Research article

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Revista Facultad Nacional de Agronomía

Morpho-agronomic assessment of introductions of butternut squash (*Cucurbita moschata* Duch.) from Central America

UNIVERSIDAD NACIONAL DE COLOMBIA

Evaluación morfoagronómica de introducciones centroamericanas de zapallo (*Cucurbita moschata* Duch.)

doi: 10.15446/rfna.v70n1.61764

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ABSTRACT

Key words:
Plant morphology
Agronomic characters
Germplasm
Squashes
Multivariate analysis

A Central American collection of butternut squash (*Cucurbita moschata* Duch.) was characterized based on a series of morpho-agronomic descriptors and its variability assessed. Floral asynchrony ranging from 10 to 15 days was observed between staminate and pistillate flowers. Differences were also observed among introductions for all quantitative characteristics evaluated ($P<0.01$). An interaction between introduction and planting cycle ($P<0.05$) was observed for 50% of the evaluated variables: fruit weight, polar diameter of fruit, wall thickness of fruit, fruit color, days to harvest, and total fruit seed weight. Cluster analysis revealed that groups 3 and 5 gathered introductions presenting high yields and larger, heavier fruits. Group 4 gathered introductions with intermediate yields, high seed production, and thick fruit walls. In all cases, genetic improvement aiming to increase the production of fruit for fresh consumption or agro-industrial purposes as well as the production of oilseed should use introductions from groups 3 and 5 in well-planned crossings with introductions from group 4.

RESUMEN

Palabras claves:
Morfología vegetal
Características agronómicas
Germoplasma
Ahuyama
Análisis multivariado

Se caracterizó una colección centroamericana de zapallo (*Cucurbita moschata* Duch.) con base en una serie de descriptores morfo-agronómicos y luego se evaluó su variabilidad. Se evidenció una asincronía floral entre flores estaminadas y pistililadas de 10 a 15 días. Se encontraron diferencias entre las introducciones ($P<0,01$) respecto a todos los caracteres cuantitativos evaluados. Se presentó una interacción introducción x ciclo de siembra ($P<0,05$) en 50% de las variables evaluadas: peso del fruto, diámetro polar del fruto, espesor de la pared del fruto, color de la matriz del fruto, días a cosecha y peso total de la semilla del fruto. El análisis de conglomerados detectó que en los grupos 3 y 5 se ubicaron las introducciones con altos rendimientos y frutos más grandes y pesados. El grupo 4 estuvo conformado por las introducciones con rendimientos intermedios, alta producción de semillas y amplio espesor de pared del fruto. En todos los casos, el mejoramiento genético dirigido a aumentar la producción de fruto para consumo en fresco o para fines agroindustriales o la producción de semillas de tipo oleaginoso deberá utilizar las introducciones de los grupos 3 y 5 en cruzamientos bien planeados con las del grupo 4.

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Received: August 15, 2016; Accepted: October 10, 2016
Rev.Fac.Nac.Agron. 70(1): 8057-8068. 2017 ISSN 0304-2847 / e-ISSN 2248-7026

The ancestral and current uses of the fruit of butternut squash (*Cucurbita moschata* Duch.) as both horticultural and edible crop not only in Colombia but throughout the Americas have been well documented by Patiño (1967), Piperno *et al.* (2000), Piperno and Stothert (2003), Piperno (2011), and Ortiz *et al.* (2013).

In the case of Colombia, butternut squash ranks first as domesticated horticultural crop, with a total planted area of 3800 hectares and an annual production of 65,000 t (FAOSTAT, 2013). Butternut squash is frequently intercropped or rotated with fruit, ornamental, and forest species as a staple crop in agro-ecosystems of rural economy. It also plays an important role as horticultural crop in the country's food security, being planted as main or transitory crop on small or intermediate farms (Jaramillo, 1980; Estrada *et al.*, 2010). Its popularity can be attributed to its versatility for fresh consumption and its industrial uses (Espitia *et al.*, 2005; Ortiz *et al.*, 2008; Ortiz *et al.*, 2013; Ordoñez *et al.*, 2014).

Because of its nutritional value, butternut squash was included in the list of priority foods that guarantee a balanced human diet and, according to FAO, form part of Colombia's basic food basket (PNSAN, 2012).

This study aimed to evaluate and characterize the initial morpho-agronomic traits of a collection of butternut squash from Central America, which would serve as basis to identify superior genotypes for release to farmers.

