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Article

Biometrics in fruits and seeds of two species of wild cucurbits from the Mexican tropics

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Abstract

The objective was to evaluate the morphometry of fruits and seeds in two species of wild cucurbits, orange melon *Cucumis melo* var. *chito* (C. Morren) Naudin and chicayota *Cucurbita argyrosperma* subsp. sororia, in 2020. Three replications of 100 fruits of each species were randomly taken. The weight, length, shape and color of fruits, seeds and embryo, and the number of seeds were recorded. Data were analyzed using central tendency measures with the SAS program. Both species have small fruits and seeds. Chicayota has fibrous flesh, yellowish white in color, and seeds with edges. The fruits of orange melons are oval, with smooth skin, yellow in color, with orange-yellow longitudinal lines and white flesh. The seeds of the two species are pyriform, yellow, with an embryo. They are little-studied species, with characteristics similar to those of their genus and can be given greater agronomic use.

Keywords:

Cucumis, Cucurbita, characterization, morphology.

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Introduction

Mexico is a center of origin of plants (Castellanos-Morales *et al*., 2019). The process and genetics of domestication is a principle that considers the selection and characterization of the quality and quantity of fruits and seeds produced by a species, which are used for food (Eguiarte *et al*., 2018; Gupta *et al*., 2019) and medicine (Cos *et al*., 2008; Jarret *et al*., 2013). It is worth mentioning that characterizing and conserving the species that have been little evaluated in the country is an activity that should not be left aside because the current effects of climate change are causing losses of various species (CONABIO, 2006; Eguiarte *et al*., 2017).

The Cucurbitaceae family consists of an average of 130 genera and 1 300 species; they belong to an important group, some very common in gastronomy since ancestral times, forming part of the milpa system (Hufford *et al*., 2012; Lozada-Aranda *et al*., 2017; Moreno-Letelier *et al*., 2018), and most are tropical (Delgado-Paredes *et al*., 2014).

The genus *Cucurbita* includes 15 species on average and most of them are found in Mexico (Lira *et al*., 2016); they are creeping, monoecious plants, their fruits are pepo-shaped, with different sizes, shapes and colors (Bisognin, 2002; Eguiarte *et al*., 2018), like seeds (Jarret *et al*., 2013), most domesticated species produce large fruits and wild species produce smaller fruits with uniform morphological characteristics (Espitia-Camacho *et al*., 2021) and the presence of cucurbitacin, with a bitter taste, as is the case of chicayota [*Cucurbita argyrosperma* subsp. sororia (L.H.Bailey) Merrick & D.M.Bates].

The species *Cucurbita argyrosperma* subsp. argyrosperma is the cultivated squash, from which the seeds are mainly consumed, whereas chicayota, *C. argyrosperma* subsp. sororia is its wild relative (Sanjur *et al*., 2002; Sánchez de la Vega *et al*., 2018), is distributed from Mexico to Central America (Lira *et al*., 2009). Studies conducted by Balvino-Olvera *et al*. (2017) show that the chicayota is mainly found in the southeast of the country, the states of Guerrero and Oaxaca, centers of diversity. The seeds measure between 1.0 and 1.5 cm in length, are yellowish white, with edges and have characteristics for oil production (Valdés, 2013; Ordoñez *et al*., 2014).

On the other hand, the genus *Cucumis* is divided into seven groups (Munger and Robinson, 1991). Melon (*Cucumis melo* L.) is native to Africa (Kerje and Grum, 2000), the fruit is eaten ripe as a dessert or unripe in salads or soups (Melo *et al*., 2000; Ibrahim *et al*., 2016). The fruits are pepo-shaped, vary in size, shapes, and texture of the skin, the flesh is thick, juicy, firm, with a pleasant aroma and flavor (Ramamurthy and Waters, 2015; Obando *et al*., 2008; Paris *et al*., 2008).

