AGRO PRODUCTIVIDAD

Colegio de Postgraduados

Fruits and seed characteristics of chihua squash (*Cucurbita argyrosperma* Huber.) accessions from Yucatan, Mexico

Rangel-Fajardo, María A.[1*]; Tucuch-Haas, J.[1]; Villalobos-González, A.[2]; Burgos-Díaz, J.[1]

[1] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. CIRSE. Campo Experimental Mococha. Yucatán, México.
[2] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. CIRSE. Campo Experimental Edzna, Campeche, México.
* Correspondence: rangel.alma@inifap.gob.mx

ABSTRACT
Objective: To evaluate some fruit and seed characteristics of six chihua squash genotypes obtained in the Yucatan Peninsula.
Materials and methods: Six collections of *Cucurbita argyrosperma* Huber, obtained in the Yucatan Peninsula, were evaluated in a randomized complete block design for two years. The number of fruits per plot, fruit weight and size, seed weight and number of total, empty and full-filled seeds per fruit were quantified, and degrees Brix of the pulp.
Results: Differences in fruit production were found between collections. The dominant fruit size was medium, fruits between 500 and 999 g, with the Chetumal collection standing out, while the variables of seed weight and number of seeds were affected between collections and between years, because of low rainfall during the production cycle of the second year. All collections recorded a reduction in weight and an increase in the number of empty seeds. Slight variations were identified in the concentration of degrees Brix of the pulp, with the Chetumal collection standing out above the rest.
Conclusions: The evaluated collections present variability within them, which can be useful to select materials for different purposes and to obtain more benefits from this crop.

Keywords: Fruit size, number of seeds, degree Brix, seed weight.

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INTRODUCTION

Mexico is the center of origin of the genus Cucurbita and there is evidence that shows that the species *Cucurbita argyrosperma* was domesticated in southern Mexico (Rio-Santos *et al.*, 2018; Khoury *et al.*, 2019). Historically, squash has been part of the diet of many American peoples (McCreight, 2016). The genus Cucurbita has 27 species of which five are domesticated: *C. pepo* L.; *C. fisifolia* Bouché; *C. moschata* (Duchesne ex Lam) Duchesne ex Poiret; *C. máxima* Duchesne ex Lam; *C. agyrosperma* Huber (Eguiarte *et al.*, 2018). According to several authors (González *et al.*, 2010; Martínez-González *et al.*, 2021), most of the genetic diversity of Cucurbita is found in Mexico, which manifests in the wide range

of sizes, shapes, colors, and yields in the field. Sánchez-de la Vega *et al.* (2018) indicated that *C. agyrosperma* is the one of lowest diversity, as is the case of *C. fisifolia* (Lebeda *et al.*, 2006) in comparison to the rest of the domesticated species. In the Yucatan Peninsula, squash is an important part of the complex milpa production system, where three of the 15 species of the American genus of Cucurbita are cultivated: *C. argyrosperma*, *C. moschata* and *C. pepo*, and where the main objective is obtaining seed for food. The diversity in the native populations of squash is maintained by traditional farmers, who are capable of recognizing variants and selecting the fruits from which they will obtain their seed in each sowing cycle, based on the preferred characteristics of color and shape (Canul *et al.*, 2005; Basurto-Peña, 2014; Hernández-Galeno *et al.*, 2015). The sizes of the fruit of the squash species that are cultivated are the result of evolutionary changes; multiple studies on morphological, genetic and agronomic diversity have shown a great variability within and between specimens of the species (Lira *et al.*, 2002; Basurto-Peña *et al.*, 2015). *C. agyrosperma* has been one of the least studied; Sánchez-Hernández *et al.* (2004) started a program for genetic improvement of this species with the aim of obtaining outstanding materials for seed production. Although it can be consumed in various ways, the seed is the main product, so in the last 10 years its production has been promoted in different regions of Mexico as monocrop system (Serna *et al.*, 2004), in response to economic studies that show that *C. agyrosperma* has economic potential that can contribute in benefit of the producers (Ireta-Paredes *et al.*, 2018). The objective of this study was to evaluate some characteristics of the fruit and seed of six genotypes of *Cucurbita agyrosperma* Huber squash cultivated in the Yucatan Peninsula, with the aim of identifying materials with potential for commercial production.