MATERIALS AND METHODS

Location

Field trials were conducted at CEUNP, the Experimental Center of the Universidad Nacional de Colombia, Sede Palmira, which is located in Candelaria (rural community of El Carmelo), department of Valle del Cauca, Colombia (03°25'25.3''N, 76°25'47.8''S), at an altitude of 972 m above sea level, with an average annual temperature of 26 °C, 76% RH, and average annual rainfall of 1100 mm (Ortiz *et al.*, 2013).

Germplasm used

Thirty-four butternut squash introductions original of Central America (Table 1) were used; of these, six disappeared during the first planting cycle due to prevalent conditions (excess rainfall or excess drought).

Nursery and planting in the field

Nurseries were established and subsequently planted in the field during two consecutive planting seasons of 2014, according to the protocol of the UNAPAL's Horticultural Program (Ortiz *et al.,* 2013), using commercial peat as substrate.

Two seeds were sown per 12-oz cup. After 20 days in the nursery, the trials were planted in the field using a randomized complete block design with three replications and five plants per replication. The experimental unit was represented by five plants, planted in 3 x 3 m arrangement in the field. Agronomic practices were coordinated by the Horticultural Program (Ortiz *et al.*, 2013).

Evaluated traits

Plant- and fruit-related traits were assessed based on the descriptors proposed for butternut squash by Esquinas and Gulick (1983), Montes *et al.* (2004), and ECPGR (2008). Three plants were sampled per furrow and two fruits per plant were evaluated in the three replications. The following variables were measured: days to staminate flowering (DSF); days to pistillate flowering (DPF); days to harvest (DH); fruit weight (FW) in kg; number of fruits per plant (NFP); fruit yield (FY) in t ha^{-1}; total seed weight per fruit (TSWF) in g; 100-seed weight (100-SW) in g; polar diameter of fruit (PDF) in cm; equatorial diameter of fruit (EDF) in cm; thickness of fruit wall (TFW) in cm; diameter of placental cavity (DPC) in cm; fruit form (FF) (scale 1–14); pericarp color (PC) (scale 1–10); fruit pulp color (FPC) (scale 1–15); fruit matrix color (FMC) (scale 1–3); and pulp quality (PQ) (scale 1–2); placenta location (PL): on the wall (1), in the middle (2).

Statistical analyses

Variance analysis was conducted to detect differences between introductions and estimate the effect of the environment on the expression of variability. The SAS 3.0 statistical package was used (SAS, 2009). Means separation was based on Fisher's Least Significant Difference (LSD) test at a 5% significance level (Steel and Torrie, 1985).

Cluster analysis was used to determine the importance of variables and genetic relationships between introductions. The Ward-Modified Location Model (Ward-MLM) was used, using the algorithm proposed by Franco *et al.* (1998), where clustering occurs under the assumption of minimum variance

Table 1. Butternut squash introductions from Central America.

Entry	Introduction	Country	Locality
1	10789	Panama	David
41	12444	Panama	El Valle-Penonome
7	12043	Nicaragua	Playitas
9	11993	Nicaragua	Rivas
30	12035	Nicaragua	Diriamba
38	12054	Nicaragua	Matagalpa-Playitas
4	15715	Guatemala	Zacapa
18	11877	Guatemala	Antigua
28	16041	Guatemala	San Marcos
46	14921	Guatemala	
10	9099	El Salvador	El Guayabal
12	9060	El Salvador	Chinameca
16	9092	El Salvador	Puerto Nuevo
29	9069	El Salvador	La Unión
47	9091	El Salvador	Puerto Nuevo
3	20120	Costa Rica	Roxana, Guápiles
11	10810	Costa Rica	Garita-Central
22	6368	Costa Rica	Central
8, 24	13425, 6369	Costa Rica	Costa Rica
14	9213	Mexico	Cunduacán
42	8009	Mexico	Chiapas de Corzo
2, 17, 37, 40, 45, 48	18943, 18932, 18942, 9284, 18859, 18834	Mexico	
23	12139	Honduras	La Paz
27	11015	Honduras	Potrerillos
36	11044	Honduras	La Esperanza
39	12168	Honduras	Siguatepeque
43	12125	Honduras	Flórez
44	12088	Honduras	Ajuterique

within the group but maximum heterogeneity between groups. Heterogeneity between groups was estimated based on Mahalanobis distances and the pseudo-F statistic determined the number of selected groups (maximum value). The number of groups was decided based on the lowest value of the function. Gower's index was used to estimate genetic distances. The data matrix was standardized and the distance matrix was estimated by the Ward-Gower method (Gower, 1971), which allows the use of continuous, nominal, and binary variables. The Proc IML, Proc Cluster, and Proc Tree procedures of the SAS 9.3 statistical package (SAS, 2009) were used in all cases.

