Morphological evaluation of an *in situ* collection of species from the Annonaceae family in Colombia

Evaluación morfológica de una colección *in situ* de especies de la familia Annonaceae en Colombia

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ABSTRACT

An *in situ* collection composed of 167 accessions of the species *Annona cherimola, A. glabra, A. reticulata,* and *A. squamosa, Rollinia* sp., and the interspecific hybrid *A. squamosa × A. cherimola* was established through bioprospecting of genetics resources of the Annonaceae family in the Colombian Andean and Caribbean regions. These accessions were distributed in 13 departments and 48 municipalities. The most representative species of this collection are *A. squamosa* and *A. reticulata*, which are derived from traditional cultivars of populated centers with a variable altitude range of up to 1,021 m a.s.l. The morpho-agronomic evaluation was carried out on 98 accessions using 25 qualitative and quantitative descriptors, which identified the phenotypic traits in *A. squamosa* and *A. reticulata* that are related to fruit quality, such as size, weight, symmetry, degrees Brix, pH, acidity, seed weight and seed number, which are the more discriminating descriptors, differentiating six clusters in *A. squamosa* and four clusters in *A. reticulata*.

Key words: *Annona reticulata*, *Annona squamosa*, genetic plant resources, germoplasm.

RESUMEN

A partir de la prospección de recursos fitogenéticos de la familia Annonaceae en las Regiones Andina y Caribe colombiano, se conformó una población *in situ* de 167 accesiones de las especies: *Annona cherimola, A. reticulata, A. squamosa, Rollinia* sp. y del híbrido interespecífico *A. squamosa × A. cherimola*, distribuidas en 13 departamentos y 48 municipios. Las especies más representativas en la población son *A. squamosa* y *A. reticulata*, conformadas por cultivares tradicionales de centros poblados de un rango altitudinal variable hasta 1.021 msnm. La evaluación morfoagronómica se realizó en 98 accesiones a través de 25 descriptores cuantitativos y cualitativos, permitió identificar en *A. squamosa* y *A. reticulata*, que los rasgos fenotípicos que se relacionan con la calidad del fruto como tamaño, peso, simetría, grados Brix, pH, acidez, peso y número de semillas son los que diferencian los seis agrupamientos conformados para *A. squamosa* y los cuatro para *A. reticulata*.

Palabras clave: *Annona reticulata*, *Annona squamosa*, recursos genéticos, germoplasma.

Introduction

The industrial and food significance of some species in the Annonaceae family (Agustín and Ledesma, 2014; Buriticá and Cartagena, 2015; Guerrero and Fischer, 2007; Moreno *et al*., 2013; Lemos, 2014) has led to the development of world-renowned commercial varieties, such as cherimoya (*Annona cherimola* Mill.) (Escribano *et al*., 2008) and atemoya (*A. squamosa × A. cherimola*), as a result of a long process of genetic improvement that has identified plants with commercially desirable agronomic characteristics that distinguish the fruit market of this family.

In Colombia, there have been few studies on species from the Annonaceae family and the studies that have been conducted focused on commercial species, such as *Annona muricata* L. (soursop), while ignoring other promising species, such as "*anon*" or sugar apple (*A. squamosa*) or recognized fruits such as cherimoya (*A. cherimola*). Other wild Annona species, with a native distribution that covers this country, still remain untapped. In the Annonaceae family, morphological studies have identified phenotypic traits (quantitative and qualitative) that characterize materials used in genetic improvement programs and that have been selected by fruit productivity and quality criteria (George *et al*., 1999).

The research that has been carried out on the Annonaceae family has contributed valuable information for the characterization process through the selection of morphological traits that have identified the phenotypic variability in an in situ population of *A. cherimola* trees (Alavez-López *et*

al., 2000) and the phenotypic variability of *A. cherimola* fruits in the province of Loja-Ecuador (Morales *et al.*, 2004).

Among the studies is to be emphasized the morphological evaluation of *A. muricata* germoplasm sampled in the Pacific and North of Nicaragua (Benavides, 2004), the incorporation of morphometric traits in the evaluation report of an *A. cherimola* germoplasm bank in Mexico (Andrés-Agustín *et al.*, 2004) and the morphometric analysis of organs of *A. cherimola* and fruit parameters for the characterization of Campas, Burtons, and White cultivars, as well as selected Mexican germoplasm (Andrés-Agustín *et al.*, 2006).

The descriptors developed for these species have been useful to evaluate an in situ collection of species from the Annonaceae family in Colombia, but also for the morpho-agronomic evaluation of *A. muricata* and *A. cherimola* ecotypes in fields and the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) collection in Costa Rica (Tacán, 2007) and for the evaluation of fruit yield and quality in an orchard of *A. muricata* L. trees (Evangelista-Lozano *et al.*, 2003).

