Morphological characterization of *Capsicum* spp. accessions from the germoplasm collection of Corpoica C.I. Palmira, Colombia

Caracterización morfológica de introducciones de *Capsicum* spp. existentes en el Banco de Germoplasma activo de Corpoica C.I. Palmira, Colombia

Diana Villota-Cerón[1], *Martha Liliana Bonilla-Betancourt*[2]*, *Horacio Carmen-Carrillo*[3], *Juan Jaramillo-Vásquez*[4], and *Mario Augusto García-Dávila*[5]

[1]Universidad de Nariño, Pasto, Nariño, Colombia. [2,3,4]Colombian Corporation for Agricultural Research, Corpoica Palmira, Valle del Cauca, Colombia. [5]Universidad Nacional de Colombia - Palmira, Department of Agricultural Sciences, Palmira, Valle del Cauca, Colombia.
*Corresponding author: mbonilla@corpoica.org.co, mlbonillab@gmail.com

Rec.: 12.10.11 Acept.: 04.03.12

Abstract

68 accessions from the *Capsicum* collection of the Colombian Corporation for Agricultural Research CORPOICA, Palmira were morphologically characterized by using 12 quantitative and 10 qualitative descriptors. The variables with highest contribution in the principal components analysis were associated to plant architecture and fruit descriptors that explained 70.8% of the total variability. Classification analysis, based on quantitative data, showed 5 groups but it did not allow discrimination between species. For the multiple correspondence analyses, 83.4% of the variability was explained by variables related with flower and fruit traits. The classification analyses, using qualitative descriptors, showed 4 groups and allowed discrimination of *C. baccatum* species. The discriminant analysis showed that *C. annuum*, *C. frutescens*, and *C. chinense* are close phylogenetically.

Key words: Accessions, *Capsicum*, morphological characterization.

Resumen

Se caracterizaron morfológicamente 68 introducciones del género *Capsicum* existentes en el Banco de Germoplasma activo del Centro de Investigaciones Agropecuarias (Corpoica) Palmira, utilizando 12 descriptores cuantitativos y 10 cualitativos. En el análisis de componentes principales las características de mayor contribución fueron las relacionadas con el fruto y arquitectura de planta, que explicaron el 70.8% de la variabilidad. El análisis de clasificación permitió conformar cinco grupos con base en características cuantitativas, pero no permitió discriminar entre especies. En el análisis de correspondencia múltiple el 83.4% de la variabilidad fue explicada por los descriptores de flor y fruto. El análisis de agrupamiento para las variables cualitativas generó cuatro grupos y

discriminó la especies *C. baccatum.* El análisis discriminante mostró que las especies *C. annuum*, *C. frutescens*, y *C. chinense* son cercanas filogenéticamente.

Palabras clave: *Capsicum*, caracterización morfológica, introducciones.

Introducción

The genus *Capsicum* is native to the Americas continent (Bolivia, Peru, south of Mexico and Colombia). However, its natural range extends from southern United States to Argentina (Arias and Melgarejo, 2000). It comprises about 25 species from which *C. annuum L., C. chinense Jacq., C. pubescens* Ruiz & Pav., *C. frutescens* L. and *C. baccatum* L. have been domesticated and cultivated primarily for its high content of vitamins A and C, and the content of capsaicinoids and alkaloid responsible for the pungency (Nuez *et al.*, 1996). The diversity available within the domesticated taxa has been little exploited, and the use of this variability is relatively easy compared to the problems of interspecific transfer of genes to other genera (Pickersgill, 1997). Their breeding depends on the availability and strategic use of genetic diversity. Genetic variation of wild species, compared to domesticated, provides novel gene complexes for strategic breeding to tolerance of biotic and abiotic factors (Votaba *et al.*, 2002).

From this research, it is expected to contribute to the study of morphological variability of 68 accessions of *Capsicum* from the active Germplasm Bank that is settled in the Research Center Corpoica-Palmira, and also to the selection of promising accessions to increase the supply of varieties of this genus.

Materials and Methods

Morphological characterization was performed at the Research Center Corpoica-Palmira, Valle del Cauca, Colombia, located at 1001 MASL, average temperature of 24°C and average rainfall of 1022 mm/year.

Plant material

68 accessions of *Capsicum* genus were characterized. Those belonged to *C. annuum, C. frutescens, C. chinense, C. pubescens* and *C. baccatum* species from the Germoplasm Bank at the Colombian Corporation of Agricultural Research (Corpoica) C.I Palmira. It was also included commercial genotypes in Colombia represented by *C. chinense* (Habanero Amarillo), *C. annuum* (Jalapeño Telica and Cayene Durke) and *C. frutescens* (Tabasco Costa) (Table 1). A completely randomized design was used with 18 plants per introduction, without replicates. Plants of each Introduction were planted in double rows at a distance of 40cm between plants and 1.20cm between rows.