RESULTS AND DISCUSSION

Phenology and fruit and seed yield

Asynchrony between DPF and DSF was detected in most butternut squash introductions (Table 2). The results agree with those of Ortiz (2009), who evaluated the Colombian collection of butternut squash and observed physical deterioration in 10-day-old plants. These plants only produced pollen-producing flowers with no receptive pistillate flowers for fertilization and fruit formation. Therefore, if pollination is not performed and seed formation is not effective, then the fruit is not developed and aborts.

Regarding DH, plants from the Central American collection matured at least 30 days earlier as compared to those of the Colombian collection (Table 2), presenting relative precocity (Ortiz, 2009; Valdés *et al*., 2010).

Although FW varied broadly, results indicated that 35% of the genotypes of the Central American collection presented heavy fruits, weighing more than 5 kg. These results agree with those of different studies conducted by UNAPAL's Horticultural Program (Montes *et al*., 2004; Ortiz, 2009; Valdes *et al*., 2014).

The NFP presented relative uniformity across introductions (Table 2), averaging 3.8. In introduction 42, however, there was a marked asymmetry, with 25 fruits per plant. The NFP of the remaining introductions of the collection did not exceed four fruits per plant. This characteristic is important from the genetic viewpoint because prolificacy is a selection factor that can be significantly affected by the environment. For example, the absence or low presence of pollinating bees can cause the early abortion of fruit due to the absence of effective pollen (Lau and Stephenson, 1993; Ortiz *et al*., 2013). Water availability at critical times of fruit fill and limited amounts of trace minerals in the soil solution can also cause early abortion of the fruit (Lopes de Sousa, 2011).

Average fruit yield (FY) of the Central American collection was similar to that of commercial butternut squash in Valle del Cauca, Colombia, which is 14 t ha^{-1}. However, 21% of the genotypes presented yields above 20 t ha^{-1}, which opens the opportunity to select prolific genotypes with heavy fruit and superior performance (Ortiz *et al*., 2013).

Regarding TSWF and 100-SW, 39% of the Central American introductions presented above-average values, which reflects in the presence of large, heavy seeds with added value for agro-industrial purposes (Ordoñez *et al*., 2014). The remaining introductions presented typical values, being similar to those reported by Valdes *et al.* (2014).

Table 2. Analysis of combined means for two planting cycles of 28 butternut squash introductions from Central America in Valle del Cauca in 2014 regarding phenology, fruit yield, and seed yield.

Introduction	DSF	DPF	DH	FW	NFP	FY	TSWF	100-SW
		(days)		(kg)	(No.)	(t ha^{-1})	(g)	
Mean/Mode	35.0	44.0	116.6	4.6	3.8	14.7	50.3	11.3
Minimum	31.0	31.7	102.4	0.5	1.9	4.7	16.0	6.2
Maximum	37.2	54.6	123.9	10.0	25.6	22.5	80.7	15.0
LSD	2.5	6.5	7.7	2.0	1.5	7.6	18.9	2.1

Fruit characterization

The results of means analysis of fruit-related traits of Central American butternut squash introductions are presented in Table 3. Characterization was based on the fruit descriptors for butternut squash developed by ECPGR, 2008; Esquinas and Gulick, 1983; and Montes *et al*., 2004 (Table 4).

Analysis results indicated that 75% of the evaluated introductions presented cylindrical, pear-, diamond-, spindle- or gourd-shaped fruits based on PDF and EDF (Table 3) and the rest, a flat, vessel-shaped fruit based on EDF (Figure 1), indicating that there are materials available that have fleshy fruits with small placental cavity, two traits that industries find attractive.

Regarding the predominant PC of the fruit, 57% of the introductions presented a cream-colored pericarp (Figure 1), which is attractive from the commercial viewpoint. However, the demand of the fresh consumption market in Colombia is for bright green fruits (Ortiz *et al*., 2013).

The TFW, a desirable character to ensure marketable butternut squash for commercial fresh consumption, presented a relatively low average for 62% of the introductions (Table 3); however, 38% presented above-average values, with introduction 30 presenting the highest TFW value (4.1 cm) (Figures 2, 3A, and 4A). Market demand determines desirable characteristics

Table 3. Analysis of combined means for two planting cycles of 28 butternut squash introductions from Central America in Valle de Cauca in 2014 regarding fruit characterization.

