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Fruit characterization of sugar apple genotypes in Presidente Dutra, Bahia

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ABSTRACT - *To identify promising genotypes for commercial cultivations and studies of genetic improvement with sugar apple, eight fruits each of 30 genotypes of the species were charactyerized by: length and fruit diameter, fruit mass, pulp mass, seed mass, rind mass and receptacle mass, pulp yield, number of seeds, thickness of the rind, pH, total soluble solids (TSS), total titratable acidity (TTA), vitamin C, TSS/TTA ratio, moisture, ash content, total, reducing and non-reducing sugars. Results were evaluated by descriptive statistics (mean, standard deviations and coefficient of variation) and statistical multivariate analysis, by grouping techniques and main component analysis. The genotypes were clustered in 10 gentically divergent groups, which allowed the selection of promising genotypes. The highly variable traits fruit, pulp, and rind mass and number of seeds contribute to the differentiation of the evaluated genotypes.*

Key words: *Annona squamosa* L., sugar apple, genetic variability.

INTRODUCTION

Sugar apple (*Annona squamosa* L.), a species of the Annonaceae family, is a plant of tropical climate, probably originated from the Antilles and surrounding regions (Simão 1972). The crop was introduced in the country in 1626 in Bahia, by the Count Miranda and brought to Rio de Janeiro in 1812 (Manica et al. 2003). From there it spread out and became known in several states of Brazil. The fruit is known in Brazil under different names: "ata", in the states in the North of the country; "pinha" in Bahia, Alagoas and Sergipe and "fruta-do-conde" in the Southwest and South.

The northwestern region is first in the production of this fruit tree, which grows well in areas with low precipitation (400 to 700 mm year^{-1}) and high temperatures (over 32 °C). According to Araújo et al. (1999), the cultivation of sugar apple provides jobs for thousands of people. Above all in the harvest time - mainly women, for their skill and careful work - are hired to wrap the fruits. The harvest lasts approximately 4 to 6 months in the producing regions in the Northwest.

The state of Bahia is the main producer, followed by Pernambuco, Rio Grande do Norte and Alagoas, especially in the municipalities of Irecê and Presidente Dutra in Bahia (IBGE 2004), where the crop helps retain the rural workers in the countryside and generate income for the municipalities. In 1995, CEASA of Minas Gerais sold 66,000 kg of sugar apple produced in the municipality of Palmeira dos Índios - Alagoas and 48,200 kg from Presidente Dutra, Bahia (Freitas and Couto 1997).

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The deficiency of production technologies for tropical fruit trees and lack of market strategies are the main problems in their commercial exploration, on the domestic and foreign market (Pinto et al. 2003). In spite of the wide acceptance of sugar apple in the consumer market, studies on genetic improvement of this crop are yet incipient. Some researchers have evaluated plant material in the ecological conditions of Paraíba (Holschuh et al. 1988), Pernambuco (Dantas et al. 1991) and Alagoas (Dantas et al. 1991), for physical, physical-chemical and yield traits. Carvalho et al. (2000) and Rocha et al. (2002) described the growth and yield traits of genotypes of the Sugar apple Gene Bank of the IPA (Agricultural Research Institute of Pernambuco), of which 10 accessions were evaluated for five years, with mean fruit yield of 7.38 to 11.73 kg per plant and fruit weight varying from 202 to 235 g.

The rareness of plant breeding studies for the cultivation of sugar apple creates the need for research in this area, targeting the implantation of new commercial orchards with high yields. Our study had the objective of characterizing fruits of sugar apple genotypes from Presidente Dutra, a municipality in the state of Bahia, to identify variability in cultivated genotypes, for plant breeding studies and the improvement of the production system.

MATERIAL AND METHODS

In the municipality of Presidente Dutra, Bahia (lat 11º 18' 15'' S , long 41º 59' 12'' W), in the region of Irecê, 30 sugar apple genotypes were characterized. The fruits were collected from four farms with similar soil and management conditions, rainfall between 400 and 1200 mm year^{-1} and a mean temperature of 26 ºC.