Orange melon *Cucumis melo* var. *chito* (C. Morren) Naudin, also known as chito melon, is a wild species that was introduced to the country by Afro-descendants with the arrival of Christopher Columbus in Mexico. The fruits are smooth, small, yellow, with slight longitudinal orange stripes, melon aroma, astringent flavor, white or cream flesh, and seeds smaller than the cultivated species (Naudin, 1859; Pitrat, 2013; Fernández, 2020).

Chicayota is a *Cucurbita* native to Mexico and the orange melon of the genus *Cucumis* is native to Africa; they are wild and develop in the Mexican Pacific. In the Costa Chica region of Guerrero, the seeds of chicayota are consumed in fresh water or roasted, the flesh is fibrous and bitter, it is used as soap (Bautista *et al*., 2016); for its part, the orange melon has no use, being an alternative rootstock for species of the same genus that are produced in the region, such as watermelon or melon, as it is resistant to pests and diseases.

It has been observed that these species develop without the help of humans the seeds germinate only in the summer or rainy season, the plant is annual, similar to domesticated relatives, but the fruits have an astringent flavor. The search for alternatives that contribute to studies that facilitate the research area, that generate basic information for the use of these species, and that serve as a basis for the selection and use of these genetic materials, motivated us to carry out the present research, which aimed to evaluate the morphometry of fruits and seeds in two species of wild cucurbits, orange melon *Cucumis melo* var. *chito* (C. Morren) Naudin and chicayota, *C. argyrosperma* subsp. sororia, present in southeastern Mexico.

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Materials and methods

The research was conducted at the Laboratory of the Autonomous University of Guerrero, Cuajinicuilapa, Guerrero, Mexico; located at 16° 28’ 28” north latitude and 98° 25’ 11.27” west longitude, at 46 m altitude, with rainfall in summer and average annual rainfall of 1 400 mm, average annual temperature of 28.4 °C, and dry tropical climate (Guerrero, 2020). The exploration and collection of the germplasm of the two evaluated species was carried out in 2020 in the municipality of Cuajinicuilapa.

The cucurbit species evaluated were: chicayota [*C. argyrosperma* subsp. sororia (L. H. Bailey) Merrick & D. M. Bates)] and orange melon [*Cucumis melo* var. *chito* (C. Morren) Naudin], which are ancestral accessions or unimproved genotypes and the seeds of chicayota are sold only in the Costa Chica region of Guerrero and Oaxaca. Exploratory field trips were carried out in the study area, and the germplasm was collected after identifying wild plants, unmanaged, visibly healthy, without diseases or damage by pests; it is worth mentioning that the collection was only made for this evaluation.

Physiologically ripe fruits were harvested and placed in 10 L plastic containers, taken to the study area, where they were conditioned, washed with 1% sodium hypochlorite, and rinsed with running water, then dried and counted, and each species was evaluated separately. Three replications of 100 fruits each were randomly taken, labeled, and ordered in workspaces to evaluate the following variables: the fresh weight (g) of the fruit and its seeds were recorded with a precision electronical analytical balance (Rhino DGN.312.01.2015.2294®).

The polar diameter (mm) was measured from the point of insertion of the floral peduncle to the posterior end and the equatorial diameter at the middle of the fruit; these dimensions were determined by using a digital vernier (Truper Stainless Steel® model: Caldi-6MP), which has an precision of 0.05 mm; the following was measured: the thickness of the flesh and the seeds in the two species, the thickness of the skin and width of the edge in chicayota, and the thickness of the flesh in a longitudinal and transverse section in orange melon.

The shape index of the fruits and seeds was determined by dividing the polar diameter by the longitudinal diameter. The number of seeds per fruit was counted. The color of the fruits, seeds, and embryo without integument was determined with the digital program of Color Grab®. The data obtained from the morphometric characteristics evaluated were analyzed with the SAS® statistical package, version 9.3 (SAS Institute, 2011), using the central tendency measures. The images were taken with a Sony digital camera (Optical SteadyShot® 24.3 megapixels).