Introduction	PDF	EDF	FF**	FC*	TFW	DPC	FPC	FMC
Mean/Mode	20.6	14.5	7.0	3.0	2.6	9.6	15.0	3.0
Minimum	6.1	7.5	1.0	1.0	0.9	5.8	1.0	1.0
Maximum	29.6	20.8	15.0	10.0	4.1	14.8	15.0	5.0
LSD	4.4	4.2	2.0	2.0		0.7	2.1	1.6

Polar diameter of fruit (PDF) in cm; equatorial diameter of fruit (EDF) in cm; thickness of fruit wall (TFW) in cm; diameter of placental cavity (DPC) in cm; fruit form (FF) (scale 1–14); fruit pulp color (FPC) (scale 1–15); fruit matrix color (FMC) (scale 1–3). * FC: fruit color.
** Based on indicators given by Esquinas and Gulick (1983), Montes *et al.* (2004); ECPGR (2008),

Figure 1. Predominant pericarp color of fruit, with 57% of the introductions of the Central American collection presenting a cream-colored pericarp.

Figure 2. Fruit pulp color characteristic of butternut squash cultivar Abanico 75, which is highly demanded by the animal feed industry as well as for human fresh consumption. Source: Ortiz *et al.*, 2013.

of fruit pulp quality (Figure 2) and serves to select the most appropriate model for genetic improvement (Ortiz *et al.*, 2013).

Contradictory results were obtained regarding the DPC of the fruit. If the diameter is wide, then the amount of seed it can hold is significant; however, a wide DPC could affect the TFW, making it necessary to find an introduction that meets both characteristics (good seed production and high TFW). In any case, 57% of the introductions presented above-average values (Table 3 and Figures 4A and 4B).

Regarding FPC, 75% of the Central American introductions presented high values of bright yellow on the Roche scale. The remaining materials were pale yellow or yellow with green or bright green stripes, which reduces their commercial value for fresh consumption (Figures 3, 4A, and 4B). A green-colored pulp is an indication that the material has a marked wild or naturalized origin (Sanjur *et al.*, 2002) and, given the cross-pollination that occurs in butternut squash, advanced genotypes could be derived that would seriously impair the breeding process for FPC. Both FMC and FPC, typically yellow in butternut squash, ranged from bright yellow in several of the Central American introductions to greenish-black for 71% of the introductions assessed (Figures 3 and 4B). This finding disagrees with the bright yellow FMC that consumers found attractive in previously evaluated collections (Ortiz, 2009; Valdes *et al.*, 2010; Valdes *et al.*, 2014). However, the greenish-black color of the pulp when the fruit is opened or several hours after processed is not an indication of fruit deterioration. The fresh consumption market in Colombia does not find introductions with a green- or black-colored matrix attractive, but their nutritional or productive qualities for the animal feed industry should be further studied.

Table 4. Qualitative descriptors for the fruit of butternut squash based on indicators given by ECPGR (2008); Esquinas and Gulick (1983); Montes *et al.* (2004).

Descriptor	Scale
Fruit shape	
Globular	1
Flattened	2
Disk-shaped	3
Oblong block-shaped	4
Elliptical (oval)	5
Heart-shaped	6
Pear-shaped	7
Dumbbell-shaped	8
Elongated	9
Coil-shaped (upper)	10
Crested	11
Coil-shaped (lower)	12
Curved	13
Gooseneck-shaped	14
Secondary color of fruit	
White	1
Green	2
Blue	3
Cream	4
Yellow	5
Orange	6
Red	7
Pink	8
Texture of fruit pericarp	
Smooth	1
Slightly granular	2
Fairly granular	3
Granular	4

Descriptor	Scale
Predominant color of fruit	
Green	1
Blue	2
Cream	3
Yellow	4
Orange	5
Red	6
Pink	7
Brown	8
Gray	9
Black	10
Design of secondary color	
Absent	1
Dotted	2
Mottled	3
Striped	4
Banded	5
Bi-sectional	6
Spotted	7
Fruit rib	
Absent	1
Superficial	2
Intermediate	3
Deep	4