Morphological characterization

12 quantitative and 10 qualitative descriptors of plant, flower, fruit and seed were selected according to IPGRI *et al.* (1995). Those were identified as discriminating in previous characterization studies (Pardey *et al.*, 2006) (Table 2). Each descriptor was evaluated in nine plants to obtain the average value of the results.

Analysis of results

Descriptive analysis, simple correlation and principal components (PCA) were performed for quantitative variables. Principal components were selected with eigenvalues >1.0, which explain the greater variability in the studied population. From PCA, the classification analysis was performed following the ranking aggregation method of Lebart *et al.* (1998).

Multiple correspondence analysis (MCA) was performed for qualitative variables to obtain a three-dimensional representation of the grouping of genotypes based on genetic distances. The statistical package NTSYS-pc version 1.80 (Rohlf, 1994) was used to get data of genetic similarity. Then, a grouping matrix and subsequently, the dendrogram were generated by the UPGMA arithmetic average, non-weighted method. Discriminant relatioships between species and group of

Table 1. *Capsicum* accessions evaluated from the existing collection in C.I Corpoica-Palmira.

Consecutive	Accession	Species	Consecutive	Accession	Species
1	Yellow habanero	*C. chinense*	35	2762	*C. annuum*
2	Jalapeño Telica	*C. annuum*	36	1371	*C. frutescens*
3	Tabasco Costa	*C. frutescens*	37	486	*C. baccatum*
4	Cayene Durke	*C. annuum*	38	2606	*C. baccatum*
5	820	*C. annuum.*	39	2577	*C. frutescens*
6	593	*C. baccatum*	40	535	*C. chinense*
7	1312	*C. frutescens*	41	820(1)	*C. annuum*
8	1391(1)[a]	*C. frutescens*	42	1404	*C. chinense*
9	1391	*C. frutescens*	43	1406	*C. chinense*
10	1390	*C. chinense*	44	590	*C. annuum*
11	346	*C. baccatum*	45	1360	*C. chinense*
12	1353(3)	*C. chinense*	46	612	*C. chinense*
13	2608	*C. baccatum*	47	2570(1)	*C. annuum*
14	1353	*C. chinense*	48	1409	*C. annuum*
15	1414	*C. chinense*	49	1378	*C. pubescens*
16	597	*C. chinense*	50	2579(3)	*C. chinense*
17	1306	*C. chinense*	51	1319(1)	*C. annuum*
18	529	*C. chinense*	52	002	*C. annuum*
19	1374	*C. annuum*	53	2550	*C. annuum*
20	1324	*C. chinense*	54	2761	*C. anuum*
21	2547	*C. annuum*	55	1381	*C. frutescens*
22	1367	*C. frutescens*	56	456	*C. chinense*
23	1334	*C. chinense*	57	333	*C. baccatum*
24	1353(4)	*C. chinense*	58	1353(2)	*C. chinense*
25	2659	*C. chinense*	59	1420	*C. annuum*
26	536	*C. annuum*	60	2570	*C. annuum*
27	039P	*C. annuum*	61	1327	*C. annuum*
28	036P	*C. annuum*	62	1372	*C. annuum*
29	038Pv	*C. annuum*	63	1307	*C. frutescens*
30	591	*C. baccatum*	64	037P	*C. annuum*
31	1390(1)	*C. chinense*	65	1375(1)	*C. annuum*
32	063	*C. baccatum*	66	1421	*C. baccatum*
33	2544	*C. baccatum*	67	2579(2)	*C. chinense*
34	1423	*C. annuum*	68	536(1)	*C. annuum*

a. Accessions coded with a number in parentheses are identified plants from accessions with segregation, that were also independently evaluated for this study..

Table 2. Quantitative and qualitative descriptors assessment of the existing *Capsicum* collection in C.I. Corpoica-Palmira.

Qualitative variables	Identification	Qualitative variables	Identification
Flower position	PF	Plant height	ALP
Corolla color	CC	Plant width	ANP
Presence/ absence of stains	PM	Leaf width	ANH
Stigma erection	EE	Blade length	LH
Anthers opening	AA	Pedicel length	LP
Calyx anular constriction	CAC	Number of flowers * axilla	NFA
Fruit shape	FF	Corolla length	LC
Apex fruit shape	FAF	Fruit length	LF
Fruit epidermis type	TEF	Fruit width	AF
Seed color	CS	Fruit weight	PF
—	—	Wall thickness of the fruit	EPF
—	—	Number of locules	NL

analysis was performed to establish relationships between species and group of individuals.