Results and discussion

Chicayota [*Cucurbita argyrosperma* subsp. sororia (L. H. Bailey Merrick & D. M. Bates)]

The central tendency measures of the morphometric characteristics of the fruits and seeds of chicayota are shown in Table 1. The Cucurbitaceae are characterized by variability in the size of the fruits, those of chicayota are the smallest (Figure 1); fruits weighing from 82.29 to 108.98 g were found in this research, which indicates that this wild species has fruits that are small but variable in size, which is related to environmental factors of the soil and of the plant itself, etc. Studies in *C. moschata* report an average weight of 590 to 1 430 g (Canul-Ku *et al*., 2005; Chí-Sánchez *et al*., 2020).

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Table 1. Morphometric characteristics of fruits and seeds of chicayota [*Cucurbita argyrosperma* subsp. sororia (L.H.Bailey) Merrick & D.M.Bates)].

Variable	Average	CV	SE
Weight (g)	96.25	10.65	10.25
Polar diameter (mm)	66.24	5.21	3.45
Equatorial diameter (mm)	62.67	4.88	3.06
Shape index	1.06	3.19	0.03
Skin thickness (mm)	1.53	6.6	0.1
Skin weight (g)	81.93	11.48	9.41
Flesh weight (g)	6.04	20.3	1.23
Flesh color	White yellow		
Skin color	Whitish green		
Num. of seeds	228	8.04	18.32
Seed			
Weight (g)	0.04	5.67	0
Polar diameter (mm)	8.73	5.03	0.44
Equatorial diameter (mm)	5.12	4.58	0.23
Shape index	1.71	6.64	0.11
Thickness (mm)	1.89	9.41	0.18
Thickness width (mm)	0.9	13.91	0.13
Embryo weight (g)	0.003	12.66	0
Seed color	Yellowish white		
Color of embryo without integument	White		

N= 300 fruits; CV= coefficient of variation; SE= standard error.

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Figure 1. a) Morphological traits in different positions of the fruits of chicayota [*Cucurbita argyrosperma* subsp. sororia (L. H. Bailey) Merrick & D. M. Bates]; and b) orange melon [*Cucumis melo* var. *chito* (C. Morren) Naudin], wild species of the dry tropics.

The plants of this species are characterized by being a climbing liana, few fruits are found on the ground; it is mentioned that the sororia subspecies was domesticated in southeastern Mexico, giving rise to what is collectively called the milpa (Sanjur *et al*., 2002), but chicayota remains completely wild. For the variable of fruit length, it was found that they have a polar diameter of 66.24 mm and an equatorial diameter of 62.67 mm, respectively; these are smooth-skinned fruits without ribs.

Studies carried out on six variants of squash (*C. moschata*) show values from 6.01 to 9.44 cm in polar diameter and from 9.78 to 17.38 cm in longitudinal diameter (Chí-Sánchez *et al*., 2020), also being small fruits. Delgado-Paredes *et al*. (2014) state that there is great morphological diversity between accessions of the same species and even more between species of the same family, considering that fruits can be from 5 cm to 1 m long, the same authors mention that small fruits are those of lengths equal to or less than 20 cm; because of these characteristics, the chicayota belongs to this group.

The shape index is a determining variable in the study of all fruits; in chicayota, the maximum value was 1.12, a figure that gives it a slightly wider than long shape, and the minimum value obtained was 1.01, relatively round fruits. The skin of this species is hard, green, and yellow with incomplete white dotted longitudinal stripes, giving a variegated color (Figure 1a). Information similar to that of this research was obtained by Moscatero *et al*. (2002), who found that the color of the skin is white or yellowish green, with irregular green longitudinal spots, white or transparent flesh and the fruit has a globose shape but is large in size, because the fruits had an average weight of 20 kg.

The skin has an average thickness and weight of 1.53 mm and 81.93 g, respectively, which is similar to that reported by Chí-Sánchez *et al*. (2020) in the flesh thickness of *C. moschata*. The flesh is composed of white to yellow fibers, with a minimum and maximum weight of 4.29 and 7.71 g.