The trees had been grown from seeds and were on average five years old. They were pruned annually after harvesting in the main and late season, cultivated under irrigation and selected based on information farmers provided about plant vigor and yield. The fruits were collected in the stage of physiological maturation, in February 2004, during the local period of fruit harvest. After maturation, the fruits were characterized for: length (cm); fruit diameter (cm); fruit mass (g); rind, pulp, central receptacle and seed mass; rind thickness (mm); number of seeds and pulp yield (%). The following chemical and physical-chemical analyses were performed: pH by the potenciometric method (AOAC 1995); total soluble solids (TSS) by the refractometric method (LTFA 1973); total titratable acidity (TTA) by the acidimetric method, vitamin C and TSS/TTA ratio, and total, reducing and non-reducing sugars (AOAC 1995).

Eight fruits per plant were evaluated by data analyses based on descriptive and multivariate statistical analysis, using the method of main component analysis. The Nearest neighbor method was used as dissimilarity measure and the Mean euclidean distance (Cruz and Regazzi 2001) as agglomerative hierarchical method. For the grouping and main component analyses the softwares Statistica (Statsoft 2002) and Genes (Cruz 2001) was used, respectively.

RESULTS AND DISCUSSION

The means, standard deviations and coefficients of variation obtained for the physical traits of sugar apple fruits are shown in Table 1. The fruit length and diameter varied from 6.56 cm (P4G25) to 9.76 cm (P1G23) and from 7.13 cm (P4G25) to 9.56 cm (P3G10), respectively. Genotypes with diameter similar to the fruit length were predominant, characterizing fruits of round or codiform shape, as observed by Dantas et al. (1991) and Holschuh et al. (1988). Maia et al. (1986) evaluated 30 fruits bought in the local trade with fruit lengths of 4.3 to 7.4 cm and diameter of 5.3 to 7.8 cm. In fruits from orchards of Mossoró, Rio Grande do Norte, Silva et al. (2002) observed length and diameter of 6.8 to 8.7 cm and 7.8 to 10.1 cm, respectively.

The mean fruits mass was 270.07 g, with wide variation from 178.10 (P4G25) to 417.68 g (P3G2), indicating high variability in the genotypes under study. Carvalho et al. (2000) determined fruit mass between 202.00 and 235.00 g and Maia et al. (1986) between 138.00 and 393.00 g. The fruit mass of 13.33 % of the genotypes was higher than the mean plus standard deviations. The attributes fruit mass, length and diameter have been used as fruit classification standard, to quantify the number of fruits per packing unit for commercialization, as presented by Yokota, cited by Kavati (1997).

The pulp mass varied from 93.71(P4G25) to 268.16 g (P3G2), in the mean 160.77 g. Rocha et al. (2002) observed a smaller amplitude of variation (97.3 to 196.2 g) in plants of the Sugar Apple Genebank in Juazeiro, Bahia. The mean pulp yield was 59.10% (52.20 to 66.80%). These values were considered high in comparison with those presented by Silva et al. (2002), from 45.03 to 53.50 %, in fruits produced in Morroró-RN.

Table 1. Physical traits of 30 genotypes of sugar apple in Presidente Dutra, Bahia