Results and discussion

Qualitative descriptors

Capsicum species share common features, but some have their own characteristics highlighting: *C. baccatum* by the stain on the corolla, *C. chinense* by constriction ring in the cup, *C. frutescens* by the erect position of the fruit, and *C. annuum* the slope position of the fruit (Table 3).

Multiple correspondence analysis

The 10 qualitative variables in the MCA allowed identifying four dimensions that explain more than 80% of the total variability (Table 4). The first dimension is defined by the variables anther opening (AA) with a contribution of 35%, fruit epidermis type (EF) with 27%, and flower position (PF) with 16%. The second dimension is defined by the descriptor corolla color (CC) with a contribution of 29%. The third dimension is defined by apex shape of the fruit (FAF). The fourth dimension is defined by the calyx ring block (CAC) in 15.2%. Photo 1 shows the great variation in flower and fruit descriptors for the evaluated accessions.

Clustering analysis

Four groups were identified in the classification analysis based on the MCA, which showed a clustering tendency by species characteristics (Figure 1).

The first group consists of accessions belonging to the species *C. baccatum*. These accessions had spots on the corolla, exserted stigma and anthers separated from the stigma. These characteristics are representa-

Table 3. Qualitative descriptors used in 68 accessions of Capsicum in the existing collection of C.I. Corpoica-Palmira.

Descriptor	Category	*C. annuum*	*C. baccatum*	*C. chinense*	*C. frutescens*	*C. pubescens*
Flower position	Pendula	21	—	—	—	—
	Intermediate	35	—	15	15	—
	Erect	42	100	85	85	100
Corolla color	White	57	—	—	—	—
	Light yellow	36	100	40	—	—
	Yellow Green	7	—	60	100	—
	Purple	0	—	—	—	—
		—	—	—	—	100
Presence/ absence of stains	Present	—	100	—	—	100
	Absent	100	—	100	100	—
Stigma exsertion	Insert	—	80	—	—	—
	At the same level	11	10	—	—	100
	Exsertedo	89	10	100	100	—
Anthers opening	Open	7	100	5	—	100
	Closed	93	0	95	100	—
Calyx constriction ring	Present	—	—	100	—	—
	Absent	100	100	—	100	100
Fruit shape	Elongated	25	100	—	25	—
	Triangle-shaped	71	—	28	75	100
	Bell-shaped	4	—	72	—	—
Apex fruit shape	Pointy	82	100	71	38	—
	Romo	17	—	—	62	100
	Sunked	—	—	28	—	—
Fruit epidermis type	Smooth	68	—	0	12	100
	Semi-rough	29	80	62	75	-
	Rough	3	20	38	13	-
Seed color	Yellor	100	100	100	100	—
	Black	—	—	—	—	100

The values indicate the percentage of accessions presenting the respective category