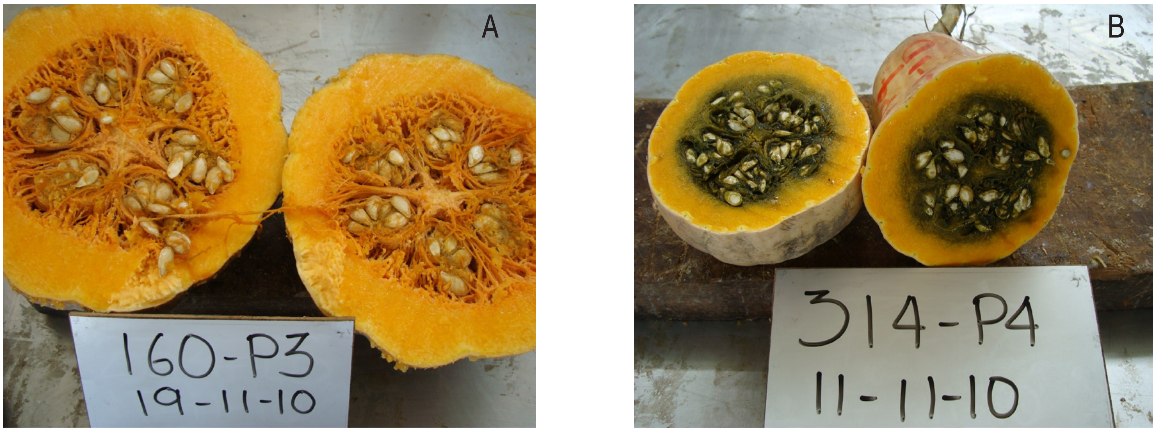

Figure 3. Fruit matrix color of two butternut squash introductions of the Central American collection, Horticultural Program, Universidad Nacional de Colombia-Palmira. A. Introduction 20120 from Costa Rica; stable, bright yellow matrix after cut. B. Introduction 9092 from El Salvador, greenish black matrix with short-term oxidation.

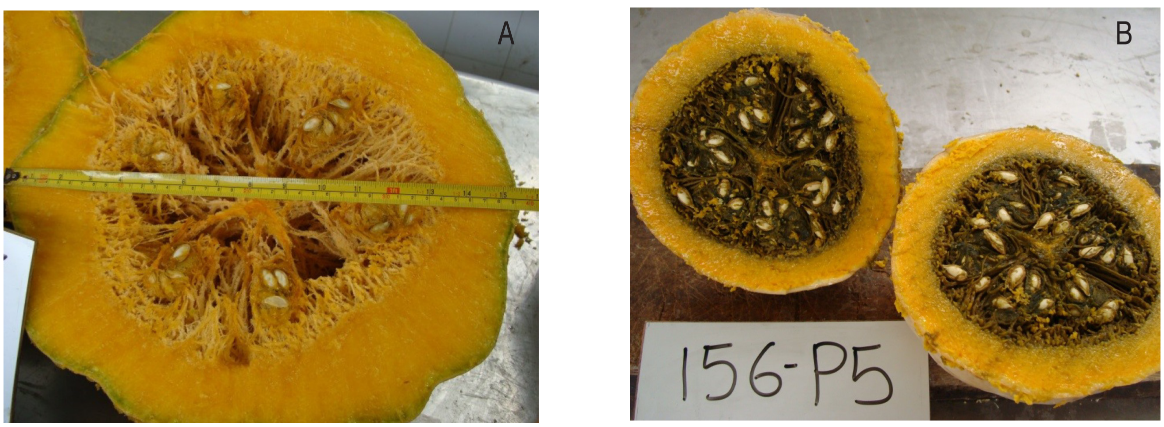

Figure 4. Thickness of fruit wall of two butternut squash introductions. A. Outstanding (5.0±2.5 cm); B. Minimal (3.0 ±1.5 cm).

Analysis of variance

The analysis of variance showed highly significant differences among introductions (P <0.01) for all study variables (Table 5). Overall, the coefficients of variation for the descriptors evaluated were low to intermediate, ranging between 5.4 and 34.2% (Table 5). This variation is considered appropriate because the assessment of traits was based on individual plants and this assumes that the variation of micro-environments has been controlled to some extent (Ceballos, 1998).

The analysis of the interaction cycle x introduction indicated no significant differences (P <0.05) for Y, NFP, DPC, FPC, PDF, PC, and 100-SW (Table 5); however, highly significant differences (P <0.01) were observed regarding FW, PDF, and FMC.