Genotypes	FL (cm)	FD (cm)	FM (g)	PM (g) (Y%)	SM (g)	NS	RiM (g)	ReM (g)	RTh (mm)
P2G1	7.85	7.53	216.72	123.40 (56.8)	20.20	57.00	69.76	3.36	7.10
P3G2	9.66	9.30	417.68	268.16 (65.4)	16.87	61.50	128.63	4.02	6.61
P1G3	8.51	9.07	338.36	197.69 (58.0)	16.55	50.80	120.08	4.4	5.80
P2G4	8.51	8.42	302.78	189.50 (62.6)	22.37	68.25	87.84	3.07	5.64
P3G5	8.32	8.15	293.28	175.13 (59.7)	19.68	54.75	95.45	3.01	5.22
P3G6	9.26	9.05	307.46	183.56 (58.9)	19.86	60.29	100.36	3.68	5.76
P3G7	8.19	8.21	275.70	167.56 (60.8)	21.36	62.46	83.74	3.04	4.74
P1G8	7.46	7.98	233.06	156.37 (66.8)	13.62	52.75	62.64	2.37	5.53
P3G9	8.44	8.92	329.49	182.89 (55.6)	18.88	50.00	124.34	3.38	5.67
P3G10	9.52	9.56	341.61	206.02 (60.5)	24.03	64.88	107.82	3.74	5.51
P1G11	7.89	7.69	226.92	129.90 (57.1)	15.83	52.30	78.45	2.74	4.93
P1G12	7.51	7.83	230.38	142.84 (60.9)	17.39	51.25	67.58	2.57	4.50
P2G13	8.06	8.00	261.83	164.41 (62.6)	18.33	64.43	76.11	2.99	5.47
P2G14	7.80	8.12	250.70	153.77 (61.4)	21.14	58.80	73.20	2.59	6.62
P3G15	8.08	8.23	254.60	156.17 (61.1)	15.08	43.83	80.68	2.67	4.94
P3G16	9.02	8.41	322.61	201.33 (62.4)	21.80	71.38	95.88	3.61	5.09
P1G17	7.98	7.88	235.55	141.46 (59.8)	17.28	51.88	74.34	2.48	4.74
P1G18	7.76	8.43	273.54	155.24 (55.9)	14.45	40.00	101.12	2.72	6.04
P2G19	8.58	8.29	292.45	176.20 (60.4)	27.71	81.75	84.55	4.00	6.21
P1G20	8.11	8.26	284.36	150.20 (52.4)	17.93	48.33	112.86	3.37	6.05
P3G21	7.29	7.47	212.82	132.28 (62.0)	17.83	57.44	59.80	2.91	3.71
P1G22	8.30	8.29	282.70	164.54 (56.6)	15.52	48.12	99.35	3.29	5.31
P1G23	9.76	9.22	415.38	248.90 (59.4)	20.33	63.20	140.30	5.85	5.63
P2G24	7.93	8.26	251.93	150.71 (59.7)	20.02	57.14	78.12	3.08	6.61
P4G25	6.56	7.13	178.10	93.71 (53.6)	10.83	29.80	70.83	2.72	5.46
P1G26	7.33	7.62	192.10	100.25 (52.2)	11.61	32.57	78.06	2.19	6.51
P2G27	8.59	8.03	268.60	162.17 (60.4)	18.30	51.00	85.02	3.11	5.10
P2G28	7.59	7.94	220.70	122.37 (55.1)	20.34	60.60	75.17	2.82	6.84
P4G29	6.84	7.68	200.12	115.52 (57.1)	10.56	28.00	71.37	2.68	5.74
P2G30	6.94	7.36	190.60	110.83 (58.3)	15.02	44.40	62.50	2.25	6.66
Mean	8.12	8.21	270.07	160.77 (59.1)	18.02	53.96	88.20	3.14	5.66
SD	0.80	0.60	59.94	39.42 (3.46)	3.82	11.86	21.02	0.72	0.78
CV(%)	9.78	7.30	22.20	24.52 (5.85)	21.22	21.99	23.84	23.04	13.73

FL: fruit length; FD: fruit diameter; FM: fruit mass; PM: pulp mass; Y(%): pulp yield; SM: seed mass; NS: number of seeds; RiM: rind mass; ReM: receptacle mass; RTh: Rind thickness; SD: standard deviation; CV: coefficient of variation

The mean seed mass of 18.02 g represented 6.67% of the fruit mass, with a variation of 10.56 (P4G29) to 27.71 g (P2G19). The percentage was lower than that found by Maia et al. (1986), of 7.6% and higher than Kavati et al. (1997), with variation of 4.8 to 5.8%, in fruits of 250 to 450 g. The average seed number was 53.96, with a minimum of 28.00 and maximum of 81.75, in agreement with Kavati et al. (1997), who found an average seed number of 51 (for fruits of 200 to 250 g) to 75 (for fruits of 350 to 450 g).

The mean rind mass was 88.20 g, corresponding to 32.66% of the fruit composition, which is below the mean of 38.2% reported by Maia et al. (1986). The variation in rind thickness (from 3.71 to 7.10 mm) is a highly important attribute regarding the resistance of the fruit for the transport. The mean central receptacle mass was 3.14 g, varying from 2.19 (P1G26) to 5.85 g (P1G23).

In the percentage composition of the fruit components, the pulp is the main constituent with 59.53%, followed by the rind with 32.66%, seed, with 6.67%, and central receptacle with 1.16% of the total mass.

The results of the physical-chemical and chemical analyses of the fruits of 30 sugar apple genotypes are shown in Table 2. The amplitude of variation for pH was 3.81 (P1G26) to 5.72 (P3G2), with a mean of 4.64. Means of 5.3, 4.62 and 4.35 were found by Andrade et al. (2001), Maia et al. (1986) and Rego et al. (1989), respectively.