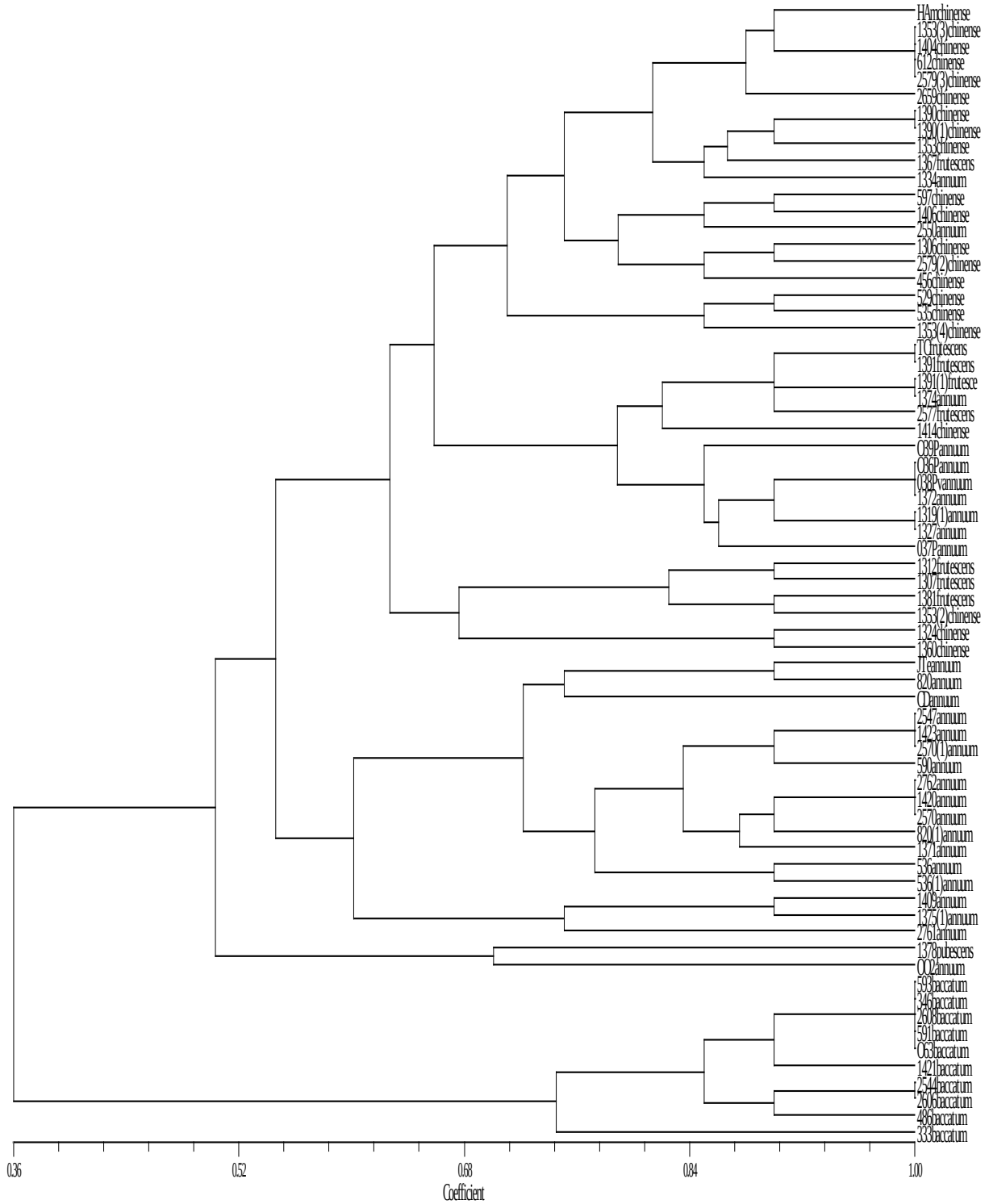


Figure 1. Hierarchical classification of 68 accessions of *Capsicum* in the existing germplasm bank in Corpoica Palmira. Obtained from multiple correspondence analysis (MCA).

tive of this species and used as taxonomic classification criteria. The opening descriptor of the anther was added to the list of des-

Table 4. Multiple correspondence analysis for qualitative variables of 68 *Capsicum* accessions in the existing collection of C.I. Corpoica-Palmira.

Number	Eigenvalue	Percentage	Accumulated percentage
1	0.0311	36.71	36.71
2	0.0198	23.35	60.06
3	0.0118	13.94	74.00
4	0.0080	9.45	83.45
5	0.0063	7.45	90.90

criptors proposed by IPGRI *et al.* (1995), and was characteristic of these species accessions.

The second group consists of two accessions 002 belonging to the species *C. annuum* and the 1378 introduction belonging to *C. pubescens* specie. The species *C. pubescens* is considered unique among domesticated capsicum by adaptation (Bosland, 1996). This introduction is characterized by purple corolla and triangular fruit, and this should have

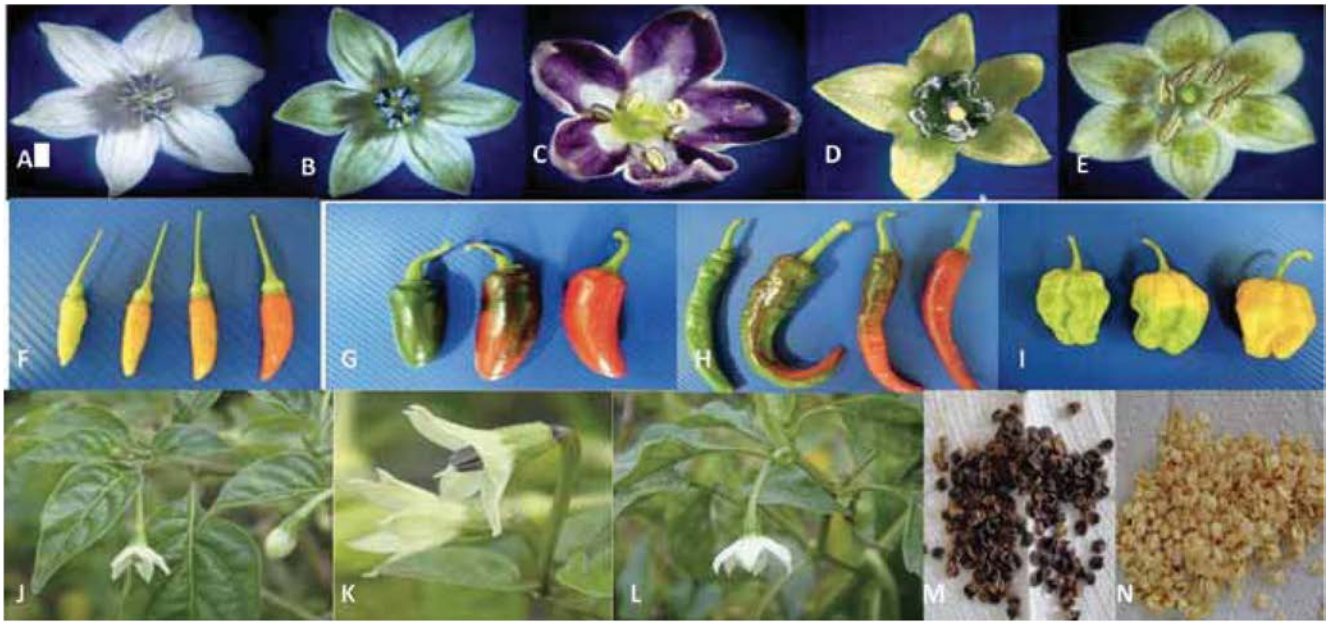
The third group consists of 17 accessions, all belonging to the *C. annuum* Specie. These accessions were characterized by a white corolla and exserted stigma.