Each fruit contained 198 to 257 seeds; Chí-Sánchez *et al*. (2020) mention that some variants of *C. moschata* have 231 to 463 seeds, these are the ones that will perpetuate the species over time; in addition, at the time of collection, it was observed that the plants did not present pests or diseases, as is common to find in commercial cucurbit specie, being an alternative to be used as a rootstock for species susceptible to root pests and diseases

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Chicayota is a completely wild species, in no genus of this species has the relationship of domestication with seed production been reported. It is worth mentioning that, in the Costa Chica region of Guerrero and Oaxaca, chicayota seeds are used to make soap and fresh water through a process of washing, dehydrating, roasting, and grinding (Bautista *et al*., 2016).

Each seed had an average fresh weight of 0.04 g, with a minimum and maximum polar diameter of 8.17 to 9.48 and equatorial diameter of 4.81 to 5.58 mm; these variables assign a pyriform, flattened shape, with an average thickness of 1.89 mm, which coincided with what was reported by Chí-Sánchez *et al*. (2020).

Delgado-Paredes *et al*. (2014) evaluated different species of squashes and determined that the medium-sized seeds are 16 to 20 mm; therefore, the seeds of chicayota are small and yellowish-white (Figure 1a), have an edge of 0.90 mm wide and a white embryo surrounded by a thin gray covering, and each embryo weighed 0.03 g.

The weight of 100 chicayota seeds was 4 g; research conducted by Canul-Ku *et al*. (2005) and Montes *et al*. (2004) mention that the minimum weight of 100 small seeds in fruits of *C. moschata* Duchense Exp. Prior is 5.32 and 6.78 g, respectively, values higher than the average weight found in the present research.

On average, the fruits of cucurbits are large in size, which means that they are marketed in parts or containers with smaller quantities than those of the whole fruit; however, to offer better quality to the consumer, it would be better to reduce the size; currently, smaller fruits are sought in the market; chicayota is the smallest fruit of this genus and can be used to initiate research work through grafting or crosses that reduce the size of the species.

Orange melon [*Cucumis melo* var. *chito* (C. Morren) Naudin]

The central tendency measures in orange melon showed that the weight of each fruit evaluated ranged between 65.77 and 103.16 g (Table 2), the plant is creeping, tendril-shaped, and slightly climbing. The fruits ripen in the months of October to November and are found in the ground like all species of its genus, of course it depends on agronomic management in edible species; Lemus and Hernández (2003) mention that the fruits of orange melon are the size of an orange; those found in this work were smaller.

Table 2. Morphometric characteristics of seeds and fruits of orange melon [*Cucumis melo* var. *chito* (C. Morren) Naudin].

Variable	Average	CV	SE
Weight (g)	84.15	14.43	12.14
Polar diameter (mm)	62.06	5.82	3.61
Equatorial diameter (mm)	53.19	4.9	2.61
Shape index	0.68	5.21	0.04
Flesh longitudinal thickness (mm)	11.74	7.09	0.83
Flesh transverse thickness (mm)	7.94	8.7	0.69
Flesh weight (g)	21.66	3.34	0.72
Num. of seeds	380.54	8.04	30.61
Skin color	Yellow-orange		
Flesh color	White		
Seed			
Fresh weight (g)	21.66	3.34	0.72
Unit dry weight (g)	0.01	9.49	0

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Variable	Average	CV	SE
Polar diameter (mm)	5.06	6.6	0.33
Equatorial diameter (mm)	2.35	5.45	0.13
Thickness (mm)	1	6.9	0.07
Embryo weight (g)	0.009	10.76	0
Embryo polar diameter (mm)	3.96	7.4	0.29
Embryo equatorial diameter (mm)	1.88	6.76	0.13
Thickness (mm)	0.83	9.71	0.08
Seed color	Yellowish white		
Embryo color	White		

N= 300 fruits; CV= coefficient of variation; SE= standard error.