Overall, broad-sense heritability was high, ranging between 66 and 98% (Table 5). Although this indicator is usually important in plant breeding processes, in the case of this study care should be taken when quantifying broad-sense heritability as, according to Ceballos (1998), heritability is not only a property of the plant trait but also of the plant population and is affected by the environmental conditions under which the individuals develop and how the phenotype is evaluated. The changing value of this trait is associated with all components of variance and will accordingly be affected by changes in cropping conditions (Espitia, 2004; Ortiz, 2009). Heritability is expected to increase in variable environments and decrease under more favorable conditions (Falconer and Mackay, 1996). Based on the above, in the cases where the biological or statistical differences observed can be attributable to the interaction planting cycle x introduction (Table 5), it is highly probable that adequate breeding methods or appropriate agronomic practices can trigger positive practices associated with high heritability.

Cluster analysis

Five groups were formed based on the Ward method (Figure 5 and Table 6). The graphic of the pseudo-maximum likelihood shows a sharp decline in group

Table 5. Mean squares of variance analysis, coefficients of variation, and heritability for different traits of butternut squash in two planting cycles in 2014 in Valle del Cauca, Colombia.

Variable	Unit	CMI	P	CM C x I	P	CV (%)	H^2 (%)
PY	t ha^{-1}	113.5	**	32.9	ns	34.2	71
FW	kg	20.1	**	2.2	**	22.5	89
NFP	#	54.6	**	1.3	ns	27.1	98
EDF	cm	106.9	**	10.9	*	12.1	90
PDF	cm	43.5	**	10.0	**	14.0	77
TFW	cm	2.1	**	0.3	*	14.2	87
DPC	cm	21.1	**	1.1	ns	11.6	95
FMC	Scale 1–3	0.2	**	1.4	**	10.0	0
FPC	1-15[1]	28.3	**	2.5	ns	14.1	91
PL	Scale 1–2	0.3	**	58.7	ns	16.8	84
Placenta color	Scale 1–2	0.2	**	0.1	ns	18.8	66
DH	days	317.3	**	85.4	*	5.4	61
100-SW	g	21.6	**	2.4	ns	12.0	89
TSWF	g	1247.4	**	193.2	*	21.1	85

CMI = mean squares of introduction; P = statistical significance with *= p=5%, **=p=1%, and ns=non-significant; CM C x I = mean square of interaction planting cycle x introduction; CV = coefficient of variation; H^2= broad-sense heritability.
[1]Scale of 1 to 15 of the Roche Color Fan.

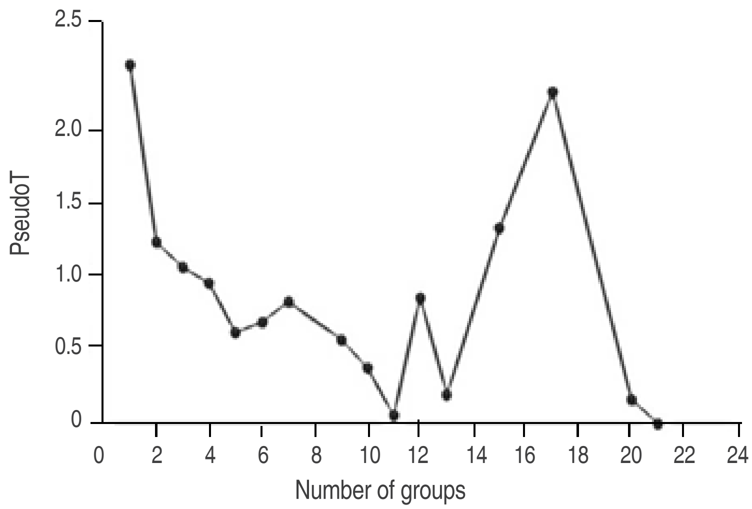

Figure 5. Comparison of pseudo-T function with number of groups estimated by Ward's method to gather 28 introductions of the Central American collection of butternut squash.

4 with a subsequent rise in group 6 and is assumed to represent the breakeven point for determining work groups. Introduction 42 was excluded from the cluster analysis because it presented an outlier value for NFP.

Figure 6 shows how the 27 introductions were grouped. Five groups were formed based on Ward's hierarchical clustering (Table 6). Group 1 was composed of four introductions, one each from Nicaragua, El Salvador, Mexico, and Honduras (accounting for 15% of the total), with an average distance of 0.57 between introductions. Group 2 was composed of seven introductions, one each from Panama, Costa Rica, and Guatemala, two from Honduras, and two from Mexico (accounting for 26%), with a distance of 0.60 between introductions and located far from groups 3 and 5. Group 3 includes seven introductions, with one introduction each from Honduras, Nicaragua, Mexico, and Costa Rica and three from El Salvador (accounting for 26%), with a distance of 0.57 between introductions and located far from groups 1 and 5. Group 4 consists of six introductions, one each from Guatemala, Salvador, and Honduras, and three from Mexico (accounting for 22%), with a distance of 0.56 between introductions. Finally, group 5 includes three introductions, one each from Costa Rica, Nicaragua, and Honduras (accounting for 11%), with a distance of 0.61 between introductions.