The fourth group comprises 57.3% of the studied accessions. The following accessions species met in this group: *C. chinense, C. frutescens*, and some accessions of *C. annuum*. These materials presented exserted stigma, yellow seed color and upright flower position, a typical characteristic of the species *C. frutescens* and *C. chinense*. To these belong the most accessions of this group.

Vallejo *et al.* (2006) and Palacios-Castro and Garcia-Davila (2008) were able to discriminate the species *C. pubescens* and *C. bacccatum*, but not between the species *C. annuum, C. frutescens* and *C. chinense*. The results of this study confirmed the hypothesis that these three species are a culti group in differentiation pathway (Pickersgill, 1997). The cophenetic coefficient (0.82) also indicated a high degree of correspondence between the similarity matrix and the dendrogram obtained as a measure of dispersion.

Relationships between species

Mahalanobis distance indicated that *C. annuum, C. frutescens* and *C. chinense* species are phylogenetically close (Table 5). The results of this study support the observations



Picture 1. Morphological variability of *Capsicum* in the existing germplasm bank in Corpoica Palmira. **A-E**, corolla color and anther aperture. F-I, fruit variability: color, shape and size. **J-L**, flower position (pendula, erect and intermediate, respectively). **M-N**, seed color.

Table 5. Square genetic distance between *Capsicum* species in the existing collection of C.I. Corpoica-Palmira.

Variables	*C. annuum*	*C. baccatum*	*C. chinense*	*C. frutescnes*	*C.pubescens*
C. annuum	1.77				
C. baccatum	**83.71**	3.83			
C. chinense	14.58	**90.32**	2.34		
C. frutescens	6.22	**88.45**	4.558	4.28	
C. pubescens	**74.05**	**215.2**	**146.34**	**114.89**	8.43

made by Garcia (2006) about the species *C. annuum, C. frutescens* and *C. chinense* because they form a group that is in the process of differentiation. This statement is attributed to the phylogenetic distances between groups and within groups based on morphological, isozyme and crossability studies among wild and domesticated species.

Quantitative descriptors

Quantitative descriptors presented a wide range of variation, which is deduced from scattering and the intervals measurements in each of the attributes (Table 6). The coefficient of variation (CV) was > 25% for 75% of the descriptors considered, confirming the importance of these descriptors to discriminate variability in active genebanks or germplasm banks of chile. The leaf length and number of cores were the descriptors that contributed the least to variability, which confirms the results of Pardey *et al.* (2006).

The highest correlations were observed between leaf length and leaf width variables, with a coefficient (r) of 0.76. Width of the plant and plant height was r = 0.65. Wall thickness of the fruit, and width and weight of the fruit were r = 0.60 and 0.68, respectively (Table 7).

Principal component analysis

PCA showed that the first four components are eigenvalues > 1, with a cumulative variability of 70.8% (Table 8). The contribution of each quantitative variable to the formation of the axes is shown in Table 9. The representation of three-dimensional space of the 12 quantitative variables in the first three principal components is presented also in Figure 1, where the major variable contribution is related to the characteristics of fruit and vegetables.

Table 6. Simple statistical for 12 quantitative traits of *Capsicum* species in the existing collection of C.I. Corpoica-Palmira.

