Article

Diagnosis of wild populations of crazy zucchini in the Central Highlands of Mexico

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Abstract

The species, *Cucurbita foetidissima* Kunth (crazy zucchini) grows in places that are not conducive to agriculture and has an agro-industrial importance, therefore, it is necessary to know its current situation to propose in the future if the plant is used sustainably. Therefore, morphological variables (foliage and root) of populations located in the region between the states of San Luis Potosí, Jalisco and Zacatecas were analyzed. The plants of La Cocona and Yoliatl San Luis Potosí, contain more guides per plant (9-12), better root attributes, by weight (2536 g), number of guides (67) and volume (2411.2 cm^3) and higher fruit content. The Guadalupe and Ojocaliente, Zacatecas plants showed greater length of guides (16-27), length of the petiole (7.5 to 12 cm) and larger leaves (13.5 to 18 cm). With respect to the Chinampas Ojuelos, Encarnación de Díaz and Lagos de Moreno, Jalisco plants, these had a root weight of 1615 g, 33.8 cm perimeter, 10.8 cm wide, 52.6 cm long, 44.5 guides, 1690.5 cm^3 in volume and 162 fruits. These low attributes may be due to the fact that the plants were located in sites characterized by warmer climates and with greater precipitation (473.5-573.2 mm) compared to the other regions. In this work, geo-referencing and the size of wild crazy zucchini plants were established as a first strategy to know their habitat status, define a conservation/propagation alternative and propose a sustainable use method according to their agroindustrial potential that is known.

Keywords: *Cucurbita foetidissima* Kunth, botanical description, characterization, multivariate statistics.

Reception date: May 2019
Acceptance date: July 2019

Introduction

The integral and sustainable use of ruderal, weed, ornamental and cultivated plants can increase the income of farmers in marginal areas of the central highlands of Mexico (Juárez-Pérez *et al*., 1991). One of these plants can be the species, *Cucurbita foetidissima* Kunth, crazy zucchini that grows in places that are not suitable for agriculture (tolerant of high temperatures, resistant to pests and diseases), the root contains carbohydrates of industrial potential 23% amylose), seeds contain up to 33.9% of oil, good protein content 34.2%, the leaves can be consumed for fodder and offers many possibilities as a food source (Granados-Sánchez and López-Ríos, 1999; Hoover, 2001).

Specifically, due to their main components, according to Ordoñes (2007) they suggested that the leaves can be used as fodder due to their high digestibility (75-85%) in goats and as human food due to their oil content in seeds, Calvo-Grajales (2003) determined that it contains palmitic, stearic, linoleic and oleic fatty acids and have similar action to commercial cooking oils (even without using antioxidants).

The species is distributed in Guanajuato, Hidalgo, Querétaro, Jalisco, San Luis Potosí and Zacatecas, as well as the southern United States of America (Villaseñor and Espinoza, 1998; Hernandez *et al*., 2000; Lira *et al*., 2009). Therefore, it is necessary to investigate, characterize and generate models on the outstanding plant characters that allow to know the growth and development of the species to make known uses more efficient. Finally, propose a sustainable use and define strategies for its conservation.

Materials and methods

Study area

The study area covers the region between the states of San Luis Potosí (Salinas, Villa de Reyes and Villa de Ramos), Jalisco (Ojuelos, Encarnación de Díaz, Lagos de Moreno) and Zacatecas (Guadalupe, Ojocaliente and La Pendencia Pinos). Field trips were made at each site, around municipal headwaters and preferably in easily accessible sites.

Characteristics of the study area

Four physiographic regions converge in this area: The Northern Upland, in central and northern Mexico; the Southern Highlands, in the south and east, the Lower Sierras, to the northeast and the High Sierras with Valleys, to the west of the area (Tamayo, 1981). There are mountains and plains, with altitudes of 1 000 to 2 600 meters above sea level. (Ferrusquia-Villafranca, 1993) and large areas of alluvium with isolated hills.

The most common substrate in the north of the area is the Cretaceous and Jurassic limestone rocks; igneous rocks, mostly rhyolites and sometimes andesites and basalts, are more common in the south and west. Calcisol-type soils predominate, distinguished by the accumulation of calcium carbonate; in the northeast there are areas of Regosol, shallow soils and low fertility (Cuanalo *et al*., 1989; Ferrusquia-Villafranca, 1993).