MATERIALS AND METHODS

The evaluation of six chihua squash accessions was established in the Uxmal Experimental Site (INIFAP), located on km. 72 of the Mérida-Campeche Highway en route to the Muna ruins, Yucatan (20° 24' 37.23" latitude North and 89° 45' 24.36" longitude West). The genotypes were obtained from different regions of the Yucatan Peninsula and given the name of the collection site, two from Chetumal (Chetumal and Cacao), three from Campeche (Edzna, Pixoyal and Becal), and one from Yucatán. Sowing was done under rainfed regime (June 13, 2017, and June 20, 2018) with the climate information presented in Figure 1.

The evaluation management was carried out in a randomized blocks design. Each plot consisted in four furrows with separation of 2.40 m and 9 m long with an area of 64 m^2 per experimental unit (Hernández *et al.*, 2006). The agronomic management recommended by Ruiz García *et al.* (2020) was conducted. The fruits were harvested when they reached physiological maturity and were evaluated in the facilities of the Mococha Experimental Field located on km 25 of the former Mérida-Motul Highway. The data obtained were total number of fruits per plot and average weight of fruits, and then they were classified according to their weight into large, of 1000 g or more, medium of 500 to 999 g, and small of less than 500 g, in addition to eliminating the fruits damaged by rotting. From each fruit, seeds were extracted and dried until constant weight; the total seeds per fruit were counted,

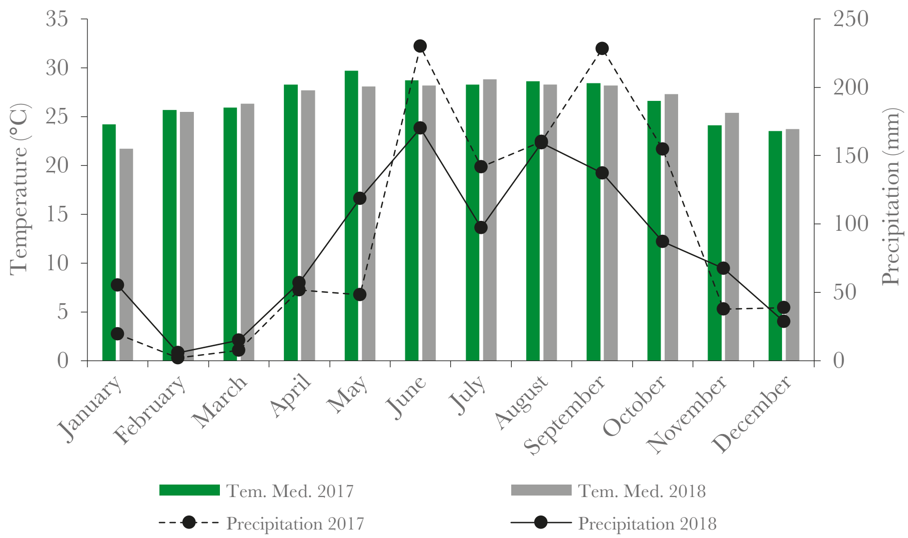

Figure 1. Mean temperature and precipitation in Yucatan during 2018 and 2017. Graph elaborated with data from: https://smn.conagua.gob.mx/es/climatologia/temperaturas-y-lluvias/resumenes-mensuales-de-temperaturas-y-lluvias.

and the hollow seeds and the seeds with complete filling were separated and counted. A sample of five fruits was obtained from the total fruits, and degrees Brix of the pulp were determined with the help of a refractometer Atago PR-32α brand while the equatorial diameter of the fruits was obtained through the most prominent part of the middle part and the polar diameter was taken from the base passing through the fruit stem. These data were reported in centimeters. All the variables were subjected to analysis of variance and Tukey's means comparison ($P \leq 0.05$) with the help of SAS 9.1®.

