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Morphological characterization of *Matisia cordata* Bonpl. in a tropical dry forest from Antioquia, Colombia

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Caracterización morfológica de *Matisia cordata* Bonpl. en un bosque seco tropical de Antioquia, Colombia

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ABSTRACT

Keywords:
Matisia cordata
Morphological diversity
Phenotype
Tropical fruit trees
Underutilized species
Sapodilla

Characterization of plant genetic resources is the first step to conserve plant diversity. Morpho-agronomic characterization is a method that requires a selection of sensible descriptors, which are characteristics that define a phenotype. Sapodilla (*Matisia cordata* Bonpl.) is a plant genetic resource and is an important part of the agricultural tradition of the nearby western of Antioquia (Colombia). However, the lack of scientific information about this species shows that it is an underutilized fruit. The local community, in its traditional knowledge, recognizes two phenotypes of sapodilla: Creole and Ecuadorian. The phenotypic diversity of 100 trees of *M. cordata* was evaluated from 28 morpho-agronomic descriptors. The Gower distance and UPGMA method were used to determine the diversity and make the dendrogram, respectively. The Bayes methodology was used to obtain the highest posterior density intervals of 95% probability and compare both phenotypes. Trees of the Creole phenotype had elliptical crown and acute shaped fruits, whereas the Ecuadorian phenotype presented a pyramidal crown and diverse fruit shapes. The Creole phenotype had stems with larger diameter at chest height (28.8 cm), more knots (10 cm), smaller leaves (25 cm), lighter fruits (301 g), larger peduncles (15.6 mm), smaller (40 mm) and lighter seeds (30 g), and an epicarp and a darker pulp than the Ecuadorian phenotype. The farmers' local knowledge was partially confirmed since most of the descriptors coincided with the local perception, except descriptors of color and flavor of the pulp.

RESUMEN

Palabras clave:
Matisia cordata
Diversidad morfológica
Fenotipo
Árboles frutales topicales
Especies subutilizadas
Zapote

La caracterización de los recursos fitogenéticos generalmente constituye el primer paso en los procesos de conservación de la diversidad vegetal. La caracterización morfoagronómica requiere descriptores, los cuales son caracteres que definen un fenotipo. El zapote (*Matisia cordata* Bonpl.) es un recurso fitogenético que hace parte de la tradición agrícola del occidente cercano antioqueño (Colombia). Sin embargo, la escasa información científica sobre esta especie muestra que este frutal es subvalorado. La comunidad local, en su experiencia y conocimiento tradicional reconoce dos tipos de zapote, uno criollo y otro ecuatoriano. Se evaluó la diversidad fenotípica de 100 árboles de *M. cordata* a partir de 28 descriptores morfológicos. Para conocer la diversidad se utilizó la distancia de Gower y el método UPGMA para realizar el dendrograma. Los dos fenotipos se compararon empleando la metodología Bayesiana, obteniendo intervalos de alta densidad a posteriori de 95% de probabilidad. Se encontró que los árboles de zapote criollo se caracterizaron por tener copa elíptica y frutos de forma aguda, mientras que los zapotes ecuatorianos presentaron formas piramidales y diversas formas de frutos. El fenotipo criollo presentó troncos con mayor diámetro a la altura del pecho (28,8 cm), mayor número de nudos (10 cm), hojas más pequeñas (25 cm), frutos más livianos (301 g), pero con pedúnculos más grandes (15,6 mm), semillas más pequeñas (40 mm) y livianas (30 g), y color de epicarpio y pulpa más oscuros que el fenotipo ecuatoriano. Se confirma parcialmente el conocimiento local, pues, aunque la mayoría de los descriptores coincidieron con la percepción local, no hubo coincidencia en los descriptores de color y sabor de pulpa.

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Plant Genetic Resources (PGR) include genetic diversity in the plant kingdom, with current or potential value (Esquinas-Alcázar, 1993; FAO, 2015). The conservation of these resources ensures the continuous evolution of the plant populations, as well as their adaptation process to different environments. An important part of PGR is the agricultural diversity and all the cropping systems, including those species in domestication process. Thus, one of the main concerns for human well-being is to maintain genetic variation between and within populations (Nodari and Tomás, 2010; Maxted *et al.*, 1997; Rivas, 2001).