The predominant climate is the BS, with the variants BS0, the driest and BS1, the least dry (García, 1973). Precipitation is scarce and irregular, with an annual average of 240 to 770 mm (Cuanalo *et al*., 1989). The average annual temperature varies from 13.5 to 20.5 °C (Anónimo, 1980).

Sample size determination

Prior to the general collection, a pilot sampling was carried out on March 19 and 27, 2014, at two sites: La Cocona, Salinas de Hidalgo San Luis Potosí and Chinampas, Ojuelos Jalisco. With the data obtained, the actual sample size was calculated. The number of plants to be sampled was obtained using the formula of Bolflor *et al*. (2000). Where: n= number of sampled plants; E= margin of error allowed for this collection; t= value of 't' of student (t= 0.05); N= total population of crazy pumpkin plants in the locality; CV= coefficient of variation; to obtain this value it is necessary to do a pilot sampling.

$$n= \frac{t^2 * CV^2}{E^2+\frac{t^2 * CV^2}{N}}$$

Descriptors analyzed

In the selected sites, 25 plants were sampled for each of them and data were taken from the following morphological descriptors: in relation to foliage, 1) number (NPG) and length of the guides per plant (LGP) were analyzed, the latter data it was measured in cm from the beginning of the stem to the apex of the last leaf, distance between internodes; and 2) leaves, considering the leaf length (LH), leaf width (AH) and petiole length (LP), measured in units of cm. In relation to the root, the length, amplitude and diameter (cm) and volume expressed in cm^3 were determined. For the latter three plants were extracted from each site, which contained 3, 8 and 13 guides.

Indicators to determine the state of development of plants

According to the following figure, the clusters of the crazy zucchini plants were determined.

Analysis of morphological data

The data of simple morphological variables were integrated in intervals according to the growth behavior and analyzed by means of comparison of averages between the sites of wild populations.

Grouping of *Cucurbita foetidissima* Kunt according to morphological components

To perform the grouping by main components, 13 morphological variables of *Cucurbita foetidissima* Kunth plants were analyzed, integrated into vegetative characters (internode distances, the length and breadth of the leaf, as well as the length of the petiole, number of total guides, the length of the guides), of reproductive development (number of flowers and number of fruits) and of the root (total weight, volume, length, broad width, length).