In the evaluated genotypes Brix varied from 18.20 (P3G6) to 26.20º (P3G13), with an average 22.96º Brix. Maia et al. (1986) found a mean of 22.36º Brix and Silva

Table 2. Chemical and physical-chemical traits of 30 sugar apple genotypes in Presidente Dutra, Bahia

Genotypes	pH	TSS (º Brix)	TTA (mg 100g^{-1})	STT/TTA	Vit.C (mg 100g^{-1})	Moisture (%)	Ashes (%)	TS (%)	RS (%)	NRS (%)
P2G1	4.69	24.60	0.17	144.71	31.10	71.59	0.76	20.32	17.18	3.14
P3G2	5.72	23.20	0.16	145.00	24.46	73.40	0.62	18.20	13.31	4.89
P1G3	5.17	23.20	0.13	178.46	28.87	76.58	0.80	21.78	15.80	5.98
P2G4	4.84	22.60	0.16	141.25	30.10	73.51	0.67	20.82	17.10	3.72
P3G5	4.83	23.60	0.22	107.27	26.26	70.73	0.99	18.06	16.85	1.21
P3G6	4.23	18.20	0.42	43.33	37.70	74.63	1.00	18.41	17.79	0.63
P3G7	5.63	22.20	0.21	105.71	25.00	75.14	0.88	18.11	14.12	3.99
P1G8	4.39	20.80	0.22	94.54	28.63	77.02	0.79	18.01	13.96	4.05
P3G9	4.52	22.60	0.40	56.50	15.22	76.90	0.62	19.03	15.37	3.66
P3G10	4.57	22.20	0.27	82.22	28.84	75.53	0.77	20.09	15.71	4.38
P1G11	4.63	24.20	0.19	127.37	25.45	76.04	0.63	20.19	15.80	4.40
P1G12	4.56	22.80	0.19	120.00	25.73	73.87	0.62	18.46	14.18	4.28
P2G13	4.52	26.20	0.24	109.17	20.64	68.13	0.91	22.40	16.63	5.78
P2G14	4.0	24.20	0.20	121.00	25.22	70.72	0.63	19.04	13.14	5.86
P3G15	4.80	21.60	0.21	102.86	24.22	75.83	0.59	20.55	19.06	1.49
P3G16	4.84	24.40	0.32	76.25	17.19	73.56	0.73	21.90	15.50	6.40
P1G17	5.42	20.00	0.14	142.85	26.52	74.39	0.74	19.49	13.86	5.62
P1G18	3.99	22.60	0.34	66.47	7.46	77.95	0.75	21.15	15.59	5.56
P3G19	5.35	24.80	0.15	165.33	41.35	72.50	0.70	20.52	17.21	3.31
P1G20	4.45	23.60	0.22	107.27	20.77	75.91	0.63	20.29	17.22	3.07
P2G21	4.99	24.00	0.14	171.43	28.57	71.50	0.66	20.80	14.06	6.79
P1G22	4.72	22.00	0.20	110.00	32.73	75.73	0.78	17.34	16.82	0.51
P1G23	4.69	24.00	0.21	114.29	25.02	74.90	0.59	19.08	15.76	3.32
P2G24	4.19	24.80	0.25	99.20	21.48	75.03	0.71	20.52	17.22	3.30
P4G25	3.95	23.50	0.41	57.32	22.09	81.60	0.85	20.36	16.79	3.57
P1G26	3.81	22.20	0.40	55.50	24.61	75.20	0.92	18.52	17.28	1.24
P2G2	74.12	22.40	0.20	112.00	19.44	74.11	0.78	20.74	15.95	4.78
P2G28	4.45	25.60	0.23	111.30	25.31	74.78	0.90	22.21	15.92	6.29
P4G29	4.34	21.30	0.44	48.41	20.93	78.21	0.82	18.40	17.57	0.83
P2G30	4.76	21.40	0.25	85.60	21.43	76.29	0.81	17.10	12.13	4.97
Mean	4.64	22.96	0.24	106.75	25.08	74.71	0.76	19.73	15.83	3.90
SD	0.48	1.68	0.09	36.16	6.42	2.62	0.12	1.47	1.62	1.82
CV(%)	10.39	7.32	37.55	33.88	25.60	3.50	15.57	7.43	10.24	46.53