One of the stages of conservation of PGR is its characterization, which estimates the existing variability of individuals of a certain population. Characterization, as a first step, is important when the objective is to specify the number of varieties managed by farmers and be able to determine their useful characteristics (Baena *et al.*, 2003; Peñaloza *et al.*, 2010). The Morpho-agronomic descriptors are used to carry out characterization; they are highly heritable attributes, which express themselves in all the environments; they are easy to measure, register, and evaluate (IPGRI, 1980). The descriptors that refer to the form, structure, or behavior of accessions are considered important and useful in describing a sample since they help to differentiate and describe the attribute in a precise and uniform way. An accurate description simplifies classification, storage, retrieval, and use of data. Descriptors are registered in qualitative or quantitative value scales (Franco and Hidalgo, 2003; Abadie and Berreta, 2001). The descriptors must have high discriminating action and low influence of the environment for the characterization, which in some cases allows registering the information *in situ* (Peñaloza *et al.*, 2010; Polanco, 2011). It is recommended to consult the lists of descriptors for the species under study published by *Biodiversity International* to proceed with characterization (IPGRI, previously).

Most of the characteristics that define a phenotype correspond to the morphological description of the plant and its architecture (Franco and Hidalgo, 2003). These are called morphological descriptors and can be grouped into the following types: (A) Botanical-Taxonomic: which are morphological characters that describe and identify the species and are common to all its individuals. (B) Morpho-agronomics: morphological characteristics that are relevant in the use of the cultivated species, allowing the estimating of the phenotypical variability, quickly and reliable (expressed in visible characteristics) (de Oliveira *et al.*, 2001). These can be qualitative or quantitative and include some of the botanical-taxonomic characteristics as well as others that do not necessarily identify the species but are important from a genetic improvement, agronomic, and market purposes. These characters can be the leaf shape, root pigmentation, stem, leaves and flowers, color and brightness of seeds and fruits, the architecture of the plant expressed as the habit of growth and types of branching. Descriptors related to the performance components are included because of their economic importance (Franco and Hidalgo, 2003; Abadie and Berreta, 2001). (C) Evaluative characteristics are expressed in response to biotic (pest and disease) or abiotic environmental factors (i.e., temperature, water, and nutrient stress). For example, the evaluation of morphological characters in tangerine "Arrayana" through descriptors allowed establishing homogeneity in a population from Department Meta-Colombia (Orduz-Rodríguez *et al.*, 2012).

The Molecular method is another way of characterization, it is based on the non-visible genetic variability, and it is of great interest in cropping improvement (Abadie and Berreta, 2001; Sánchez-Urdaneta and Peña-Valdivia, 2011). This method is highly sensitive and is not easily performed on promising species due to its cost, absence of molecular markers, and difficult extraction of their DNA. The main objective of characterization and evaluation is the identification and determination of the individuals' agronomical value. Nevertheless, the most reasonable approximation would be the integration of different characterizations, starting with the morphological description (Fernández and Negrillo, 2006).

Sapodilla (*Matisia cordata* Bonpl.) is a promising species that belongs to the Bombacoideae subfamily (Fam: Malvaceae). It is a native tree from the Amazon. Bees, hummingbirds, and bats visit its hermaphrodite flowers, and monkeys disperse its seeds in the natural habitats (Tschapka, 2004; Álvarez-Loayza and Terborgh, 2011). The sapodilla pulp has a sweet and nice taste, with a good content of fiber, potassium (454 mg $100g^{-1}$), phosphorus (28.5 mg $100g^{-1}$), and calcium (22-25 mg

100g^{-1}) (USDA, 2016). Once the fruit is physiologically mature and harvested, it can be kept for up to one week under shade. The hard consistency of its shell allows the fruit to be in good condition after transport. The wood of the tree is soft and light, used in sawmills, and as firewood. The Sapodilla trees can give shade to cocoa and coffee crops, and their leaves give a good fodder to animals (Geilfus, 1994; Villachica *et al*., 1996).

Sapodilla gives the identity to the nearby western of Antioquia region and represents an important source of income for local producers, collectors and traders that offer Sapodilla fresh fruit, and juices to the tourists. Currently, the cropping area has been reduced due to changes in the land use caused by the tourist development of the region, without any mitigation project in this situation (CCM, 2016). The region has traditional management of sapodilla crops, with very low technology and yields. Traditional orchards can be constituted by sapodilla trees mixed with other species, such as cocoa, banana, or ornamentals. It is also common to find cropping areas where sapodilla is the dominant species with planting distances between 7 and 9 m. Irrigation is essential since *M. cordata* is native to the tropical rainforest; therefore, it is intolerant to drought. Annual harvest is generally obtained in the months from July to October, which corresponds to an important income for the families.