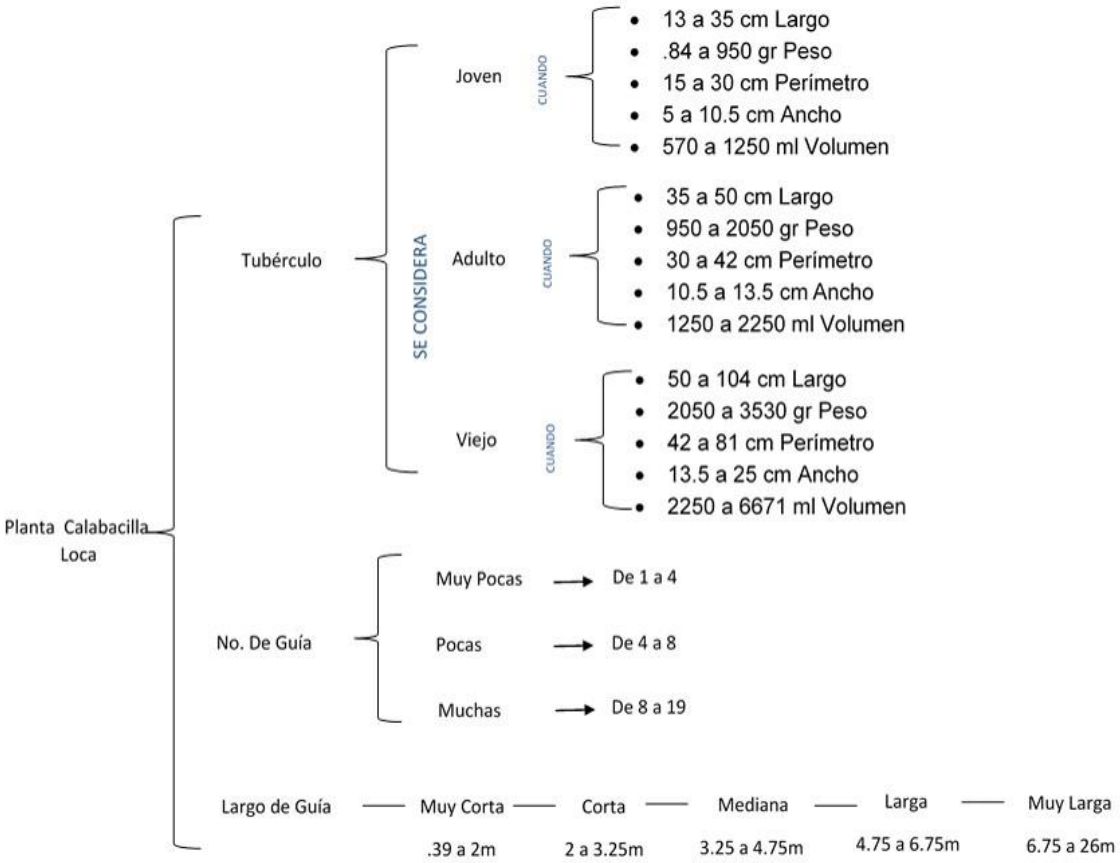

Figure 1. Indicators that allow to identify the state of development of the plant. Human (1991). Sweet potato descriptors. CIP/AVRDC/IBPGR.

With the database, a multivariate analysis was carried out based on principal component analysis (ACP) to decrease inference and grouping by similarity to understand the information of groups of plants with similar characteristics, discriminating groups using the minimum internal variance (Ward) to form types of plants, Infostat was used (Di Rienzo, 2014).

Results and discussion

Geo-referencing of wild zucchini habitats

In general, the sampled areas were found on roadsides or fields, with a slope between 15 and 45 °C and an altitude of 1 814 and 2 475 meters above sea level. The coordinates, altitude and characteristics of each collection location are mentioned. The plant communities we found were different conditions according to the region and the characteristics of the collection site (Figure 2 and Table 1).

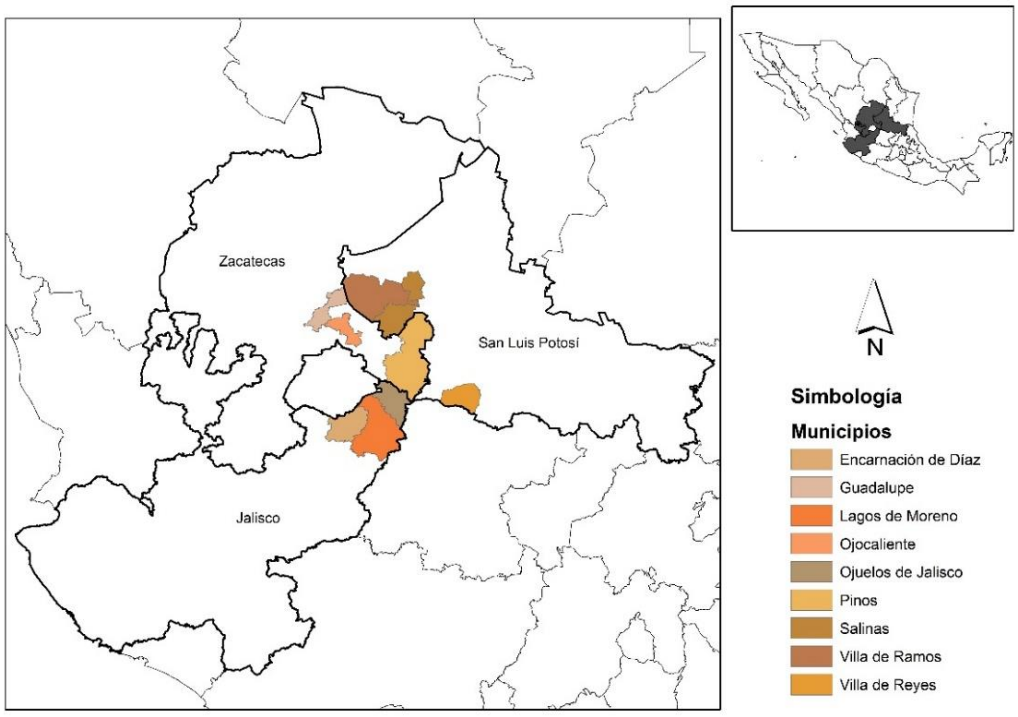

Figure 2. Municipalities where the study of crazy zucchini was carried out.