RESULTS AND DISCUSSION

Fruit production during the two years of evaluation of the collections showed variations. Differences were found ($p \leq 0.05$) between the collections; the collection from Chetumal surpassed all the collections in fruit production, while the collections Yucatán and Pixoyal were lower, with a difference of 50% compared to the collection with the highest number of fruits (Figure 2a). When it comes to the fruit size, the production was concentrated in the medium size and was higher in 53.72 and 54.49 % than the large and small sizes (Figure 2b); differences were found ($p \leq 0.05$) between the accessions, with Chetumal standing out, which produced the highest amount of fruits that were concentrated in the medium size, followed by Becal, while the collections Yucatán and Pixoyal were lower in all the fruit sizes and this production trend of medium fruits prevailed in the two years of evaluation (Figure 2c). When it comes to fruit weight during 2017, the collections Pixoyal, Edzna and Becal resulted in the highest averages with weights of 2234, 2191 and 1844 grams, respectively, while for 2018 these collections had averages of 976, 918 and 1005 g, respectively, reducing their weight in up to 50 % (Figure 2d).

The seed production in weight and number of seeds per collection was affected in the two years of production. Differences are observed ($p \leq 0.05$) when comparing seed

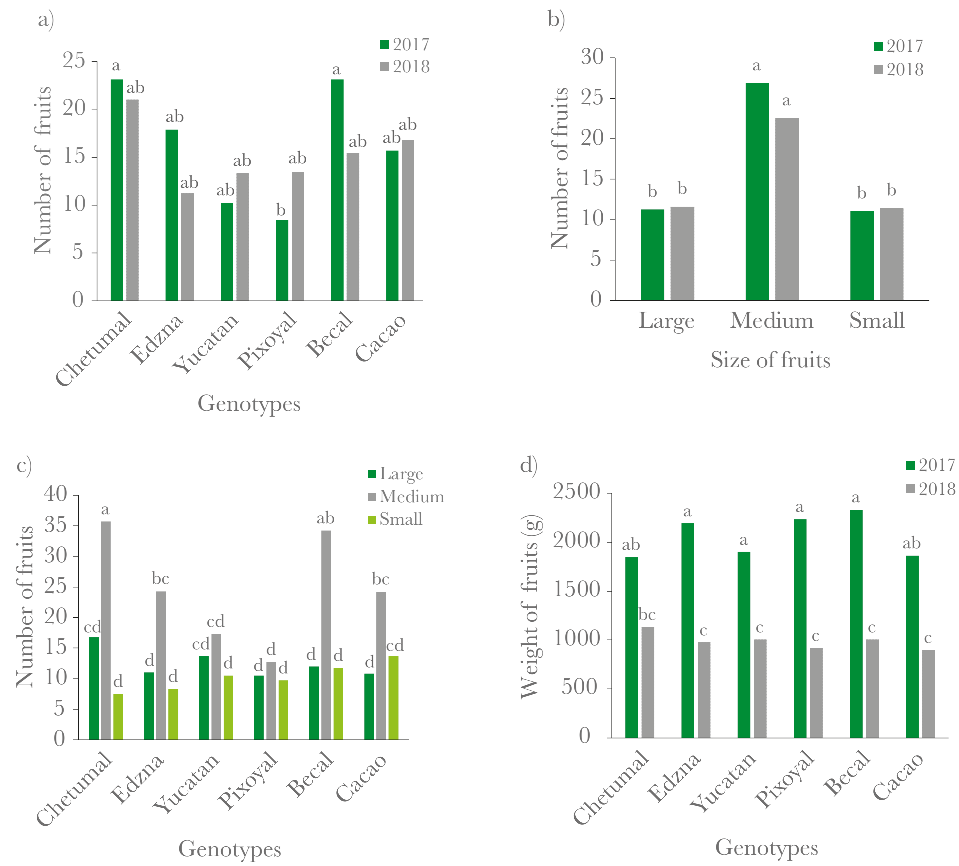

Figure 2. Characteristics of the chihua squash fruit production during 2017 and 2018 in the Uxmal Experimental Site. a) Number of fruits produced by collection per year; b) Number of fruits produced per year and classified by sizes; c) Number of fruits produced by collection per size; d) Average weight of the fruits obtained during the evaluation.

production from each collection in each year: for 2017, Pixoyal and Becal stand out from the rest in number of seeds with 366 and 343, respectively, while Pixoya is superior for total seed weight with 76 g; for the year 2018, all the collections showed low seed production, as well as low seed weight per fruit, and in that year Chetumal and Becal stand out regarding seed weight with averages of 38 and 34 g/fruit, respectively; however, Edzna and Yucatán showed the highest number of seeds per fruit with 167 and 171 (Figure 3a).