Sapodilla is currently cultivated in tropical dry forest (bs-T) area, in the nearby western of Antioquia, Colombia. Although there is little technical information about the crops, farmers of the region have accumulated traditional knowledge and experience with the diversity of this species. They recognize two phenotypes of sapodilla, the “Creole” and the “Ecuadorian,” and differentiate them by morphological characteristics such as the size of their fruits, leaves, and the flavor of their pulp. In Colombia, no studies of morphological characterization of *M. cordata* are reported. However, in the department of Cauca, two varieties are recognized, one from Ecuador and the other one from Cauca. The Ecuadorian has heavier fruits. On the other hand, the Caucana variety is sweeter, the color of its pulp is brighter, and the fiber content is lower, which makes it more attractive for fresh consumption (Alegría *et al*., 2007). In the north of Peru, there is a type of sapodilla with low fiber content and superior flavor (Morton, 1987), and in Ecuador, there is a similar species *Matisia ochrocalyx* (sapotillo) with smaller fruits (Villachica *et al*., 1996).

This research aimed to study the phenotypic diversity of *M. cordata* in traditional orchards of the nearby western of Antioquia and to establish whether there are differences between the Creole and the Ecuadorian genotypes.

MATERIALS AND METHODS

This study was carried out in producing farms in the municipality of Sopetrán (Antioquia-Colombia) (6°30’21.5’’N 75°44’24.8’’W), in a dry forest life zone (bs-T), with an average temperature of 27.6 °C, an average annual precipitation of 1097 mm, and an average environmental humidity of 73.2% (IDEAM).

The sapodilla descriptors were elaborated using the document “Descriptors for tropical fruits (Descriptores para frutas tropicales)” (IPGRI, 1980) as a guide, since the specific descriptors for *M. cordata* are unknown. Interviews with producers and harvesters of the region were carried out, and field and laboratory observations were considered. The field guide was elaborated, and a pilot study with a few trees was done to discard the descriptors that did not show any variation or show many variations within the same individual. Finally, the definitive list of the descriptors was obtained.

One hundred trees of *M. cordata* in the reproductive stage, distributed in seven farms from 619 to 740 m.a.s.l., were selected and georeferenced (Table 1).

Field data

A total of 50 trees of the Creole phenotype and 50 of the Ecuadorian phenotypes were sampled. The Creole or the Ecuadorian phenotypes were established according to the criteria of farmers. Characterization was carried out during August and September 2014. The leaf, the fruit, and the seed descriptors of the plant were evaluated. The characterization process had two phases: *in situ* and in the laboratory. The qualitative descriptors were the crown shape (CS), the leaf apex (LA), and phenotype (PT). The quantitative descriptors were diameter at the chest height (DCH), the number of knots (NK), the leaf length (LL), the leaf width (LW), the petiole length (PL) and the number of major veins (MV), fruit weight (FW), diameter of the persistent chalice (DPC),

Table 1. Sites sampled in the municipality of Sopetrán for the characterization of *Matisia cordata* Bonpl.

No.	Village	Farm	Geographic coordinates		Altitude (m.a.s.l)	Number of trees
1	La Miranda	El Ensueño	6°30'44.5"N	74°45'13.2"W	675	20
2	La Miranda	Raúl	6°30'29.9"N	74°45'35.2"W	619	20
3	El Llano de Montaña	La Ceiba	6°29'39.9"N	75°45'35.2"W	660	12
4	El Llano de Montaña	Los Comuneros	6°29'45.3"N	75°45'35.2"W	664	3
5	Otra Banda	El Clavel	6°30'38.8"N	75°45'35.2"W	709	20
6	Otra Banda	Teresa	6°30'41.2"N	75°45'35.2"W	713	10
7	El Llano de Montaña	El Porvenir	6°29'22.3"N	75°45'35.2"W	740	15
Total						**100**

length of peduncle (LP), epicarp weight (EW), epicarp thickness (ET), Mesocarp weight (MW), total of soluble solids (TSS), number of seeds per fruit (NSF), weight of seeds per fruit (WSF), seeds length (SL), seeds width (SW). The color was obtained from the measurement with a colorimeter, which performs the measurement in the Red, Green, and Blue (RGB) color scale. These values are expressed in a combination of three numbers whose minimum and maximum values are 0 and 255, respectively. The variables for color were defined as R-pulp parameter (RPu), G-pulp parameter (GPu), B-pulp parameter (BPu), R-epicarp parameter (REp), G-epicarp parameter (GEp), and B-epicarp parameter (BEp). Table 2 records each descriptor and its units of measurement.