Table 1. Location where wild populations of *Cucurbita foetidissima* Kunth were found.

State	Location	Coordinates	Altitude (m)	Precipitation in rain (mm)*	Characteristics of the collection place
San Luis Potosí	La Cocona, Salinas	21º 48’ 5.1” N 101º 48’ 55.6” W	2 099	391	Roadside, heading plot
	El Centenario, Villa de Reyes	21º 46’ 38.6” N 100º 56’ 58.3” W	1 814	360	Roadside, creek edge
	Yoliatl, Villa de Ramos	22º 59’ 4.56” N 101º 54’ 38.0” W	2 190	429.6	Roadside, side of farmland
Jalisco	Chinampas, Ojuelos	21º 48’ 5.12” N 101º 48’ 55.6” W	2 095	473.5	Roadsides, stream of sewage and on the side of farmland
	Encarnacion de Diaz	21º 38’ 48.44” N 102º 16’ 40.4” W	1 851	564	Roadside on gravel ground
	Lagos de Moreno	19° 50’ N 103 59’ W	1 876	573.2	In the middle of the highway, next to field agostadero

State	Location	Coordinates	Altitude (m)	Precipitation in rain (mm)*	Characteristics of the collection place
Zacatecas	La Pendencia, Pinos	22º 25' 37.7" N 101º 34' 37.7" W	2 475	429.6	Roadside, stream and next to farmland
	Guadalupe	22º 45'4.57" N 102º 26' 22.2" W	2 272	500	In the middle of the highway on stony ground
	Ojocaliente	22º 30' 33.56" N 102º 14' 58.6" W	2 019	500	Roadside and even side of farmland

According to Anónimo (2016); *= documents by municipality of the governments of the states of San Luis Potosí, Jalisco and Zacatecas.

Behavior of morphological variables (guides and leaves). In general, in Table 2, the quantitative values of the vegetative growth of a total of 25 plants analyzed in nine plant sites of *Cucurbita foetidissima* Kunth are indicated. It was observed that there is a great variation in the number of guides per plant (1-19), plants with less than eight guides predominate, the Chinampas Ojuelos plants and, in an outstanding way, the plants located in La Cocona, Salinas de Hidalgo and Yoliatl Ramos Villa. San Luis Potosí showed more guides (9-12) probably at a greater number of years or less favorable climatic conditions (natural requirement of the plant).

Table 2. Description of the vegetative growth of the *Cucurbita foetidissima* Kunth plants of the Central Highlands of Mexico.

Variable	Jalisco		San Luis Potosí			Zacatecas			Subtotal/ group
	A	b	c	d	e	f	g	h	
Guides per plant									
Of 1-4	14	6	20	4	9	19	6	7	85
Of 5-8	10	3	2	9	7	6	17	17	71
Of 9-19	1	2	3	12	9	-	2	1	30
Subtotal-region	25	11	25	25	25	25	25	25	186
Guide length									
Of 0.39-200 cm	18	2	13	34	1	4	27	6	105
Of 201-325 cm	26	4	15	23	8	9	32	14	131
Of 326-475 cm	15	13	14	18	15	7	10	27	119
Of 476-675 cm	1	9	8	1	34	15	1	20	89
Of 676 cm-26 m	1	-	5	-	12	16	-	2	36
Subtotal-region	61	28	55	76	70	51	70	69	480
Petiole length (cm)									
Short	12	27	3	1	31	6	1	10	91
Medium	28	1	21	39	38	25	23	22	197
Long	13	-	18	27	1	11	39	15	124
Very long	8	-	13	9	-	9	7	22	68
Subtotal-region	61	28	55	76	70	51	70	69	480