An important characteristic is the amount of complete or full-filled seeds. When the behavior of each collection along the years is observed, it is possible to highlight that Pixoyal produced the largest number of complete seeds per fruit (315) and Chetumal the smallest number of hollow seeds (29), while in the year 2018 the number of complete seeds per fruit per collection remained between 79 and 105 seeds; however, the amount of hollow seeds increased with regards to what was obtained in the year 2017, Chetumal showed 50% more hollow seeds than in 2017, while Edzna increased on average to 42 hollow seeds in 2018, affecting the weight of the seed produced. Although the collections from Becal and Cacao reduced the amount of complete seeds by 2018, they also reduced the hollow seeds in 2018 in comparison to 2017 (Figure 3 b).

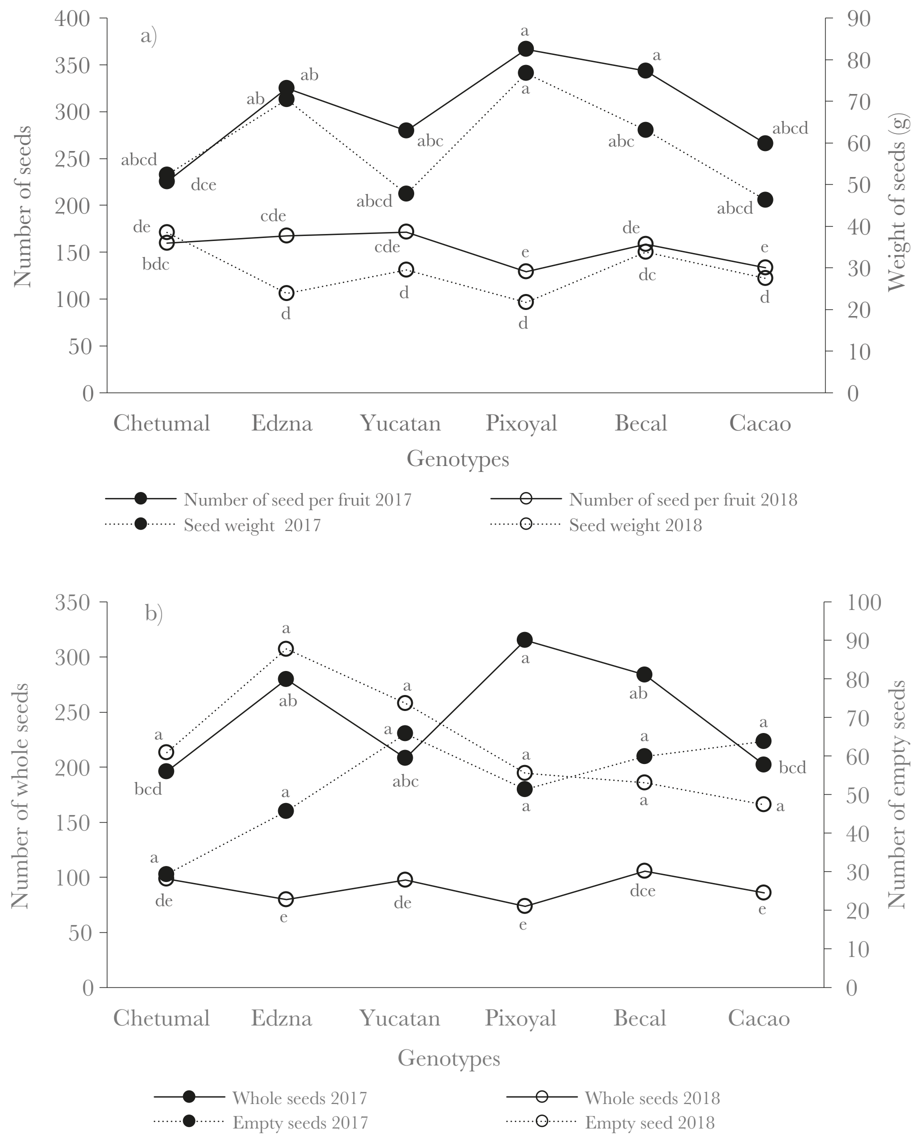

Figure 3. Characteristics of chihua squash seed production during 2017 and 2018 in the Uxmal Experimental Site. a) Number of seeds produced and seed weight; b) number of full-filled and hollow seeds during the evaluation.