The latter reported on advances in the morphological evaluation of species of the family, in which *in situ* and *ex situ* collections of *A. cherimola* have been established. It has been noted that fruit and leaf characteristics are relevant traits for differentiating genotypes in germoplasm collections. The present study aimed to morphologically evaluate an *in situ* collection of species in the Annonaceae family from the Andean and Caribbean regions of Colombia in order to contribute to the knowledge and establishment of a pioneer *Annonaceae* germplasm collection.

Materials and methods

The *in situ* collection (167 accessions) was based on the paper "Design of the collection of three species of the genus *Annona* of interest to Colombia" (2009) prepared under the project "Establishment of the Colombia Anon *(Annona squamosa* L.*)* Germplasm Collection", from the Universidad Nacional de Colombia (Parra, 2009). This process included selected accessions that had been collected before 2009, as well as selected material that had been collected for this study in 2010 and 2011 (Tab. 1).

Based on the information generated from the collection design, representative individuals from the Andean and Caribbean study areas were collected. During collection expeditions, individuals were selected to create the *in situ* collection that had little phytosanitary damage on the trunks, stems, leaves, flowers, and fruits, and, when possible, were in the process of blooming and fructification.

For the field identification and definition of accessions in the *in situ* collection, visits were made to home orchards, plots, and crops, where material from the species *A. squamosa, A. glabra, A. reticulata,* and *A. squamosa × A. cherimola*, including a few accessions from *A. cherimola* and *A. purpurea* (known as "soncoya"), were collected in areas with a natural distribution. The sample sites were visited

TABLE 1. General information of the *in situ* collection of Annonaceae species in Colombia.

Departments	Number of accessions	Species	Municipalities
Tolima	33 (19.76%)	*A. reticulata* (custard apple), *A. squamosa*	Alvarado, Ambalema, Armero, Carmen de Apicala, Coyaima, Espinal, Flandes, Guamo, Melgar, Piedras, Saldaña
Valle del Cauca	28 (16.77%)	*A. cherimola, A. squamosa × A. cherimola, A. reticulata, A. squamosa, Rollinia* sp. (anon del pacifico)	Guacari, La Union, La Victoria, Obando, Roldanillo, Sonso, Toro, Zaragoza, Zarzal
Cundinamarca	26 (15.57%)	*A. reticulata, A. squamosa*	Apulo, Cambao, Girardot, Guataqui, Jerusalen, Nariño
Santander	20 (11.98%)	*A. reticulata, A. squamosa*	Cepita, Piedecuesta
Guajira	13 (7.78%)	*A. reticulata, A. squamosa*	Dibulla, La Jagua del Pilar, San Juan del Cesar, Urumita, Villanueva
Nariño	11 (6.59%)	*A. cherimola*	Funes, Yacuanquer
Magdalena	11 (6.59%)	*Annona glabra* L. (anón), *A. reticulata, A. squamosa*	El Reten, Fundacion
Cordoba	8 (4.79%)	*A. glabra, A. reticulata, A. squamosa*	Lorica, San Antero, Tuchin
Atlantico	7 (4.19%)	*A. squamosa*	Ponedera, Sabanagrande, Sabanalarga
Casanare	4 (2.40%)	*A. reticulata, A. squamosa*	Trinidad, Yopal
Sucre	3 (1.80%)	*A. squamosa*	Sampues
Cesar	2 (1.20%)	*A. squamosa*	Valledupar
Bolivar	1 (0.60%)	*A. squamosa*	Santa Catalina

on one or two occasions, the individuals were georeferenced with a gps, and the environmental site conditions and plant morphological traits were recorded.

In order to obtain more detailed information from the *in situ* collection, 67 descriptors were used for cherimoya (*A. cherimola*), as defined by Bioversity International (2008); 29 of the descriptors corresponded to passport information, six to site and environmental site conditions, seven to tree characteristics or plant descriptors, and 25 to plant traits, related to leaf, fruit, and seed shapes and sizes, which were employed in the morphological evaluation (Tab. 2). The data compiled for these descriptors made up the *Annona in situ* collection data base.

For the identification of accession groups according to their morphological similarity (Tapia and Legaria, 2007; Franco and Hidalgo, 2003), a general analysis of the available information on morphological descriptors for each accession was carried out, followed by a univariate statistical analysis at the inter and intraspecific levels (with measurements of central tendency and dispersion), as well as an intraspecific multivariate statistical analysis with a principal components analysis -PCA- (quantitative and qualitative descriptors), cluster analysis with the UPGMA method-Unweighted Pair Group Method with Arithmetic Mean-, and Gower distance (Gower, 1971), using SAS® 9.1 and PAST 2.17 (Polly, 2007).