Five fruits per tree in harvest season were sampled. The evaluated fruits were healthy fruits, in a stage of commercial maturity, which is traditionally defined when the fruit develops a yellow halo around the persistent calyx (Figure 2). Harvested fruits were packed in bags and taken to the laboratory for the second step of characterization.

The second phase, related to the characterization of fruit and seeds, were carried out at the Botany and Plant Physiology laboratory of El Politécnico Colombiano Jaime Isaza Cadavid and at the Food Control and Quality laboratory of Universidad Nacional de Colombia, campus – in the city of Medellin. In order to obtain the color of *M. cordata* fruits, an X-Rite spectrocolorimeter with CIELAB color spectrum was used, and the RGB scale conversion (0-255) was made using the EasyRGB® (2014) online color calculator.

Phenotypic diversity analysis

The Gower distance (Gower, 1971) was used since it allows simultaneous analysis of quantitive and qualitative variables; distances were used to generate the dendrogram based on the paired grouping method with the unweighted arithmetic mean (UPGMA). In order to know the dendrogram reliability, the cophenetic correlation coefficient (CCC) was calculated. Subsequently, a cut distance was visually established in order to determine the groups. The R statistical environment (R Core Team, 2016) was used to do this statistical analysis.

Comparison of *Matisia cordata* phenotypes

The Bayesian methodology was used with the implementation of Markov chains in Monte Carlo simulation (MCMC). The mean of *a posteriori* distribution of the parameter was used as a Bayes estimative. Furthermore, the highest posterior density intervals (HPD) of the 95% of probability was obtained using the CODA package (Plummer, 2015) from the R environment (R Core Team, 2016).

In order to know if there was any difference between phenotypes measures, the difference between each sample of the effective Markov chain was calculated. The respective mean and HPD of the 95% of probability were obtained. For the qualitative variables (Table 2), the proportion of individuals of each category in each phenotype was determined, and such proportions were compared using the Bayesian methodology as described for quantitative variables: the Binom and the Bayesian First Aid.

RESULTS AND DISCUSSION

Phenotypic diversity analysis

Twenty-four quantitative and four qualitative descriptors were established for the discrimination between the Ecuatorian phenotype and the Creole phenotype of *M. cordata* (Table 2).

Table 2. List of descriptors and general descriptive statistics for the quantitative variables evaluated in *Matisia cordata* Bonpl.

No.	Organ	Descriptor	Symbol	Unit	Mean	SD	CV (%)
1	Tree	Diameter at chest height	DCH	cm	24.92	6.55	26.30
2		Crown shape	CS	Elliptical/Pyramidal/Oblong/ Spherical	-	-	-
3	Leaf	Number of knots	NK	unit	9.54	2.44	25.61
4		Leaf length	LL	cm	32.56	5.78	17.74
5		Leaf width	LW	cm	26.62	4.91	18.45
6		Petiole length	PL	cm	23.59	6.34	26.89
7		Number of main veins	MV	unit	9.87	0.99	10.05
8		Leaf apex	LA	Cusp/Obtuse	-	-	-
9	Fruit	Fruit weight	FW	g	383.65	**130.04**	**33.90**
10		Diameter of the persistent chalice	DPC	mm	51.83	5.28	10.19
11		Length of peduncle	LP	mm	3.54	0.99	28.00
12		Diameter of peduncle	DP	mm	14.95	2.52	16.89
13		Epicarp weight	EW	g	209.18	75.84	**36.26**
14		Epicarp thickness	ET	mm	9.16	2.36	25.78
15		Mesocarp weight	MW	g	138.31	53.03	**38.34**
16		Total of soluble solids	TSS	°Brix	12.18	2.68	22.05
17		R-Pulp parameter	RPu	R	189.50	18.55	9.79
18		G-Pulp parameter	GPu	G	106.13	9.55	9.00
19		B-Pulp parameter	BPu	B	30.74	9.34	30.40
20		R-Epicarp parameter	REp	R	110.41	8.37	7.58
21		G-Epicarp parameter	GEp	G	87.24	7.90	9.05
22		B-Epicarp parameter	BEp	B	50.85	6.31	12.41
23		Fruit shape	FS	Acute/Piriform/Oblong/ Obovate	-	-	-
24	Seed	Number of seeds per fruit	NSF	unit	4.30	**0.94**	22.00
25		Weight of seeds per fruit	WSF	g	36.16	13.32	**36.83**
26		Seeds length	SL	mm	41.50	3.72	8.96
27		Seed width	SW	mm	19.57	2.82	14.42
28		Phenotype	FT	Creole/Ecuadorian	-	-	-