TSS: total soluble solids; TTA: total titratable acidity; TS: total sugars; RS: reducing sugars; NRS: non-reducing sugars; SD: standard deviation; CV: coefficient of variation.

et al. (2002) detected a variation of 23.14 to 30.85º Brix. The total soluble solids (TSS) indicate the quantity, in grams, of the solids dissolved in the pulp. According to Oliveira et al. (1999), these consisted of water-soluble compounds that represent substances such as sugars, acids, vitamin and some pectins. TTS is used as index of the total sugars in fruits, indicating the maturity degree. A high proportion of sugars accounts for the extremely sweet taste, since the sweetening power of these fruits is by 1.7 times higher than of saccharose (Manica et al. 2003).

The values of total titratable acidity (TTA) varied from 0.14 (P1G3) to 0.44 mg 100g^{-1} (P4G29) of citric acid, with a mean of 0.24 and a coefficient of variation of 37.55%, which shows great variation among the evaluated genotypes. Maia et al. (1986) found 0.21% and Beerh et al. (1983), cited by Pal and Kumar (1995), found results of acidity oscillating from 0.30 to 0.40 mg 100 g^{-1}, predominantly citric acid. Acidity is an important parameter in the evaluation of the conservation status of food products (IAL 1985). Organic acids are intermediary products of the respiratory metabolism, related to taste and flavor (Oliveira et al. 1999).

A mean Vitamin C content of 25.08 mg 100 g^{-1} was observed, in a range of 7.46 (P1G18) to 41.35 mg 100 g^{-1} (P2G19), which shows high variation between the genotypes. Maia et al. (1986) detected at 13.75 mg 100 g^{-1} Vitamin C and Andrade et al. (2001) found values of 35.00 mg 100g^{-1} in sugar apple fruits from the Amazon region. The data show that this fruit is yet another source of Vitamin C among fruit trees.

The ratio solid soluble total/total titratable acidity is one of the best forms of evaluating the taste, for being more representative than the separate mediation of sugars and acidity. A high TSS/TTA ratio is desirable for the national market of fresh fruits (Chitarra and Chitarra 1990). The results of our analyses showed high variability among the genotypes, with an overall mean of 106.75 and minimum and maximum values of 43.33 (P3G6) to 178.46 (P1G3), respectively (Table 2). These values agree with those of Maia et al. (1986), who evaluated the pulp of ripe sugar apple at 106.48. Alves et al. (1997) found values between 113.79 and 200.00 and Dantas et al. (1991) observed a variation of 89.5 to 284.0 for TSS/TTA.

The content of ashes varied from 0.59 (P3G15) to 1.00% (P3G6), with a mean of 0.76%. Guedes and Oriá (1978) found a mean of 0.64% and Maia et al. (1986) of 0.69%. Almeida et al. (1966) observed a mean of 0.44%, while the Instituto de Nutrición de Centro América y Panamá (1961) reported a value of 0.80%.

For moisture, a mean of 74.71% was observed, varying from 68.13 (P3G13) to 81.60% (P4G25), with a coefficient of variation of 3.50%, demonstrating a low variability among the genotypes. The values observed are consistent with the described in the literature by Maia et al. (1986), 74.64, Guedes and Oriá (1978), 77.58%, Instituto de Nutrición de Centro América y Panamá (1961), 72.80% and by Andrade et al. (2001), 65%.

The total sugars contents varied from 17.10 (P2G30) to 22.40% (P3G13), with a mean of 19.73%. Maia et al. (1986) found a mean of 18.07% and Almeida and Valsechi (1966), 17.57%, while values of 11.75 and 14.60 % were observed by Chan Junior and Heu (1975) and Moura Campos et al. (1951), respectively.

The levels of reducing sugars varied from 12.13 (P2G30) to 19.06% (P3G15), with a mean of 15.83% and the non-reducing between 0.51 (P1G22) and 6.79% (P3G21), with mean of 3.90% and coefficient of variation of 46.53%, which shows a wide variation among the evaluated genotypes.