Results and discussion

Geographical distribution and habitat

The *in situ* collection was established primarily with germplams from cities and populated centers (52.69%), mostly with traditional cultivars (82.04%) that were not a part of crop systems (94.61%), given that the individuals were generally found in isolated conditions in plots or farms. During germplasm collection activities, the species *A. squamosa* was found as well-established crop only in the municipality of Apulo (Cundinamarca). Regarding the environmental site descriptors compiled for the *in situ* collection, the predominant agriculture type corresponded to 51.50% natural trees and shrubs and 40.70% general urban vegetation in the collection site and surrounding areas.

Interspecific morphological variability

The interspecific univariate analysis of 98 accessions (from all of the species) with 39 plant descriptors represented more than 80% of the information. In addition, there was no symmetry in the data and high dispersion was observed because of the variability of some descriptors, such as leaf

TABLE 2. Plant descriptors used for the morphological evaluation of the *in situ* collection of Annonaceae species in Colombia.

Aspect	Characteristic	Abbreviation
Tree	Tree height (cm)	H
	Circumference at breast height -GBH (cm)	CAP
	Canopy height (cm)	AC
	Canopy length (NS direction)-cm	LCNS
	Canopy length (EW direction)-cm	LCEW
	Ramification	RAM
	Sucker growth	SERP
Leaf	Leaf shape	GH
	Leaf apex	AH
	Leaf base	BH
	Length (mm)	LH
	Width (mm)	ANH
Flower	Petal length (mm)	LP
	Petal width (mm)	ANP
Fruit	Fructification habit	HABF
	Fruit shape*	FF
	Number of fruits	NF
	Fruit weight (g)	PF
	Symmetry	SIM
	Polar diameter (mm)	DPOL
	Equatorial diameter (mm)	DECU
	Type of exocarp	TEXO
	Exocarp color*	CEXO
	Exocarp weight (g)	PEXO
	Exocarp thickness (mm)	GEXO
	Percentage of exocarp	%EXO
	Percentage of pulp	%P
	Raquis weight (g)	PR
	Pulp weight (g)	PP
	Brix degrees	BRIX
	Acidity	ACID
	pH	PH
Seed	Seed weight (g)	PS
	Number of seeds per fruit	NS

Source: Bioversity International (2008). * Modified by the authors: attributes were included to complete the morphological descriptors.

length and width, fruit shape, polar and equatorial diameter, exocarp type and thickness, degrees Brix, acidity, pH, and exocarp and pulp percentage.

The interspecific multivariate analysis of the accession groups with 98 accessions showed that the first 16 components contributed 86.87% of the total variability (Tab. 3). Nonetheless, the components related to leaf and fruit

morphological characteristics had the highest contribution to the analysis and corresponded to 20 of the 25 descriptors for leaf and fruit shape and size (Tab. 4). In this case, the first three components explained 40.61% of the variation.

The morpho-agronomic analysis of the *in situ* collection of Annonaceae species (*A. cherimola, A. squamosa × A. cherimola, A. glabra, A. reticulata, A. squamosa*, and

TABLE 3. Eigenvalues and percentage of variance explained by the PCA for 98 accessions of the Annonaceae species of the *in situ* population from Colombia.

PC	Eigenvalue	Variance (%)	Accumulated variance (%)
1	7.86	20.16	20.16
2	4.10	10.52	30.68
3	3.87	9.93	40.61
4	2.75	7.06	47.67
5	2.06	5.29	52.96
6	1.96	5.04	58.00
7	1.72	4.41	62.41
8	1.66	4.26	66.67
9	1.44	3.68	70.35
10	1.22	3.12	73.47
11	1.11	2.83	76.30
12	1.03	2.63	78.93
13	0.95	2.43	81.36
14	0.80	2.04	83.40
15	0.73	1.88	85.27
16	0.62	1.59	86.87

Rollinia sp.) showed that the quantitative characteristics of the fruit, such as weight, polar and equatorial diameter, exocarp, raquis, and pulp weight, degrees Brix, acidity, and seed weight contributed more to the variation based on the coefficient of variation.

The cluster analysis of the set of Annonaceae accessions (*A. cherimola, A. glabra, A. reticulata, A. squamosa, A. squamosa × A. cherimola* and *Rollinia* sp.) showed six groups, at a Gower distance of 0.26, which supported the difference between the species based on their morphological affinity. The groups were characterized by clusters of same species individuals, according to qualitative morphological characteristics of the leaves and fruits. In this case, the quantitative characteristics had variation between the groups, except for group H, which contained the only *Rollinia* sp. accession and had the higher values for most descriptors (Tab. 5, Fig. 1). This analysis was developed by suggestion of experts, aiming to corroborate the morphological differences between species and provide statistical support of the in situ collection.