Variable	Jalisco		San Luis Potosí			Zacatecas			Subtotal/ group
	A	b	c	d	e	f	g	h	
Leaf length (cm)									
Very small	11	15	7	16	18	7	2	7	83
Little	20	10	16	22	38	18	9	7	140
Median	9	3	15	22	12	12	19	15	107
Big	14	-	12	13	2	13	23	25	102
Very big	7	-	5	3	-	1	17	15	70
Subtotal-region	61	28	55	76	70	51	70	69	480
Leaf width (cm)									
Very small	14	13	3	11	38	3	1	5	88
Little	23	14	14	29	26	25	17	20	168
Median	6	-	6	16	3	10	15	2	58
Big	14	1	26	18	3	13	30	20	125
Very big	4	-	6	2	-	-	7	22	41
Subtotal-region	61	28	55	76	69	51	70	69	480

a) Chinampas; b) Encarnación de Díaz; c) Centenario; d) Cocona; e) Yoliatl; f) Guadalupe; g) La Pendencia; and h) Ojocaliente. The town of Lagos de Moreno, Jalisco, no data are reported due to pruning effect on the roadside.

In length of guides prepondered those with less than 6.75 m and the longest were found in Guadalupe Zacatecas. In the length of the petiole, those of large-medium size (7.5 to 12 cm) in length predominated, although those of Ojocaliente stood out for greater length, with shallow soils. In leaf size, the plants showed from small to large (16.5 to 27 cm) and in an outstanding way, the Ojocaliente plants. They presented a larger quantity of larger leaves (13.5 to 18 cm).

According to the collection sites, the Chinampas, Ojuelos Jalisco, plants are located mainly on the banks of roads and roads, cohabit with fast-growing pastures and are sometimes 'pruned roadside' so that their growth is differentially induced in relation to plants from other sites analyzed.

The plants of La Cocona, Salinas de Hidalgo, San Luis Potosí. They form agglomerated populations with a very short separation between plants (0.5-1 m) so there is high competition for the few water and mineral resources they have. The plants of Encarnacion de Díaz, Jalisco, were found in a pile of gravel roadside, showed several years and did not compete with any weeds, so they have the shortest petiole.

The plants of Guadalupe, Zacatecas, compete with grasses that limit the optimal growth of the squash, so they tend to develop longer petioles so that the leaves get sunlight were found plants such as jaral (*Cistus ladanifer*), arnica (*Arnica angustifolia*), brush or ant grass (*Pathenium hysterophorus* L.), prickly pear (*Opuntia* spp.), cardenche (*O. imbricata*) and mesquite (*Prosopis laevigata*) preferably, indicating a synergy that leads to generally large plants (676 cm).

In Lagos de Moreno Jalisco, the plants develop as "medium plants" (326-475 cm). At the El Centenario site, Villa de Reyes, San Luis Potosí, the climate is wetter so there are few populations of 'Crazy zucchini' due to higher grass growth in susceptible places.

In Yoliatl, Villa de Ramos. San Luis Potosí, *Cucurbita foetidissima* Kunth. It requires little water and grows faster in arid and semi-arid environments (Web Academia, 2013). The plants that develop are located in a cradle of reliefs and cohabit with plants such as the giant (*Nicotiana glauca*), prickly pear (*Opuntia* spp.), yucca (*Yucca* sp.) and very short grass (*Boutelova curtipendula*) (Anónimo, 2016).

Description of the *Cucurbita foetidissima* Kunth tubers. In general, the Chinampas (Ojuelos), Encarnación de Díaz and Lagos de Moreno (Jalisco) plants showed intermediate values between the studied regions in their root variables (Table 3).

Table 3. Characteristics of the *Cucurbita foetidissima* Kunth tuber.