Table 6. Absolute, percentage, and cumulated frequency of groups of Central American introductions of butternut squash formed based on cluster analysis.

Group	Absolute frequency	Percentage frequency	Cumulated frequency	Mean distance
1	4	15	15	0.57
2	7	26	41	0.60
3	7	26	67	0.57
4	6	22	89	0.56
5	3	11	100	0.61

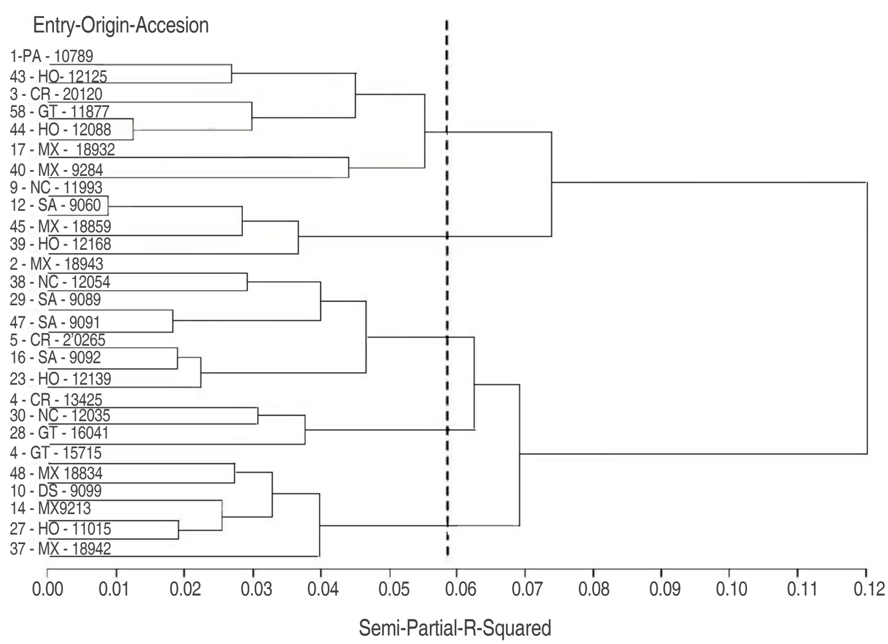

Figure 6. Cluster analysis of 28 introductions of a Central American butternut squash collection, based on Ward's hierarchical grouping.

Although phenotypic variability is evident in the Central American collection of butternut squash introductions studied, the cluster analysis failed to group introductions according to origin (country), probably because of the very active exchange of germplasm in Central America. Butternut squash, maize, and beans are the basis of Milpa agriculture and food security crops in traditional family-based farming systems in Central America (Patiño, 1967; Piperno *et al.*, 2000; Piperno and Stothert, 2003; Piperno, 2011).

Table 7 presents the results of means analysis and the coefficient of variation for study variables for the five groups, based on Ward's method. Groups 1 and 2 gathered the introductions with the lowest means for traits related to fresh fruit yield per hectare, smaller and lighter fruit, lower PDF and EDF, less TFW and DPC, fewer seeds, lower 100-SW, and lower TSWF. Fruit with green-colored pulp predominated, and introductions of group 1 matured the earliest. Therefore, the introductions

Table 7. Means analysis and coefficient of variation for variables assessed in five groups for 28 Central American introductions using Ward's method for two planting cycles in 2014.