Variable	Media	Max. Value.	Min. Value	S.D	C.V. (%)
Plant height	111.160	179	34	33.76	30.38
Plant width	93.237	154	40	23.97	25.71
Leaf width	4.625	7.4	1.9	1.1609	25.10
Leaf length	8.803	12.5	3.5	1.914	21.74
Corolla length	1.828	3	0.9	0.4462	24.41
Number of flowers per axill	1.338	2	1	0.4766	35.62
Pedicel lenght	3.450	10	0.7	1.4356	41.61
Fruit lenght	5.235	10.9	0.4	2.8433	54.31
Fruit width	1.986	3.81	0.76	0.8085	40.70
Fruit weight	5.913	18.6	0.18	4.840	81.85
Wall fruit tickness	0.200	0.4	0.02	0.0937	46.65
Number of cores	2.529	4.0	2.0	0.5591	22.10

Table 7. Coefficient matrix of Pearson correlations between 12 quantitative variables of *Capsicum* species in the existing collection of I.C. Corpoica-Palmira.

Variables	ALP	ANP	ANH	LH	LC	NFA	LP	LF	AF	PF	EPF	NL
Plant height	1.00											
Plant width	**0.65***	1.00										
Leaf width	0.25	0.32	1.00									
Leaf length	0.43	0.34	**0.76**	1.00								
Corolla length	-0.27	-0.35	-0.30	-0.23	1.00							
Number of flowers / axil	-0.13	0.36	0.27	0.29	-0.39	1.00						
Pedicel length	-0.17	-0.09	0.03	-0.10	0.26	-0.11	1.00					
Fruit length	-0.18	-0.04	-0.007	0.04	0.46	-0.19	0.18	1.00				
Fruit width	-0.30	-0.22	0.18	-0.01	0.33	-0.02	0.41	0.08	1.00			
Fruit weight	-0.39	-0.34	-0.02	-0.07	0.47	-0.21	0.27	**0.60**	**0.56**	1.00		
Fruit wall tickness	-0.38	-0.41	-0.16	-0.23	0.43	-0.25	0.32	0.32	**0.60**	**0.68**	1.00	
Number of cores	-0.06	-0.01	0.17	0.08	-0.07	0.01	0.04	0.38	0.21	0.43	0.29	1.00
	ALP	**ANP**	**ANH**	**LH**	**LC**	**NFA**	**LP**	**LF**	**AF**	**PF**	**EPF**	**NL**

* Values in bold are significant (P < 0.001).

Table 8. Principal component analysis (PCA) for quantitative variables of *Capsicum* species in the existing collection of C.I. Corpoica-Palmira.

Number	Eigenvalue	Percentage	Accumulated percentage
1	3.9641	33.03	33.03
2	2.2364	18.64	51.67
3	1.2338	10.28	61.95
4	1.0619	0.090	70.80
5	0.8686	0.072	78.04

Table 9. Quantitative variables contribution to the formation of the first four principal components (PC) of *Capsicum* species in the existing collection of C.I. Corpoica-Palmira.

Variable	CP1	CP2	CP3	CP4
Plant height	-0.3287	0.1517	0.2795	0.3400
Plant width	-0.3257	0.2307	0.1847	0.2301
Leaf width	-0.1763	0.5207	-0.1707	0.0300
Leaf length	-0.2233	0.4698	0.0445	0.1247
Number of flowers/axil	-0.2298	0.2053	-0.3552	-0.2044
Corolla length	0.3446	-0.0526	0.2114	0.4539
Pedicel length	0.2112	0.1462	-0.2989	0.4964
Fruit length	0.2520[a]	0.2530	0.5579	0.0458
Fruit width	0.2921	0.2860	-0.4553	0.1111
Fruit weight	0.3999	0.2676	0.1097	-0.1037
Wall fruit tickness	0.4007	0.1289	-0.1076	-0.3990
Number of cores	0.1384	0.3622	0.2323	-0.5419

a. Underlined variables are the ones with the highest contribution to each component

Variables with the highest contribution to the first CP construction are related to fruit variables like: fruit weight (PF), wall thickness of the fruit (EPF), fruit width (AF) and fruit length (LF).

The second CP is determined by the descriptors of plant: leaf width (ANH), leaf length

(LH) and width of the plant (ANP). Pardey *et al.* (2006) found similar results when studying characteristics of fruit and plant, which had the highest contribution to the formation of the first two components, respectively, discriminating the variability between and among species.

The variable plant height (ALP) makes the largest contribution to the third component, while the fourth CP was defined by floral structures like the length of the corolla (LC) and the length of the pedicel (LP).

Results from this study confirm that the variability of the genus *Capsicum* is defined first, by the characteristics of the fruit, followed by the architecture of the plant and flower descriptors (Pardey *et al.*, 2006; Vallejo *et al.*, 2006).