The latter was markedly observed for the species *A. reticulata* from Santander, Cundinamarca and Tolima, Córdoba and Valle del Cauca, which can be clearly differentiated into groups A, B, E, and F. Meanwhile, the species *A. squamosa* had the greatest representation in group D and originated from different provinces of Colombia. On the other hand, the species *Rollinia* sp. and *A. cherimola* were located in dissimilar groups (H and G, respectively) and,

TABLE 4. More informative variables according to the eigenvector values of the principal components for 98 accessions of Annonaceae species from Colombia.

						Informative variables									
1*	2*	3*	4*	5*	6*	7*	8*	9*	10*	11*	12*	13*	14*	15*	16*
LH (0.25)	P (0.29)	PS (-0.30)	LCEW (-0.24)	RMA (0.38)	AC (-0.39)	VEGS (-0.49)	FF (0.37)	SIM (0.33)	DRE (0.43)	H (0.39)	HABF (0.56)	%EXO (-0.25)	CAP (0.29)	BH (0.37)	CAP (0.29)
PF (0.31)	TA (-0.32)		TOP (0.34)	SERP (0.44)	LCNS (0.25)			TEXO (0.30)		PH (0.56)	NF (0.44)			ESP (-0.39)	ANH (-0.38)
DPOL (0.27)	FH (0.31)		FT (0.36)		AH (-0.28)			CEXO (-0.30)							
DECU (0.31)	BRIX (0.30)				%P (0.22)			GEXO (-0.38)							
PEXO (0.25)	ACID (0.31)							NS (0.00)							
PR (0.27)															
PP (0.31)															

* Principal component.

Shaded descriptors corresponded to 20 traits for leaf and fruit shape and size. See abbreviations in Tab. 2.

in other cases, some cluster groups (E and F) of accessions of more than one species were seen, but their geographical distribution is specific to one department (Tab. 5, Fig 1). This could be due to the centralized sampling strategy that was used and the progressive incorporation of individuals from other species during collection.

The descriptors that had higher contribution to the phenotypic variability in Annonaceae species in other collections of *A. cherimola*, matched with the descriptors used in this study, included: leaf shape, degrees Brix, number of seed per fruit, pulp weight, seed weight per fruit, fruit weight, pH, and percentage of pulp (Tab. 6). This information is useful to compare results from the characterization and morphological evaluation process of the collection established in this study and other previous efforts.

Intraspecific morphological variability

For the species *A. squamosa*, the principal components analysis included 24 descriptors that were related to

TABLE 5. Main aspects of the cluster analysis of the *in situ* collection of Annonaceae species in Colombia.

| Species	Cluster	Number of accessions and representativity in the collection	Origin
A. reticulata	A	2 (2.04%)	Santander
A. reticulata	B	3 (3.06%)	Cundinamarca and Tolima
A. squamosa	C	20 (20.41%)	Cundinamarca and Tolima
A. squamosa	D	47 (47.96%)	Nine departments
A. glabra and *A. reticulata*	E	4 (16.33%)	Mainly from Cordoba (*A. reticulata*) and Magdalena (*A. glabra*)
A. reticulata. A. squamosa and *A. squamosa* × *A. cherimola*	F	16 (16.33%)	Mainly from Valle del Cauca (except for one accession from Tolima)
A. cherimola	G	5 (5.10%)	Yacuanquer (Nariño)
Rollinia sp.	H	1 (1.02%)	Obando (Valle del Cauca)
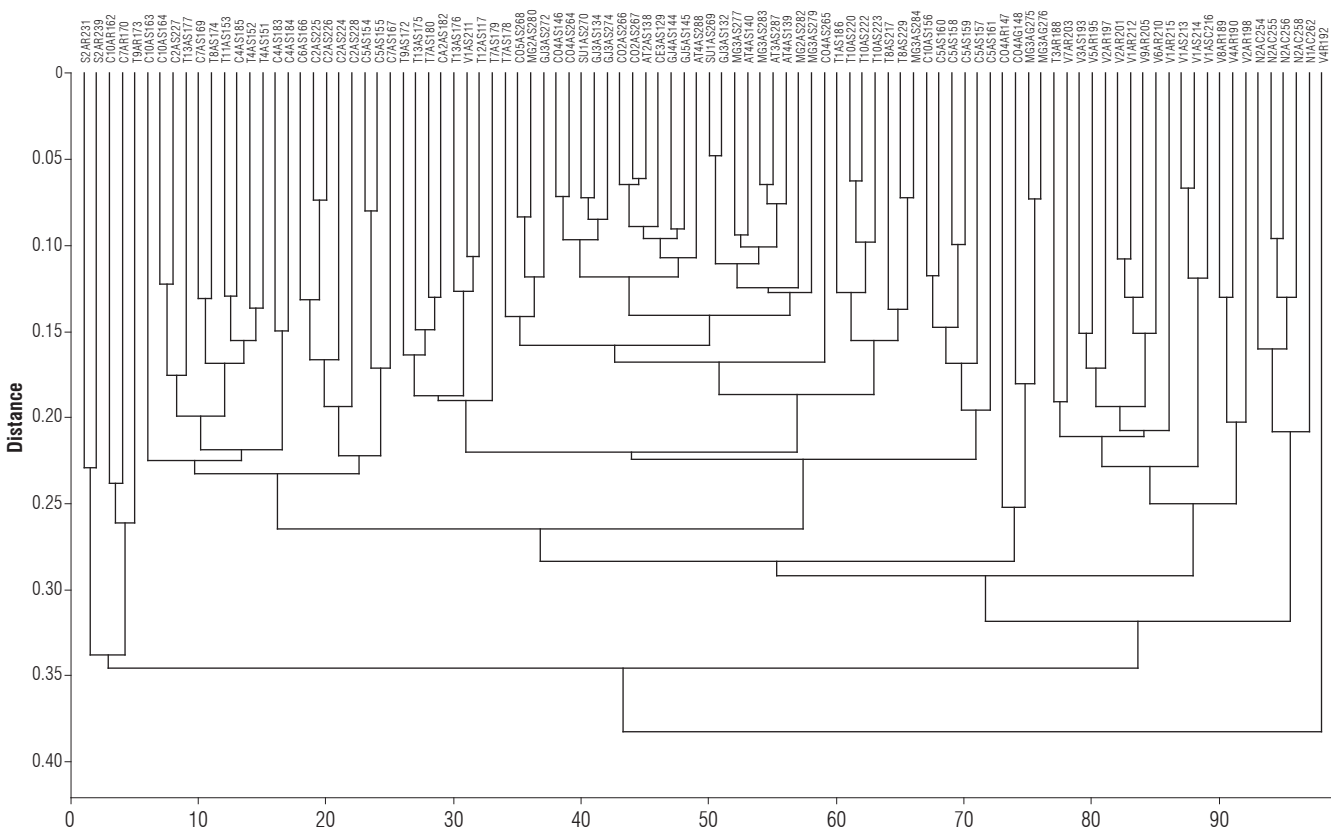
FIGURE 1. Dendrogram of morphological traits of 98 accessions of the *in situ* collection of Annonaceae (Gower distance) from Colombia.

