit	Slight		Slight	
Pedicel with stem	Intermedite		Persistent	
Placenta length	> 1/2 fruit length		> 1/2 fruit length	
Quantitative characteristics	Average	CV (%)	Average	CV (%)
Fruit Weight (g)	0.26	22.12	0.58	23.40
Fruit lenght (cm)	1.15	2.58	1.72	11.15
Fruit width (cm)	0.54	42.27	0.58	9.86
Fruit pedicel lenght (cm)	2.83	12.64	2.65	22.30
Fruit wall thicknees (mm)	0.49	8.22	0.51	16.80
Number of locules	3.00	0	2.0	0

CV=Coefficient of variation.

Seed

The surface of the Maax pepper seed was considered rough due to the bumps it has on its surface, while the Pico Paloma pepper seed was considered smooth. Judging by its length and diameter, the Pico Paloma pepper had slightly larger seeds than the Maax pepper (Table 5).

Table 5. Morphological *ex situ* characteristics of the seed of the Maax (*Capsicum annuum* var. *Glabriusculum*) and Pico Paloma (*Capsicum frutescens*) pepper ecotypes.

Qualitative characteristics	Ecotype			
	Maax chili		Pico paloma chili	
Seed colour	Straw (deep yellow)		Straw (deep yellow)	
Seed surface	Rough		Smooth	
Seed size	small		small	
Quantitative characteristics	Average	CV (%)	Average	CV (%)
Seed lenght (mm)	3.08	7.79	3.62	8.01
Seed dianeter (mm)	2.48	36.69	2.97	6.39
1000-seed weight [g] (g)	2.0	4.03	3.43	6.06
Number of seeds per fruit	11.4	35.35	11.0	35.63

CV=Coefficient of variation.

The weight of 1,000 seeds was another differential characteristic between the two morphotypes of pepper. The weight of 1000 seeds for Pico Paloma (3.43 g) is similar to the 3.57 g found by Alonso *et al.* (2008).

CONCLUSIONS

The morphological characterization of the Maax and Pico Paloma pepper ecotypes allowed us to establish the *ex situ* differential morphological characteristics of both ecotypes. In all the growth stages of the plant (seedling, plant, flower, fruit, and seed), we were able to identify characteristics that help to explain the morphological variation. The results contribute to the knowledge about the Maax and Pico Paloma, chili peppers of great importance for the state of Campeche.

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