Variable	Group 1		Group 2		Group 3		Group 4		Group 5	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
PY per ha	10.7	32	10.9	47	18.9	17	15.3	24	18.9	22
FW weight	3.2	31	3.2	50	5.5	23	5.0	26	7.8	26
NFP	3.2	15	3.2	42	3.3	9	3.0	18	2.2	16
100-SW	11.0	22	9.2	11	12.2	9	13.4	11	11.9	12
TSWF	47.7	18	33.8	16	60.0	20	65.9	19	49.7	39
Number of sedes	450.1	21	383.2	21	504.1	15	499.2	11	430.0	30
PDF	20.1	13	18.1	18	25.3	10	19.4	7	23.7	25
EDF	12.3	20	12.8	19	15.7	17	15.8	13	18.4	7
TFP	2.1	23	2.4	29	2.8	9	2.8	18	3.5	14
Diameter placental cavity	8.4	18	8.2	22	9.8	16	11.3	17	11.9	12
DH	114.5	4	119.6	3	115.7	2	115.3	6	117.7	4
Days to male flowering	34.8	4	35.1	2	34.6	2	35.3	2	36.2	2
Days to female flowering	45.9	16	46.8	15	41.0	9	42.7	8	48.3	10
Color seed border	4.0	29	3.4	23	1.9	58	1.7	62	3.7	31
Fruit rib	1.0	0	1.9	58	2.1	63	1.8	41	3.7	16
Fruit color	1.5	67	4.4	74	3.1	74	2.7	31	2.3	49
Pulp color	15.0	0	12.0	23	15.0	0	13.3	24	13.7	17
Spots on leaves	2.8	35	2.0	50	1.9	20	1.7	31	2.0	87
Peduncle insertion	4.0		2.0		2.0		2.0		2.0	
Final fruit shape	4.0		2.0		4.0		2.0		2.0	
Transversal shape of fruit	1.0		1.0		1.0		2.0		4.0	
Matrix color	3.0		3.0		3.0		3.0		3.0	
Shape of leaf lobe	1.0		1.0		1.0		1.0		1.0	
Leaf size	2.0		2.0		3.0		2.0		3.0	
Seed size	2.0		2.0		2.0		2.0		2.0	
Shape of seed margin	2.0		2.0		2.0		5.0		2.0	
Secondary color design	7.0		1.0		7.0		1.0		7.0	
Fruit peel texture	1.0		1.0		1.0		1.0		7.0	

of these groups rank low when selecting for fresh fruit yield, seed yield, and fruit pulp quality.

In the case of group 2, the only relevant trait regarding the rest of the introductions evaluated was the yellow color of the pulp (Table 7). The remaining variables presented average or below-average values.

Groups 3 and 5 gathered introductions with higher average values for traits related to PY, FW, PDF and EDF, number of seeds per fruit and 100-SW (Table 7). However, at the same time introductions maturing the latest in terms of days to harvest also took the longest in terms of DSF and DPF. Unfortunately, green-colored pulp and fruit matrix predominated in group 3, presenting rapid oxidation and blackening (Figure 3B), which disqualifies these introductions for fresh consumption.

Group 4 gathered introductions presenting higher averages regarding TSWF, 100-SW, seed size, EDF, and DPC; intermediate values for PY per hectare, FW, NFP, and DH (late). The bright yellow color of the pulp of these introductions stands out, which adds value for fresh consumption.

Group 5 gathered introductions presenting higher averages in terms of PY per hectare, FW, PDF and EDF, TFW, DPC, and FPC. The positive traits of the introductions of this group were yellow-colored pulp, TFW, TFP, and wide DPC (Figure 3A) and DH. Negative traits included a longer time to DPF and DSF, marked ribbed fruit, fruit pericarp with a rough to frogskin-like or bumpy texture, and green color matrix with rapid oxidation and blackening (Figure 3B).

If the products of cluster analysis (Figure 6) and means analysis (Table 7) are integrated, it can be inferred that the introductions that would prove useful for a breeding program that aims to develop materials that produce fruit for fresh consumption or for agro-industrial purposes are those that correspond to group 3 (introductions 2, 5, 16, 23, 29, 38, 47) and group 5 (introductions 4, 10, 14, 27, 37, 48) (Table 7). The same methodology was used by Ortiz (2009), Valdes *et al.* (2010), and Ortiz *et al.* (2013) to develop cultivars for fresh consumption and agro-industrial purposes.

Furthermore, to produce grain derived from seed for oilseed purposes (Ordoñez *et al.*, 2014), the recommendation is to use genotypes derived from group 3 (introductions 2, 5, 16, 23, 29, 38).

CONCLUSIONS

The Central American collection of butternut squash introductions evaluated in this study presents variability regarding traits of interest, indicating the availability of source material to develop a breeding program to produce squash fruit for fresh consumption or agro-industrial purposes as well as to produce oilseed.

There was no interaction between introductions regarding planting time, indicating that introductions of the Central American collection tend to be stable over time.

Breeding processes aiming to increase either the production of fruit for fresh consumption or for agro-industrial purposes or to increase oilseed production should use the introductions identified in groups 3 and 5 in well-designed crosses with introductions of group 4.

ACKNOWLEDGEMENTS

Our sincere thanks to the Research Program of Genetic Breeding, Agronomy and Horticultural Crop Seed Production, Universidad Nacional de Colombia, Sede Palmira.

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