TABLE 6. Comparison of morphological descriptors for current and previous characterizations of *A. cherimola* from Colombia.

Trait	Eigenvector values and principal component		Authors of the compared study
	This study	**Other studies**	
Leaf shape	0.3109, PC2	0.4521, PC6	Alavez-López *et al.* (2000)
Degrees Brix	0.3011, PC2	-0.39, PC1	Tacán (2007)
Number of seeds per fruit	-0.2979, PC3	-0.687, PC1. 0.3069, PC3. 0.56, PC2	Andrés-Agustín *et al.* (2006); Alavez-López *et al.* (2000); Tacán (2007)
Pulp weight	0.3126, PC1	0.3237, PC1. -1.04, PC1	Alavez-López *et al.* (2000); Tacán (2007)
Seed weight	-0.3046, PC3	0.307, PC3	Alavez-López *et al.* (2000)
Seed weight per fruit	-0.3046, PC3	-1.52, PC2. 0.3070; PC3	Tacán (2007); Alavez-López *et al.* (2000)
Fruit weight	0.3089, PC1	0.705, PC1	Andrés-Agustín *et al.* (2006)
pH	0.5576, PC11	-0.3448, PC3. 0.585, PC3. 0.45, PC2	Alavez-López *et al.* (2000); Andrés-Agustín *et al.* (2006); Tacán (2007)
Percentage of pulp	0.2218, PC6	-0.446; PC1	Andrés-Agustín *et al.* (2006)

commercially defined fruit quality parameters. The descriptors did not include exocarp type because it behaved as a constant in the univariate analysis. The PCA revealed that the first 10 components contributed 85% of the total variability (Tab. 7). The more informative variables were fruit weight, polar and equatorial diameter, exocarp weight, raquis and pulp weight, exocarp and pulp percentage, seed weight, and number of seeds (Tab. 8).

TABLE 7. Eigenvalues and percentage of variance explained by the PCA of 24 descriptors for the species *A. squamosa* from Colombia.

PC	Eigenvalue	Variance (%)	Accumulated variance (%)
1	6.20	25.83	25.83
2	3.33	13.89	39.72
3	2.66	11.07	50.79
4	2.12	8.83	59.62
5	1.53	6.37	65.99
6	1.22	5.08	71.07
7	1.12	4.65	75.72
8	0.92	3.84	79.56
9	0.80	3.33	82.89
10	0.74	3.08	85.97

The cluster analysis identified six accession groups, at a Gower distance of 0.28. These groups did not reflect any relationship with the geographic origin of the accessions, but there was evidence of the morphological differences of fruits and seeds between species. Groups C and D contained most of the accessions of A. *squamosa* (Fig. 2), followed by Group F, with clusters of some accessions of A. *squamosa*, A. *reticulata* and A. *squamosa* × A. *cherimola*. Additionally, groups A and B contained accessions of A. reticulata, and groups G and H had some accessions of A. cherimola, *Rollinia* sp.