Collection site	Variable analyzed						
	Tuber weight (g)	Perimeter (cm)	Amplitude (cm)	Length (cm)	Volume (cm^3)	Guides (number)	Fruits per site
Jalisco							
Chinampas (Ojuelos)	1 403.3(754.1)	30.2(3.4)	10(1.1)	54.8(10.6)	1 530 (825)	61	44
Encarnación de Díaz	2 368.3(1 103.1)	44(6.2)	13.6(1.8)	52.6(10.7)	2393.3 (1047.4)	28	118
Lagos de Moreno	1 073.3(336.5)	27.3(4.7)	8.83(1.6)	50.3(6.6)	1 148.3 (293)	nd	nd
Average	1 615(902.4)	33.8(8.8)	10.8(2.5)	52.6(8.4)	1 690.5 (878.1)	23.3*	81*
San Luis Potosí							
La Cócona, Salinas	3 560(3881.4)	41.8(19.2)	14.6(7.7)	42.6(16.9)	2 977 (3 244.3)	76	116
Yolíalt, V. de Ramos	2 024(1330.2)	61(20.5)	18.6(6.5)	63(35.5)	2178.3 (1 169.1)	70	649
El Centenario, V. Reyes	2 024(1330.2)	33.9(12.4)	12.6(4.6)	49.8(21)	2 078.3(1 015)	55	5
Average	2 536(2 289.35)	45.5(19.5)	15.3(6.1)	51.8(24)	2 411.2(1 847.3)	67(10.8)	769(256)
Zacatecas							
La Pendencia, Pinos	836.6 (163.5)	17(1)	9.4(0.5)	26(3.6)	859(252.5)	70	75
Guadalupe	1 440(677.4)	30(2.9)	11.5(2.6)	31.3(4.5)	1 426.6(598.1)	51	53
Ojocaliente	1 470(913.2)	30(14.1)	10 (4.3)	30(14.7)	2 436.6(1 697.6)	69	90
Average	1 248.8(652.4)	25.7(9.7)	10.3(2.7)	29.1(8.2)	1 574.1(1 142.2)	63.3(10.6)	218
General average	1 404.8	35.03	12.15	44.52	1 891.96		

Nd= undetermined; *= average of two populations.

These showed a weight of 1 615 g, perimeter of 33.8 cm, width of 10.8 cm, length of 52.6 cm, number of guides of 44.5, a volume of 1 690.5 cm^3 and fruit content of 162. The above may be due to the fact that the plants they grow in climatic conditions not very favorable to the optimum needs of the plant, since these sites are characterized by warmer climates and with greater precipitation (in Chinampas Ojuelos, 473.5 mm, Encarnación de Díaz 564 mm and Lagos de Moreno 573.2 mm respectively) .

In an outstanding way, the plants of La Cocona (Salinas), Yoliatl (Villa de Ramos) and Centenario (Villa de Reyes) corresponding to the State of San Luis Potosí, showed, on average, the greatest attribute of the root with a weight (2 536 g), perimeter (45.5 cm), amplitude (15.3 cm), length (51.8 cm), number of guides (67), volume of 2 411.2 cm^3 and fruit content of 769 (in full).

The factors that can possibly influence 'this optimal development' can be the following: higher incidence of solar radiation, little competition with 'aggressive' pastures and lower rainfall index (La Cocona Salinas with 391 mm, Yoliatl Villa de Ramos with 429.6 mm and El Centenario Villa de Reyes with 360 mm respectively). The plants with lower attributes in the root variables are found in those in the state of Zacatecas with a weight of 1 248.8 g, perimeter of 25.7 cm, amplitude of 10.3 cm, length 29.1 cm, number of guides of 63.3, a volume of 1 574.1 cm^3 and fruit content of 218.

The lower attributes of the root of this area may be due to a higher altitude above sea level, lower annual average temperature, low environmental humidity or because the soils are less fertile or shallow, since rainfall is intermediate between regions studied (La Pendencia, Pinos, 429.6 mm, Guadalupe, 500 mm and Ojocaliente, 500 mm respectively).

Fruits

In the number of fruits per site (Table 3), Yoliatl stood out with 649 fruits in total, followed by Encarnación de Díaz (118) and La Cocona, Salinas de Hidalgo, San Luis Potosí (116). Here we deduce that the climate is an important factor in the pumpkin plants, since we find more fruits in places with less rainfall and greater solar incidence.

The number of fruits per sites is important and complements what was found by Flores (2016) where he reports that crazy zucchini from these places have 100 seeds weighing 3.70 g and 27 017 seeds per kilogram. On the other hand Flores (2016) determined that the linoleic and linolenic acids (essential fatty acids) that the seed contains are of great value for possible use as edible oils. According to the above, the most recommended place to collect fruits and seeds is Yoliatl in Villa de Ramos, San Luis Potosí.