The Fruit weight descriptors, FW, EW, WSF, and MW, showed a greater variability with the highest CV values (33.90%, 36.26%, 36.83%, and 38.34%, respectively). Additionally, the FW was the most variable descriptor (SD=130.04).

According to the qualitative descriptors, most of the trees showed pyramidal crown shape (51.0%) (CS), leaf apex (LA), and acute fruit shape (FS) (53%) (Figure 1).

Descriptor	Percentage
Crown shape (CS)	Elliptical 47% Oblong 2% Pyramidal 51%
Cusp leaf apex (LA)	Cusp 78% Obtuse 22%
Fruit shape (FS)	Acute 53% Oblong 19% Obovate 25% Pyriform 3%
Phenotype (PT)	Creole 50% Ecuadorian 50%

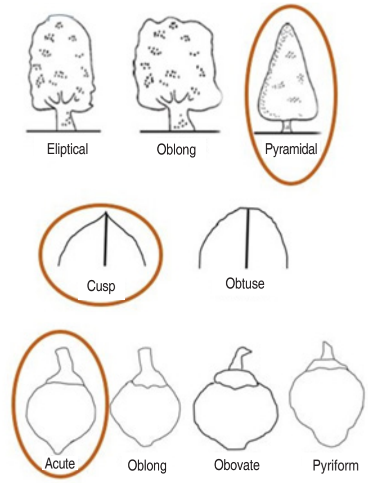

Figure 1. General frequencies of qualitative descriptors for 100 sapodilla individuals (CS: crown shape; LA: leaf apex; FS: fruit shape; PT: phenotype).

The cophenetic correlation coefficient found was 0.668, indicating that the dendrogram obtained by the UPGMA method represents 67% of the information in the Gower distances matrix, approximately. The dendrogram presents three groups of *M. cordata* individuals when cutting at a Gower distance of 0.30. The three groups differ by 30% (cut distance:0.30), which is an important percentage to evaluate diversity (Figure 2).

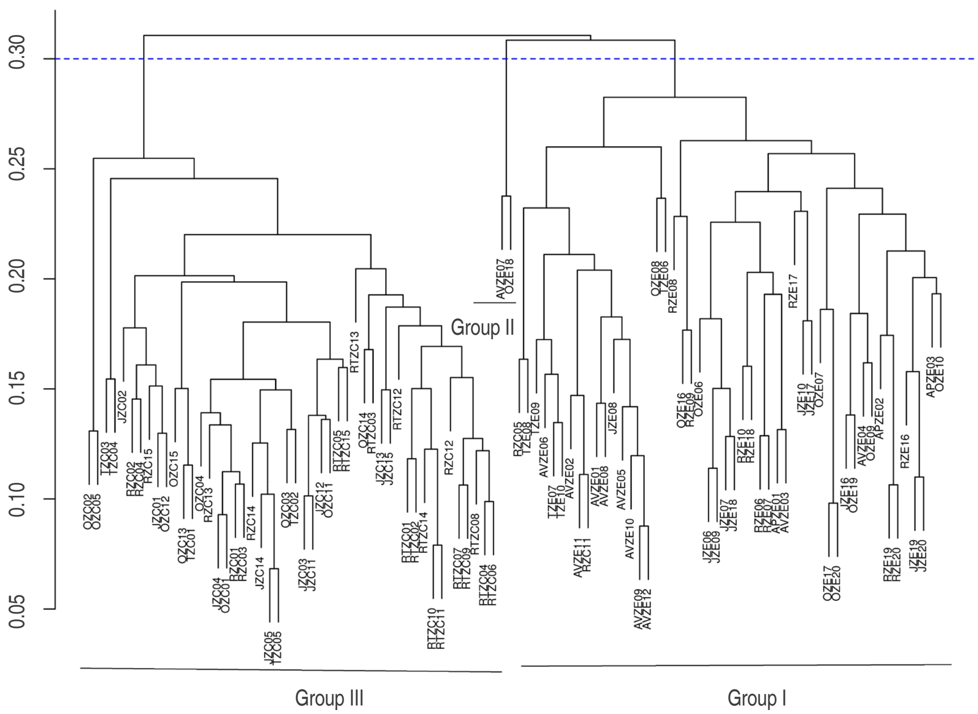

Figure 2. Dendrogram of *Matisia cordata* Bonpl. population from the morpho-agronomic data, generated by the UPGMA grouping method and the Gower distance.