These clusters could be explained by the flow of materials within the country's regions as a result of the historical anthropic selection of these perennial fruits. According to Gepts (2002), this type of selection has taken place in domestication processes in order to increase species adaptation to crop conditions and the use of harvest products, such as grains, fruits, and fibers. However, Lobo *et al.* (2007), based on their study on the characterization of A. *cherimola* and A. *muricata* seed germination and latency, stated that "perennial fruits are species in an initial

TABLE 8. Informative variables according to eigenvectors values for each principal component in *A. squamosa*.

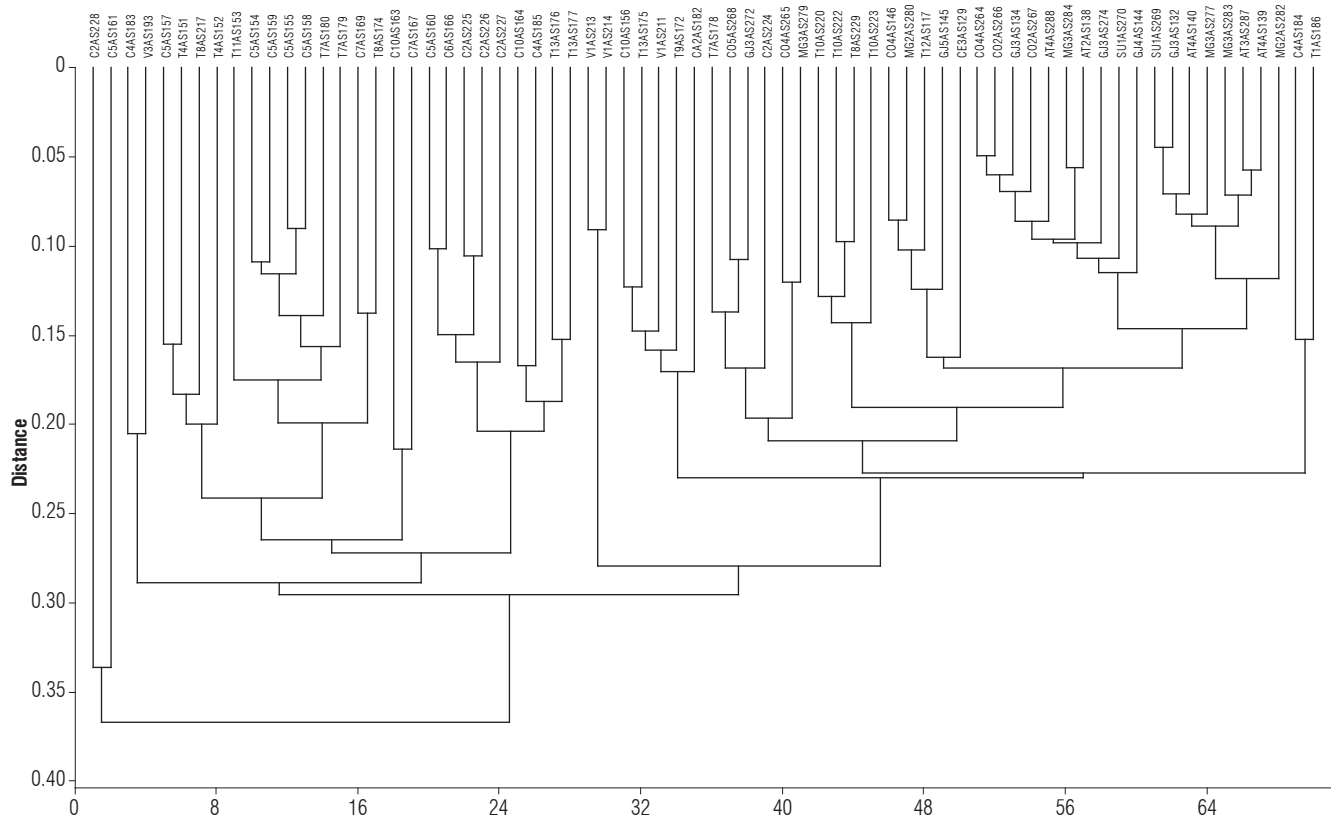| 1*	2*	3*	4*	5*	6*	7*	8*	9*	10*
PF (0.94)	FH (0.83)	AH (0.49)	LH (0.58)	SIM (0.59)	NF (-0.65)	HABF (0.48)	HABF (0.48)	GEXO (0.48)	
DPOL (0.84)	BH (-0.76)	CEXO (0.47)	ANH (0.47)						
DECU (0.88)	FF (-0.52)		PH (-0.60)						
PEXO (0.80)	BRIX (0.54)								
PR (0.67)	ACID (0.66)								
PP (0.84)									
%EXO (-0.61)									
%P (0.58)									
PS (0.70)									
NS (0.61)									

* Principal component. See abbreviations in Tab. 2.