On the other hand, the variables of polar and equatorial diameter had differences between the collections ($p \leq 0.05$); the collection from Edzna and Becal exceeded in both variables, while in Pixoyal only the polar diameter and the cacao collection reported the lowest values in both variables; in terms of the years evaluated, 2017 presents the highest values, and the behavior of the Edzna and Becal collections in the two years of evaluation remain as outstanding in both variables during the two years (Figure 4).

The amount of degrees Brix in each of the collections has discordances ($p \leq 0.05$); in 2017, Becal recorded on average 4 °Bx, although for 2018 Chetumal resulted in an increase of 1.19 °Bx in comparison to 2017, the same as Cacao (0.14 °Bx) and Becal decreased 1.19 °Bx and the collections Ezdna (0.68 °Bx), Yucatán (0.34 °Bx) and Pixoyal (0.26 °Bx) (Figure 5).

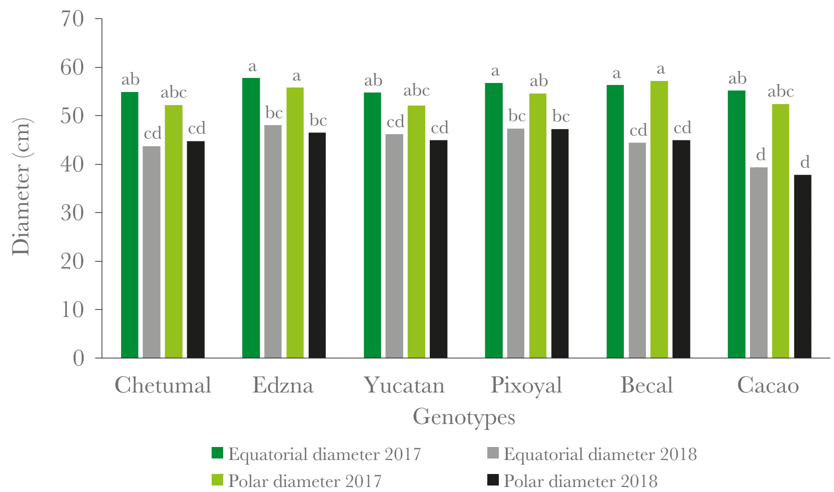

Figure 4. Equatorial and polar diameter of fruits from six chihua squash collections produced in the Uxmal Experimental Site, Yucatán.

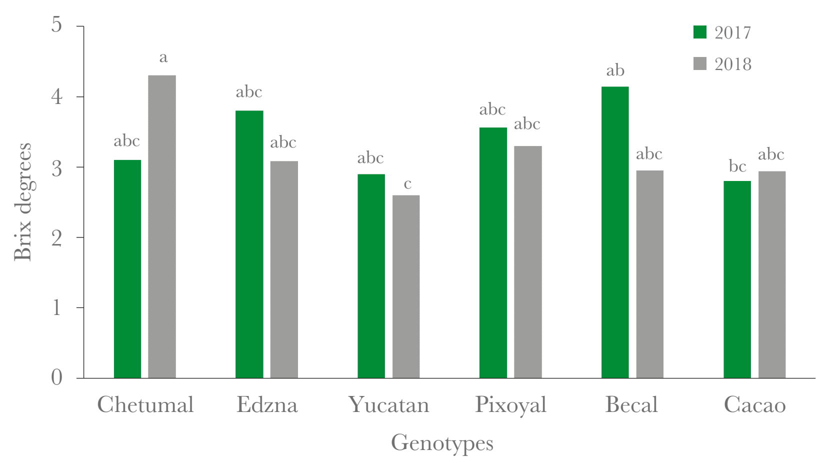

Figure 5. Degrees Brix of six chihua squash collections produced during 2017 and 2018 in the Uxmal Experimental Site, Yucatán.