Groups characteristics

Group 1. Formed by 50 individuals, 48 of them belonging to the Ecuadorian phenotype, and two of them to the Creole phenotype. This group is constituted by trees with the pyramidal CS, the largest leaves of the groups (LL:33.54 cm, and LW:28.4 cm), the largest petioles (PL:24.68 cm), and the cuspid apices (LA). The fruit has different forms (FS), the heaviest among the groups (FW:463.08 g), with a high mesocarp weight (pulp) (MW:167.19) and a high number of seeds (NSF:4.4). The fruit has dispersed solid content (SST), reaching 5.7 and 21.8 °Brix values.

Group 2. An atypical group formed by two Ecuadorian phenotype individuals. FW, EW, MW, and WSF descriptors are the most variable descriptors in the group with higher CV values within and between groups. These trees have the thinnest stems (DCH:2.47 cm); the leaves cuspided apex (LA), which are the smallest among the groups; 50% of the individuals show leaves that have less than 20 cm in length (LL:21.15 cm, LW:17.5 cm). The descriptor with the lowest variation is the DPC (CV:4.96%), with fruit with the highest soluble solids content (TSS:16.06); this does not coincide with the 9.0 °Brix found by Alegría *et al.* (2007) in sampling the Ecuadorian variety in the department of Cauca. The separation of these two individuals could be due to the highest values of TSS and color components, both in pulp and epicarp, being very sweet fruit with pulp and peel of orange and brown-green colors, respectively.

Group 3. Formed by 48 Creole phenotype individuals corresponding to 96% of the Creole trees evaluated, which are distributed in five of the seven sites sampled. This indicates that their origin was not an influential variable in the grouping. The trees show the highest average DCH (27.29 cm); therefore, they are older trees with thicker stems. This agreed with the versions of the local farmers, who affirm that the Creole sapodilla arrived first to the region than the Ecuadorian phenotype. The fruit is the lightest among the groups (FW:297 g), with a lighter epicarp, a lighter mesocarp, and lighter seeds. Nevertheless, Bajaña (2016) found that the lightest fruit weighed 324.08 g in Naranjito, Ecuador, while in Villachica *et al.* (1996) found fruits of 200 g; the fruit shape is acute (FS acute:93.8 %), their pulp is less sweet with the lowest average value of SST (11.8). WSF and the BPu are the descriptors with the greatest variation.

The Group 2 presented the highest color components values in the epicarp (REp:122.5, GEp:94.37, BEp:58.55) and in the pulp (RPu:191.8, GPu:111.7, BPu:33.6), it is to say that they have very light-colored peels and pulp. Individuals in this group showed an extreme color data,

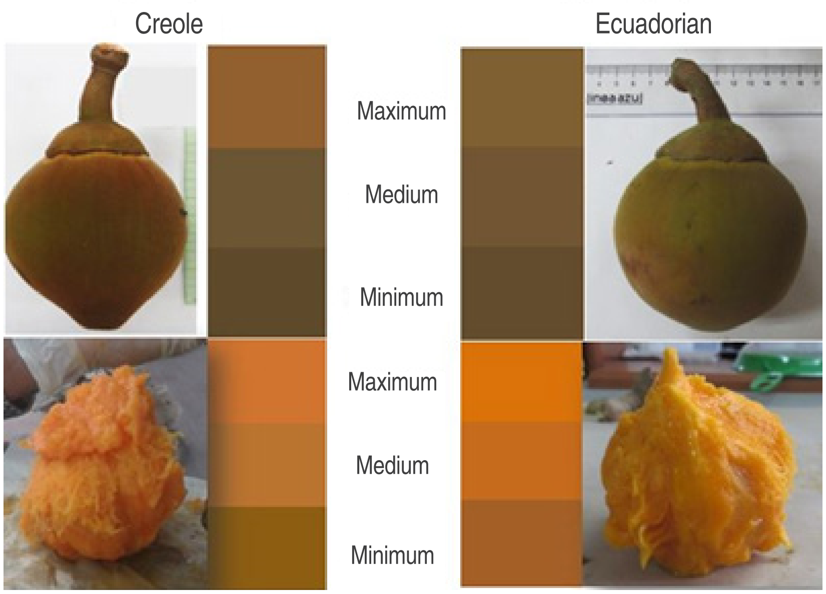

Figure 3. Maximum, medium, and minimum values of the pulp and epicarp color in Creole and Ecuadorian phenotypes of *Matisia cordata*, measured in the RGB scale (1-255).