FIGURE 2. Dendrogram of morphological traits of 70 accessions of *A. squamosa* (Gower distance) from Colombia.

domestication process, derived from the fact that most of these species have turned from being wild type plants to cultivated plants, with a syndrome of incomplete domestication" (Gepts, 2002).

For the species *A. reticulata*, the principal components analysis included 25 descriptors related to commercially defined fruit quality parameters. The PCA revealed that the first seven components contributed 86% of the total variability and showed eigenvalues above 1 (Tab. 9). Based on the eigenvalue vectors, the more informative variables were leaf length and apex, fruit weight, polar and equatorial diameter, exocarp type, color, and weight, raquis weight, pulp and seed, and number of seeds (Tab. 10).

The cluster analysis identified four accession groups, at a Gower distance of 0.32. These groups did not reflect any relationship with the geographic origin of the accessions. Group A contained the greatest number of accessions, from the departments of Tolima, Valle del Cauca, Santander, and Córdoba (Fig. 3), while the rest of the groups contained few accessions.

The detailed analysis of the six and four accession groups of *A. squamosa* and *A. reticulata*, respectively, showed that

TABLE 9. Eigenvalue vectors of the variance explained by the PCA (25 descriptors) for the species *A. reticulata* from Colombia.

PC	Eigenvalue	Variance %	Accumulated variance %
1	8.65	34.61	34.61
2	3.55	14.21	48.82
3	2.78	11.13	59.95
4	2.20	8.78	68.73
5	1.65	6.59	75.32
6	1.40	5.60	80.92
7	1.19	4.75	85.67

the phenotypic traits defined the principal homologies and differences between the groups, which, for sugar apple, are basically due to fruit quality (size, weight, symmetry, degrees Brix, pH, acidity, and seed weight and number).

In the *in situ* collection, the accessions of *A. squamosa* and *A. reticulata* showed a morphological-geographical association, given that the accessions from the Caribbean region and a few from the Andean region are located in a big group. On the contrary, a number of accessions of the two more representative species of the collection, from Cundinamarca, Tolima and Valle del Cauca, were grouped in different clusters and their morphological characteristics

TABLE 10. Informative variables according to eigenvectors values for each principal component in *A. reticulata* from Colombia.

1*	2*	3*	4*	5*	6*	7*
AH (-0.82)	FH (0.67)	ANH (-0.47)	HABF (0.66)	FF (0.75)	NF (0.60)	
LH (-0.55)	BH (-0.58)	BRIX (0.78)	ACID (0.66)			
PF (0.95)	SIM (0.65)	PH (0.81)				
DPOL (0.85)	GEXO (-0.64)	%EXO (0.59)				
DECU (0.76)		%P (-0.54)				
TEXO (-0.65)						
CEXO (0.67)						
PEXO (0.68)						
PR (0.88)						
PP (0.94)						
PS (0.76)						
NS (0.79)						