Estimate of the development status of *Cucurbita foetidissima* Kunth populations in relation to morphological characteristics. With the information of the morphological variables analyzed, an estimate was made (Table 4) of the probable development condition presented by the native populations of zucchini, inferring a plant classification according to their size. Thus, generally, Jalisco plants that have a root volume of 1 690.5 cm^3 are considered of intermediate size, while that of San Luis Potosí with a root volume of 2 411.2 cm^3 plants are considered large in size and finally, the plants of the State of Zacatecas with a root volume of 1 574.1 cm^3 are considered small plants.

Table 4. Age inference of crazy zucchini plants, *Cucurbita foetidissima* Kunth according to morphological variables of the root.

Component	Morphological feature	Plant size according to its morphological character		
		Small (Zacatecas)	Intermediate (Jalisco)	Big (San Luis Potosí)
Root	Thickness (cm)	5-10.5	10.5-13.5	13.5- 25
	Length (cm)	13-35	35-50	50-104
	Weight (g)	84-950	950-2 050	2 050-3 530
	Perimeter (cm)	15-30	30-42	30-42
	Volume	570-1 250	1 250-2 250	2 250-6 671
Guides	Number plant^{-1}	1-4	4-8	8-19
	Length (cm)	200-325	325-475	475-675 some up 26 m

Grouping of *Cucurbita foetidissima* Kunt, according to morphological components.

It is worth mentioning that some plants stood out in guide length (plus 26 m) despite the limited agroclimatological conditions. This classification can be used to propose a way to identify, compare populations, select plants in optimal growth status and complement the morphological variables according to the purpose of agroindustrial use of the plant (fodder, oil, bioenergy, reforestation).

The analysis of the morphological components generated eight groups of plants, determining as the main component, the amplitude of the root with 61% of the variability and the length of the second internode along the guide with 22% of additional variance), which it was divided into two slopes corresponding to the content of number of guides and length of internodes (Table 4 and 5).

The distribution of groups in different regions groups 1 and 6 prevail in almost all populations of crazy zucchini. This is important to quickly and easily locate populations of crazy zucchini in a certain place (Table 5 and 6).

Table 5. Groups generated by morphological characters of the crazy zucchini.

		Group	Description
Root amplitude	Number of guides	VI	Intermediate number of guides with wide root and normal size
		II	Intermediate number of guides and wide root with very thin guides
		V	Large number of guides with wide root
	Internodes	IV	Short, with large root volume
		VIII	Long, with large root volume
		VII	Intermediate size and small root volume
		III	Very wide with broad root
		I	Broad with broad root

Table 6. Communities integrated into groups 1 to 8.

Community	Group							
	I	II	III	IV	V	VI	VII	VIII
Jalisco								
Chinampas, Ojuelos	2							1
Encarnación de Díaz	1		1	1				
Lagos de Moreno							3	
San Luis Potosí								
El Centenario		1	1	1				
La Cocona	1				1			1
Yoliatl				1	1	1		
Zacatecas								
Guadalupe	1	1						1
La Pendencia	2							1
Ojocaliente	1	1	1					
Total	8	3	3	3	2	1	3	4

Conclusions

There are morphological differences and growth stages of crazy zucchini plants depending on the edafo-climatic regions, with the highest incidence of sunlight, lower rainfall and medium altitude above sea level as the optimal conditions for the best behavior. The populations of Yoliatl, Salinas de Hidalgo, San Luis Potosí, stood out with greater content of guides and fruits per plant, therefore, these plants can be used as germplasm banks for their different applications (conservation of diversity or sustainable agroindustrial exploitation).

This is the first report on wild populations of wild zucchini that indicate it is geo-referencing and state of growth and development to implement a strategy of possible exploitation by the inhabitants of the region.

Acknowledgments

To the Campus-SLP of the Graduate College, for the facilities to carry out the field trips to be sampled and to Line-3, Alternative energy and biomaterials of the Graduate College, for the financing of reagents and materials to carry out this research.

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