Clustering analysis

The dendrogram shows four representative groups (Figure 2), where its clusters correspond to materials with similar quantitative attributes, but showed no obvious relationship between species or collection environments based on the passport data.

The first group represents 34% of the accessions. This group consists of genotypes of all the studied species: yellow habanero, 1404, t.co, 1307.1367, 1374, 036P, 038Pv, 037P, 590, 1421.2570, 1414, 612, 1378, 1372, 2579-2, 1390, 1390-1456,2579-31353-2. Despite the differences between species, 87% of genotypes have in common narrow leaves (width is lower than the overall average 4.6 cm) and the corolla lenght is lower than the overall average (1.83 cm).

Group 2 is represented by jtel, 536-1, 2570 to 1.1327, 536, 1423.820, 1409 and 2761, 597, 529, 820-1 accessions, which mainly belong to *C. annuum*. Those are characterized by solitary flowers and fruits with two cores. mThe presence of single flowers is a characteristic of the *C. annuum* species (Vallejo *et al.*, 2006).

The third group consists of accessions: Cayenne Durke, 1420, 593, 2608, 1353-3, 1353, 1353-4, 2606, 591, 063, 1375-1, 1421, 1414, 612, 535, 2570, 346, 2544, 1406 and 486. These accessions represent 30% of the studied population. ,This group includes most of the accessions of *C. baccatum* characterized by one flower per axillar bud and three locules in the fruit, which is representative of the *C. baccatum* specie.

The fourth group is comprised of accessions: 1306, 1360, 002.1406, belonging to the *C. chinense* and *C. baccatum* species. These accessions are grouped by wider and longer leaves.

Group five consists of the accessions 1312, 1319-1, 1324, 2577, 1391-1, 1391,

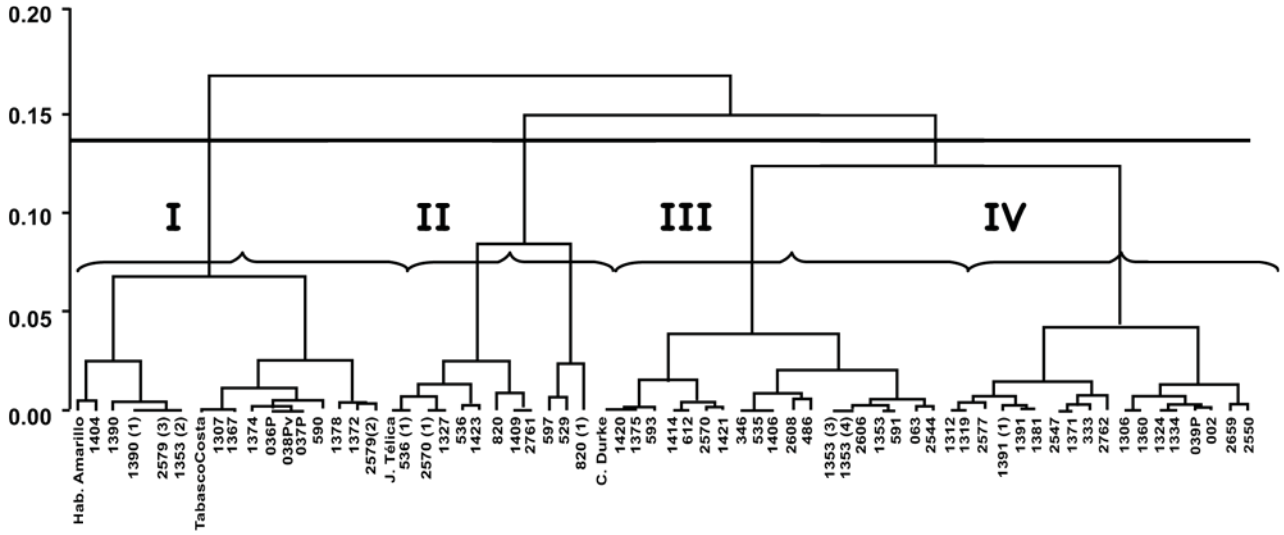


Figure 2. Dendrogram of the hierarchical classification analysis of 68 accessions of Capsicum from the existing Germplasm Bank of Corpoica Palmira. Retrieved from the principal component analysis (PCA) using SAS statistical software version 6.0 (1989).

1381, 2547.1371, 039p, 1334, 2659, 2550, 2762 and 333. This group includes accessions of *C. annuum, C. chinense, C. baccatum* and *C. frutescens* species. Those have similar characteristics of plant architecture like wider and taller plants with big leaves, wall fruit thicker than the overall average, approximately 80% have fruit length and weight lower than the overall average (5.23 cm) and (5.8 cm) respectively.