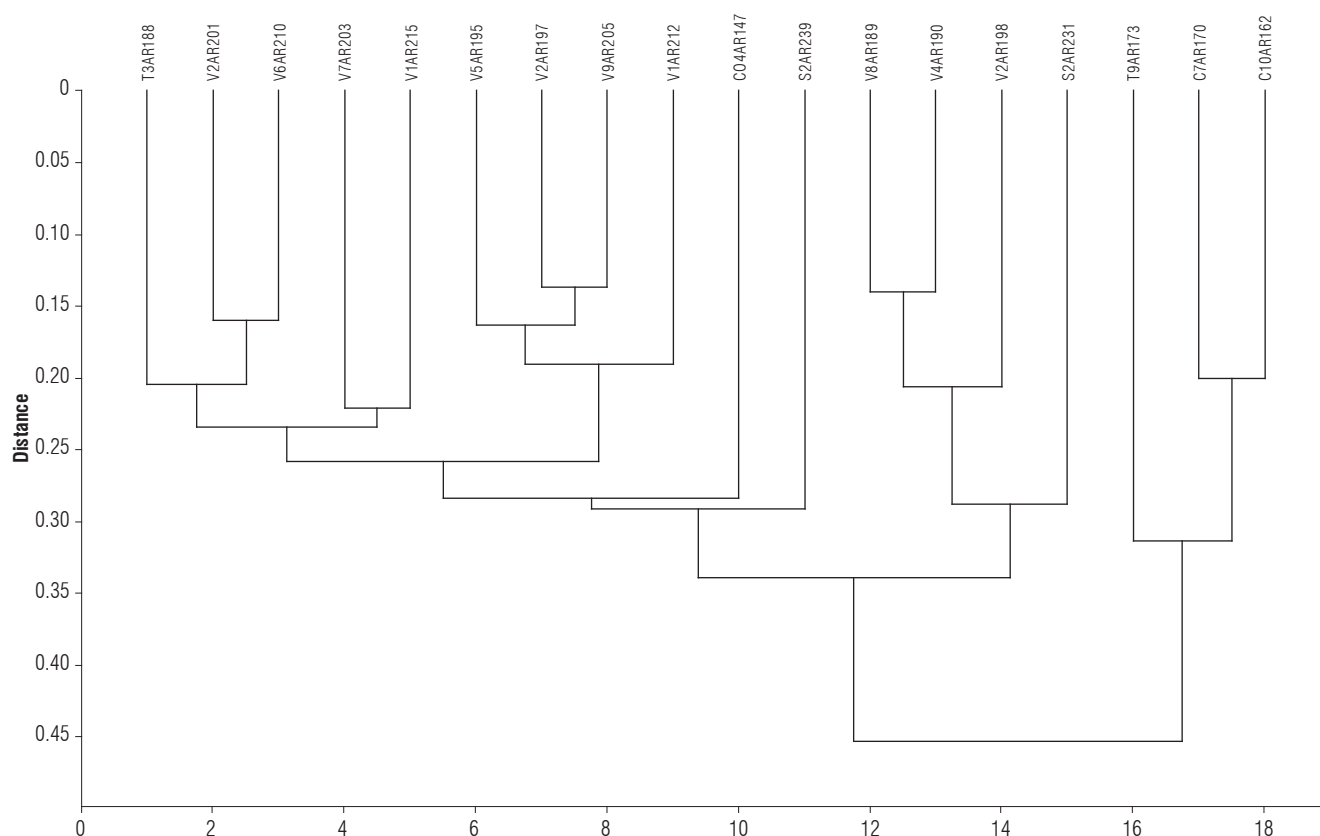* Principal component. See abbreviations in Tab. 2.

FIGURE 3. Dendogram of morphological traits of 18 accessions of *A. reticulata* (Gower distance) from Colombia.

are relevant for marketing and consumption. The clustering of the accessions according to their morphological and origin similarity could be attributed to the interaction between the genotype and the environment from which the individuals came from. However, complementary studies on these aspects must be conducted in order to derive conclusions on this topic.

A comparison of the physical characteristics of genotypes of the *in situ* anon (*A. squamosa*) collection in Colombia with *A. squamosa* genotypes in Brazil revealed that the average number of seeds per fruit varied between 13 and 84, which is equal to the value variation obtained by Cavalcante *et al.* (2011), who found a variation between 11 and 47 seeds per fruit among genotypes of an active germoplasm bank.

Although the population in this study, with 70 accessions from 10 departments, was much greater than that obtained by the Brazilian researchers, with 12 genotypes from one municipality, the reference values found by the Brazilian researchers were useful in this study as a measure of productivity in *A. squamosa*.

In the *in situ* collection, the comparison of the *A. squamosa* fruit shape with the relationship between longitudinal and transversal fruit diameters (relation DL/DT) showed values between 0.76 and 1.03, which produced round fruits suitable for the fruit market. According to Silva *et al.* (1998), fruits are round when the value nears 1.0, a favorable trait for quality fruit markets, and a relevant characteristic for freshly consumable anon. Cavalcante *et al.* (2011) conducted the same comparison in *A. squamosa* genotypes and found that these fruits met the characteristics required by the Brazilian market. This relationship may be taken into consideration in future research.

Although this study did not evaluate the genotype x environment interaction, the intraspecific morphological variations could have been partly due to the wide geographical distribution of the accessions and the different environmental characteristics of the collection sites.

Conclusions

The morphological traits that contributed to the differentiation of the *A. squamosa* accessions included fruit weight, polar and equatorial diameter, exocarp weight, raquis and pulp weight, exocarp and pulp percentage, and seed weight and number. On the contrary, for *A. reticulata*, leaf length and apex, as well as exocarp type and color, were the traits that contributed to the differentiation of this species.

The intraspecific morpho-agronomic evaluation of the *in situ* population of Annonaceae in Colombia revealed ten accession groups of *A. squamosa* and *A. reticulata*, six and four, respectively, that were characterized by similarities in traits such as fruit size, weight, symmetry, Brix degrees, pH, and acidity, in addition to seed weight and number.

For *A. reticulata* and *A. squamosa*, superior category fruits (cordiform, symmetrical, greater weight and a Brix degrees content above 15°) were found in the departments of Cundinamarca and Tolima, while, for *Rollinia* sp. and *A. squamosa* x *A. cherimola*, they were found in Valle del Cauca. Most of the fruits of the species assessed in the *in situ* population were classified as common because their characteristics differed greatly from those required by the international fruit market.

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