Studies carried out by Laínez and Krarup (2008) in *C. melo* cv. Glamour and Emerald indicate that the average weight per fruit ranges between 1 120 and 1 010 g, respectively, in contrast to what was found in this research, in orange melons.

The polar diameter of the smallest fruit was 5.92 cm and the longest was 6.94 cm, observing a 1.02 cm difference in this measurement among the fruits evaluated; nevertheless, it was found to be 4.8 and 5.75 cm for the equatorial diameter; there was a close difference in these values of fruit length. These measurements gave the shape index, with values between 0.61 and 0.74, giving an elongated or oval shape, similar to that of the commercial melon cv. Emerald (Laínez and Krarup, 2008), this variety presented 13.8 ±0.7 and 12.8 ±0.9 cm of polar and equatorial diameter.

The fruits are characterized by having a smooth thin skin, no more than 1 mm thick, completely attached to the flesh, green with longitudinal stripes, intense green when the fruits are developing or immature, and the color turns yellow with orange-yellow stripes when the fruit ripens (Figure 1b). The flesh is soft white, melon-flavored, it has a longitudinal thickness of 1 to 1.27 cm and a transverse thickness of 0.67 to 0.9 cm and with a flesh weight of between 20.51 and 23.26 g; considering the above, these fruits have 74.27% flesh compared to the weight of the seeds and their size, which indicates that they contain sufficient flesh to improve some quality traits, both physical and chemical, for example, sweetness, these are astringent or acidic (Lemus and Hernández, 2003).

This species is only used for preserves or pickles. The fruit with the lowest number of seeds had 317 and the one with the highest 418; it was found that in one centimeter difference in the size of the fruit, they developed 101 seeds on average, a figure that could be verified by performing a greater number of tests. The average weight of the seeds in fresh was 21.66 g; it is worth mentioning that it coincided with that of the flesh; therefore, each fruit has the same amount of flesh and seeds plus juicy mucilage on average.

Each dehydrated seed weighs 0.01 g, measures 4.54 and 5.44 mm in length, has a diameter between 2.11 and 2.55 mm and thickness from 0.89 to 1.15 mm, respectively, and is yellowish white (Figure 1b); they are flattened, pyriform in shape and do not have width thickness, characteristic of the genus. Each seed has an embryo weighing 0.009 g, with a length of 3.96 and 1.88 mm, with a thickness of 0.83 mm, on average; they are white in color and occupy the entire internal space of the seed.

It is worth mentioning that, for genetic improvement, both the weight and diameter of the fruits are selection criteria, as indicated by studies carried out in *Benincasa hispida* [(Tumb.) Cong.] (Espitia-Camacho *et al*., 2021), in order to obtain more productive species, in number and size of fruit and seeds (Pradhan *et al*., 2018). The species evaluated in this research have these characteristics, but they are not grown in the region and to obtain chicayota seeds, the fruits are collected from wild plants when their cycle has ended.

The two species have an annual cycle, germinate at the beginning of the rains, and dry up when their fruits ripen. In the region, the fruits and seeds of orange melons are not used; therefore, these

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species are being lost due to burning, grazing, and the excessive use of herbicides, producers identify them among the unwanted species (Tingle and Chandler, 2003; Tingle *et al*., 2003; CONABIO, 2006). Both *Cucurbita* and *Cucumis* have high conservation potential (Kader, 2002; Shellie and Lester, 2006; Laínez and Krarup, 2008); in this research, the shelf life was not evaluated, but it was observed that the fruits remain on the ground for months.

Conclusions

The chicayota is a small globose wild squash, with a smooth skin, variegated green in color, without ribs; the flesh is composed of yellowish fibers and flattened pyriform seeds with an edge, characteristic of the species of this genus. The orange melon is also the smallest of its genus, is oval, yellow, with yellow or orange stripes, white flesh, aromatic and with astringent flavor; small pyriform yellowish-white seeds.

The two wild species evaluated have particular biometric characteristics, each with its own variability; it is highlighted that the size of the fruit determines the number and size of the seeds and it can be used as a selection criterion for future research.

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