possibly contributing to the separation of the other groups. The Group 3 presented the lowest values of color parameters in both the epicarp (REp:107.1, GEp:84.37, BEp:49.8) and the pulp (RPu:188.5, GPu:104.9, BPu:30.3), which corresponds to opaquer colors, i.e., a darker brown-green peel and a pale orange pulp. Group 1 presented intermediate values in color parameters; however, the values are higher than those of Group 3, i.e., the fruits have lighter tones (Table 2 and Figure 3).

Comparison of *Matisia cordata* phenotypes

When comparing both phenotypes, 64% of the variables showed significant differences (16 quantitative and two qualitative) according to HDP intervals of 95% of probability (Table 3).

Table 3. Comparison of the Creole phenotype and Ecuadorian phenotype of *Matisia cordata* Bonpl., according to the statistical significance descriptors.

No.	Descriptor	Symbol	Creole	Ecuadorian
1	Diameter at chest height (cm)	DCH	28.8±3.3	22.0±2.9
2	Number of knots	NK	10.0±0.7	8.0±0.7
3	Leaf width (cm)	LW	25.0±1.1	28.0±1.1
4	Fruit weight (g)	FW	301.0±20.0	465.0±22.0
5	Diameter of peduncle (mm)	DP	15.6±0.54	14.2±0.53
6	Epicarp weight (g)	EW	162.8±15.0	254.7±16.0
7	Epicarp thickness (g)	ET	8.57±1.0	10.1±1.0
8	Mesocarp weight (g)	MW	108.6±8.0	168.0±9.0
9	Total soluble solids (°Brix)	TSS	11.6±0.9	12.6±0.8
10	Weight of seeds per fruit (g)	WSF	30.0±2.8	42.0±2.7
11	Seeds length (mm)	SL	40.0±1.5	42.0±1.5
12	Seed width (mm)	SW	17.7±0.4	21.38±0.5
13	Red-Pulp parameter	Rpu	185.6±7.2	191.0±7.0
14	Green-Pulp parameter	GPu	104.0±1.3	107.0±1.5
15	Red-Epicarp parameter	REp	107.4±2.0	113.0±2.2
16	Green-Epicarp parameter	GEp	84.7±3.3	89.6±3.1
17	Crown shape	CS	Elliptical	Pyramidal
18	Fruit shape	FS	Acute	Obv-Pir-Ob

When comparing the crown shape of the tree, the elliptical crown shape (61%) and the pyramidal crown shape (61%) predominated in the Creole and the Ecuadorian phenotype, respectively. On the other hand, 86% of the fruits with an acute shape were of the Creole phenotype, and the 98% of the obovate shaped were of the Ecuadorian phenotype (Figure 4).

In general, the Creole phenotype is characterized by a thicker stem (DCH:28.8 cm), a higher number of knots (NK:10.0), and smaller leaves (LW:25.0 cm). The trees of the Ecuadorian phenotype presented thinner stems (DCH:22.0 cm), and larger leaves (LW:28.0 cm). This coincides with the appreciations of local people, who say the Ecuadorian sapodilla tree was introduced to the region after the Creole. This indicates that these trees are younger than Creole ones; therefore, they have thinner stems. Bajaña (2016) described these phenotype leaves of the Ecuadorian with a smaller width than 24.0 cm, while the trees in Sopetrán-Antioquia presented larger leaves (LW:28.0 cm). The Creole sapodilla fruit had thicker peduncles (DP:15.6 mm) and thinner epicarp (ET:8.5 mm).