The principal component analysis showed that the two first (PC1 and PC2) contributed with over 97% to the total accumulated variance, which satisfactorily explains the difference expressed in the evaluated traits. The traits that contributed most to the genetic divergence were fruit mass, pulp mass, and rind mass and number of seeds (Table 3), where the respective weighting coefficients, variance of the eigenvalue and accumulated variance of each component considered are presented. A dispersion graph was drawn with the underlying principal components PC1 and PC2, grouped according to the Tocher method (Cruz and Regazzi 2001) (Figure 1), where the formation of 10 distinct groups is observed.

Group I comprised the genotypes P2G14, P2G24, P1G17, P1G12, P1G11, P1G8, P2G1, P3G21, and P2G28 (30%). Group II contained P1G3 and P3G9 and group III P3G7, P3G13, P2G4, P3G6 and P3G5. Group IV was composed of the genotypes P4G25, P1G26 and P4G29;

Table 3. Principal components (PC) and estimates of the eigenvalues of the analysis of 30 traits and weighting coefficients of the variables that contributed most to the formation of these components

Principal Component	Estimate of eigenvalues			Weighting coefficients		
	Root (%)	accumulated (%)	FM	PM	RiM	NS
PC1	76.9420	76.9420	0.5660	0.3525	0.4948	0.5570
PC2	20.5118	97.4539	-0.1159	0.8579	-0.5030	0.0193

FM: fresh matter; PM: pulp mass; RiM: rind mass and NS: number of seeds

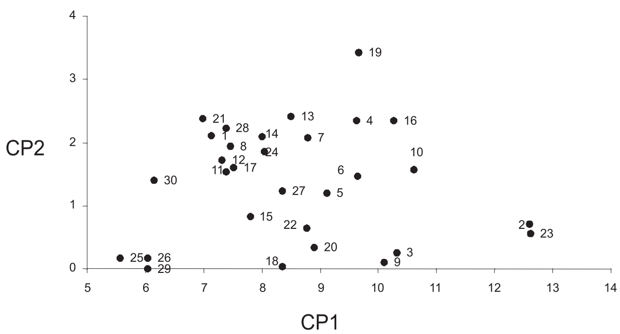

Figure 1. Graphic dispersion of the scores of 30 sugar apple genotypes, in relation to the principal components (PC) 1 and 2. Genotypes codes are shown in Table 1

Group V of P3G15, P2G27, P1G22, P1G18. The groups VI, VII, VIII, IX and X comprised the genotypes P3G2 and P1G23; P3G10 and P3G16; P2G19; P1G20 and P2G30, respectively. According to Dias (1998), two populations are considered similar when they are found in the same region of the multidimensional space, with a short distance between each other. The classification is consequence of the similarity in the set of traits evaluated in one year of production.

CONCLUSIONS

1. The evaluated genotypes are genetically divergent and formed distinct groups, which allowed their inclusion in improvement studies of sugar apple;

2. The traits fruit, pulp, and rind mass and number of seeds are highly variable, contributing to the differentiation of the evaluated genotypes, according to the formation of the main components;

3. The genotypes: P3G2, P1G3, P2G4, P3G6, P3G7, P3G9, P3G10, P3G16, P2G19, P1G22, P1G23 stood out with a fruit mass of over 270 g and length and diameter of 8.12 and 8.21 cm, respectively; these should be reevaluated for use in the production system in the future.

Caracterização de frutos de genótipos de pinheira em Presidente Dutra, Bahia

RESUMO - *Com o objetivo de identificar materiais promissores para cultivos comerciais e futuros trabalhos de melhoramento genético com a pinheira, foram caracterizados oito frutos de 30 genótipos da espécie avaliando-se: comprimento e diâmetro do fruto, massa do fruto, da polpa, da semente, da casca e do receptáculo, rendimento de polpa, número de semente, espessura da casca, pH, sólidos solúveis totais (SST), acidez total titulável (ATT), vitamina C, relação SST/ATT, umidade, cinza, açúcares totais, redutores e não-redutores. Os resultados foram avaliados por estatística descritiva (média, desvio padrão e coeficiente de variação) e análise estatística multivariada, por meio de técnicas de agrupamento e análise de componentes principais. Os genótipos avaliados apresentam divergência genética com a formação de dez grupos distintos, possibilitando a seleção de materiais promissores. Os caracteres massa do fruto, da polpa, da casca e número de sementes apresentam alta variabilidade, contribuindo para a diferenciação dos genótipos avaliados.*

***Palavras-chave**:* Annona squamosa *L., pinha, variabilidade genética.*

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