Cophenetic coefficient (0.78) indicates a high degree of correspondence between the similarity matrix and the dendrogram obtained as a measure of dispersion. In other words, the hierarchical structure of the dendrogram represents in a tight way, the true distances between individuals.

Conclusions

- The studied accessions from the Germplasm Bank at Corpoica-Palmira, have a wide variability for qualitative and quantitative characters. Quantitative polymorphisms were primarily related with attributes of the fruit, foliage and flower structures. These results confirm what other authors have said about the variability of the *Capsicum* genus, which is defined by the characteristics of fruit, followed by the architecture of the plant and flower descriptors.
- The variability that was found in this study indicates that there is germplasm with enough quality, excelling the accessions 1391 (1) 1312, 1390, 346, 1353, 1324 and 039P. Those were identified as promising materials in sensory studies with capsaicin content of >1 mg/ml, surpassing commercial controls. Moreover, those have outstanding yields and other organoleptic characteristics of great importance to the industry as color and aroma that can make it become an important germplasm for future breeding work.
- Morphological characterization was not distinguished between *C. annuum, C. chinense* and *C. frutescens* species, which were reflected in the clusering analysis. The discriminant analysis also indicated that *C. annuum, C. frutescens* and *C. chinense* species are phylogenetically close.

Acknowledgements

To the Ministry of Agriculture and Rural Development of Colombia and the Colombian Vegetable and Fruit Association for supporting this research. To the Colombian Agricultural Research Corporation (Corpoica) CI La Selva, Dr. Mario Lobo. To the Universidad Nacional de Colombia-Palmira. Dr. Gilberto Gomez Caribia from the Caribia Experimental Station. To the Corporation Research Center for Technology Management of Passiflora del Huila (CEPASS). To the farmers for their collaboration in the collections, and the students Fernando Silva and Hugo Mario Reyes for their collaboration in the development of this research.

References

Arias, J.; and Melgarejo, L. M. 2000. Ají. Historia, diversidad y usos. Instituto Amazónico de investigaciones científicas Sinchi. Minambiente y Colciencias. 29 p.

Bosland, P. W. 1996. *Capsicums*: Innovative uses of an ancient crop. En: Progress in new crops. Janick, J. (ed.). ASHS Press, Arlington, VA, USA. p. 479 - 487

García, M. A. 2006. Estudio de la variabilidad genética del género *Capsicum.* Proyecto de tesis doctoral. Palmira. Universidad Nacional de Colombia. 93 p.

IPGRI; AVRDC; CATIE. 1995. Descriptores para *Capsicum* (*Capsicum* spp.). Instituto Internacional de Recursos Fitogenéticos, Roma, Italia; Centro Asiático para el Desarrollo y la Investigación relativos a los Vegetales, Taipei, Taiwán; Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica. 51 p.

Lebart, W., L.; Morineau, A.; and Piron, M. 1998. Statistique exploratoire multidimensionnelle, ed. Dunod. París.

Nuez, F.; Gil, R.; and Costa, J. 1996. El cultivo de pimientos, chiles y ajíes. Madrid: Mundiprensa. 607 p.

Palacios-Castro, S.; and García-Dávila, M. A. 2008. Caracterización morfológica de 93 accesiones de *Capsicum* spp. del Banco de Germoplasma de la Universidad Nacional de Colombia- sede Palmira. Acta Agronómica 57 (4):247 - 252.

Pardey, C.; García, M.; and Vallejo-Cabrera, F. A. 2006. Caracterización morfológica de cien introducciones de *Capsicum* del Banco de Germoplasma de la Universidad Nacional de Colombia, sede Palmira. Acta Agronómica 55(3):1 - 9.

Pickersgill, B. 1997. Genetic resources and breeding of *Capsicum* spp. Euphytica 96:129 - 133.

Rohlf, F. J. 1994. Numerical taxonomy and multivariate analysis system. Versión 1.80 Applied Biostastics. Stauket, N.Y.

SAS Institute Inc. 1989. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2, Cary, NC: SAS Institute Inc.

Votaba, E. J.; Nabhan, G. P.; and Bosland, P. W. 2002. Genetic diversity and similarity revealed via molecular analysis among and within an in situ population and ex situ accessions of chiltepin (*Capsicum annuum* var. *glabriusculum*). Cons. Gene. 3:123 - 129.

Vallejo, F. A.; García, M. A.; Durán, T. M.; and Pardey, C. 2006. Caracterización morfoagronómica de 195 introducciones de *Capsicum* del Banco de Germoplasma de la Universidad Nacional de Colombia- sede Palmira. 260 p.