The Ecuadorian sapodilla showed a higher average of TSS (12.6) than the Creole phenotype (TSS=11.6). This does not match with the findings of Alegría *et al*. (2007),

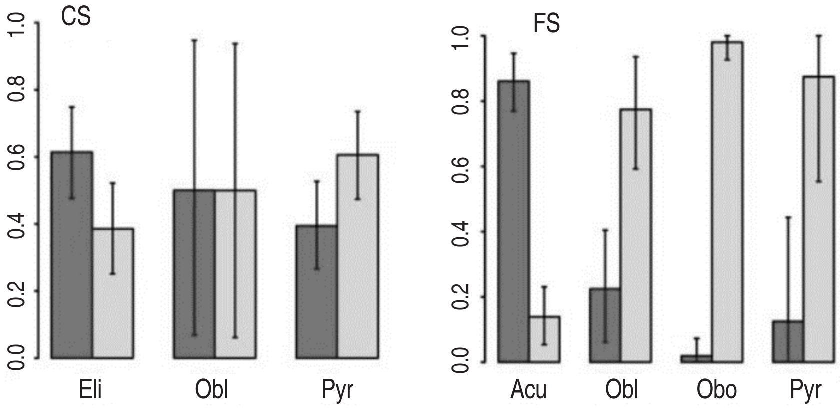

Figure 4. Comparison of the Creole and the Ecuadorian phenotypes of *Matisia cordata* Bonpl., according to the crown shape (CS) and the fruit shape (FS). The error bars indicate the limits of 95% of *a posteriori* high probability interval. The black and grey bars correspond to the Creole (C) and the Ecuadorian (E) phenotype, respectively.

who found values of 9.0 °Brix for the Ecuadorian variety and 11.0 °Brix for the Caucana variety in the department of Cauca (Colombia). The Ecuadorian phenotype has higher values than those reported in the department of Cauca, which may be due to the environmental conditions of this region. The information found does not agree with the traditional differentiation in the region that considers the fruits of the Creole variety sweeter than the Ecuadorian one.

The Creole phenotype was lighter (FW:301.0 g), also the epicarp (peel) (EW:162.8 g), the mesocarp (pulp) (MW:108.6 g), and the seeds (WSF:30.0 g). Additionally, the seeds were slightly smaller (SL:40.0 mm and SW:17.7 mm) than the Ecuadorian phenotype. Alegría *et al.* (2007) found differences in fruit weight between the Caucana variety (lighter fruit, 197.9 g) and the Ecuadorian variety (heavier fruit, 500 g). Although the Ecuadorian phenotype is heavier (WS:465 g), findings in the Cauca variety (Colombia) showed heavier fruit, which leads to inquiring about the origin of the Ecuadorian phenotype. Differences between the Caucana variety and the nearby western sapodilla of Antioquia suggest that a study comparing the two producing regions is necessary to determine the characteristics of each variety or regional phenotypes.

Both the Creole and the Ecuadorian phenotypes showed differences in the color of the pulp and the epicarp. The Creole sapodilla showed lower values in the red and in the green components of the pulp color (RPu:185.6, GPu:104.6) and of the epicarp (REp:107.4, GEp:85.2), which give to the Creole less intense tones than the Ecuadorian fruit (Figure 4). The more intense orange color was found in the Caucana variety in the department of Cauca, Colombia (Alegría *et al.*, 2007). This does not agree with the color results obtained in this study, as well as the appreciations of the interviewed people, who perceive the pulp of Creole sapodilla with a more intense color than the Ecuadorian pulp color.

In general, the Ecuadorian sapodilla showed better productive characteristics because it produces heavier fruit with greater pulp weight and a more attractive pulp color for the consumers. The fact of having wider leaves could influence the photosynthetic capacity of trees, making them more productive. In addition, this phenotype presented a large diversity of fruit shape, which questions the intraspecific diversity in the studied region.

CONCLUSIONS

The Ecuadorian sapodilla from the Nearby western of Antioquia was characterized by having larger leaves, diverse shaped and heavier fruit, and a heavier epicarp and pulp. It also has larger and heavier seeds than the Creole phenotype from the same region, which presented the fruit of acute shape, with pale orange pulp and epicarp of brown tonalities, and an elliptical-shaped tree crown. The Ecuadorians presented more intense orange pulps, dark green epicarps, and trees with Pyramidal crowns. The local knowledge of phenotypic variability of the sapodilla in the region is partially confirmed because the color and the flavor descriptors of the pulp did not agree with the local perception.

There is a lack of information and studies of *M. cordata*. Therefore, this study corresponds to pioneering and base work in Colombia, and it will be useful in the application of the proposed descriptors for future studies. This morphological study could be complemented by other molecular and/or morphometric works to support the obtained results better.

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