A wide variety of squashes can be found in the Yucatan Peninsula, particularly *C. moschata* and to a lesser degree *C. agyrosperma*, according to Sánchez-de la Vega *et al.* (2018). This species presents low levels of genetic variation in the Yucatan Peninsula and high levels of kinship with local wild species, which indicates that the populations of *C. agyrosperma* are genetically isolated. The crop is particularly associated to the milpa system, where corn, bean and chili pepper are produced (Canul *et al.*, 2005). There are characteristics to which farmers pay special attention to select the seeds for the next production cycle; for example, amount and size of the fruit, amount and size of the seed, fruit color (Barrera-Redondo *et al.*, 2020). The variables of fruit weight, seed weight, and number of seeds agree with what was reported by Garza-García *et al.* (2020) in hybridization assays on collections of *C. agyrosperma* obtained in the Huasteca region. When it comes to the fruit size, Hernández-Galeno *et al.* (2015) report some characteristics of fruit size from *C. agyrosperma* collections obtained in the state of Guerrero, which they describe as elliptical fruits with diameters of 70.6±7 cm; rounder fruits with smaller diameter were found in the results obtained (Figure 5), probably due to the number of medium fruits (Figure 2). The characteristics evaluated were variable between them and between the years evaluated and respond to the conditions of moisture and temperature present during cultivation. The characteristics of fruit weight and fruit size were affected in the two years evaluated, and this behavior was identified by Sánchez-Hernández *et al.* (2014) in fruits obtained in two localities; for the particular case of this study, differences in fruit weight were obtained between the years. Although there was sowing in the same site but in different year, this affected the production both of number of fruits and the fruit size, which is why it is believed that the accessions evaluated are affected by the conditions of rainfall between both years, during 2017 there was higher rainfall than in the year 2018 (Figure 1). According to Aguirre *et al.* (2020), the climatic conditions where *C. agyrosperma* is distributed range from 15 to 30 °C and average annual rainfall of less than 1000 mm to 2000 mm, which is a very broad interval, so it would be necessary to understand the optimal conditions for the production of this species.

Urbanek Krajnc *et al.* (2017) indicate that the climate changes lead to considerable losses in the production in squash production as well as anatomical modifications. This condition of water stress could affect in the same way the variables of seed weight, total number of seeds, number of complete seeds and hollow seeds, since the lowest values were obtained during 2018. These results also agree with what was found by Garza-Ortega *et al.* (2010), who reported differences in the variables of fruit weight, seed and concentration of soluble solids during two cycles of evaluation of lines, hybrids and landraces of *C. agyrosperma*; these differences are related to the climatic conditions present during the production cycles. Despite this reduction in yield, all the collections showed production indicating that there can be certain tolerance to water stress (Pedroza-Sandoval *et al.*, 2018).

On the other hand, options have been sought for exploitation of the fruit, since this species was used to obtain the seed, wasting the pulp; in this sense, Dorantes-Jiménez *et al.* (2016) report *C. agyrosperma* with potential for the diets of farm animals. However, Ruiz García *et al.* (2020) have reported variations in the amount of protein and oils in different collections of *C. agyrosperma*. In this sense, the amount of sugars can play an important role in the palatability of the pulp and in the acceptance by animals of the feeds; the collections found variations in the concentrations of sugars of the fruits evaluated, primarily when conditions of water stress were present. Sánchez-Hernández *et al.* (2000) did not show degrees Brix in the evaluation and they report an improvement in taste, from insipid-bitter to sweet, for the two years of selection; however, the concentration of sugars in the pulp will depend on the amount of water it can contain.

CONCLUSIONS

The characteristics of *C. agyrosperma* evaluated help to identify materials that can be used with different objectives, such as animal feed or exploitation of seeds for oils or direct consumption. The collections evaluated behaved differently depending on the conditions of temperature and moisture during the years evaluated; however, these responses contribute to identify characteristics that can be taken advantage of, such as the increase of sugars in the pulp, or else to generate information that contributes to the elaboration of a technological package for management of the species.

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