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Genetic variation of surinam cherry based on characterization of fruits

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Abstract: The characterization of accessions of surinam cherry (*Eugenia uniflora* L.) is important to allow identification and selection of superior materials for commercial growing as well as for genetic improvement programs. The present study's aim was to select surinam cherry accessions for raw consumption and/or industrial processing based on physical and chemical characterization of the fruits, as well as to select accessions for future genetic improvement efforts. Fruits were collected of 42 surinam cherry accessions in three consecutive years. Different methods were applied for their physical and chemical characterization. The data were submitted to descriptive analysis, correlation analysis between traits and multivariate analysis. The analyses of the fruits revealed high phenotypic variability. More than 70% of the accessions presented above pulp yield 75%, which is considered a high yield. Strong correlations were obtained, mainly between the physical characteristics related to production. The multivariate analysis allowed the formation of seven groups, with G4 and G7 containing the ten accessions (PIT-01, PIT-03, PIT-04, PIT-13, PIT-15, PIT-16, PIT-22, PIT-23, PIT-32 e PIT-33) of greatest interest for raw consumption and/or industrial processing, due to high pulp yield (> 65%) and high levels of soluble solids (SS), titratable acidity (TA) and SS/TA ratio. Phenotypic diversity exists among the genotypes evaluated, and all produce fruits with favorable traits for commercial exploitation and for use in genetic improvement programs.

Key words: Agro-industry, *Eugenia uniflora* L., Multivariate analysis.

Variação genética de pitangueira com base na caracterização de frutos

Resumo: A caracterização de genótipos de pitangueira (*Eugenia uniflora* L.) é estratégica, pois permite identificar, selecionar e indicar materiais superiores para a exploração comercial, bem como para programas de melhoramento genético. O presente trabalho teve como objetivo selecionar genótipos de pitangueira para o consumo *in natura* e/ ou agroindustrial a partir da caracterização física e química dos frutos, bem como selecionar genótipos para futuros trabalhos de melhoramento genético. Frutos foram coletados de 42 genótipos de pitangueira em três anos consecutivos. Foram realizadas diferentes caracterizações física e química dos frutos. Os dados foram submetidos à análise descritiva, análise de correlação entre os caracteres e análise multivariada. Após as análises dos frutos pode-se verificar uma alta variabilidade fenotípica. Mais de 70% dos genótipos apresentaram rendimento de polpa acima de 75% o que é considerado um alto rendimento. Foram obtidas altas correlações, principalmente entre as características físicas relacionadas à produção. A análise multivariada permitiu a formação de sete grupos, sendo os grupos G4 e G7 contendo dez acessos (PIT-01, PIT-03, PIT-04, PIT-13, PIT-15, PIT-16, PIT-22, PIT-23, PIT-32 e PIT-33) de maior interesse para o consumo *in natura* e/ou agroindustrial por possuírem um bom rendimento de polpa (> 65%), altos níveis de sólidos solúveis (SS), acidez titulável (AT) e SS/AT. Existe diversidade fenotípica entre os genótipos avaliados e todos apresentam frutos com características de interesse para exploração comercial e para ser utilizados em programas de melhoramento genético

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Palavras chave: Agroindústria, *Eugenia uniflora* L., Análise multivariada.

Introduction

Surinam cherry (*Eugenia uniflora* L.) (variously known as Pitanga, Brazilian cherry or Cayenne cherry, among others) belongs to the family Myrtaceae Juss. It is a fruit-bearing tree or shrub native to the east coast of South America, ranging from Surinam to southern Brazil and parts of Paraguay, Uruguay and Argentina (Lopes et al*.,* 2013 & Soares et al., 2014). This wide distribution is possible due to the species' high adaptability to diverse edaphoclimatic conditions.

The fruits are typically sweet when ripe and have a strong and distinctive smell. They are classified as berries, with average diameter of about 16 mm, concave at the ends and with eight to ten lengthwise grooves. The fruits can be consumed raw or used to make many processed products, such as jams, jellies, juice, ice cream, popsicles and wine, among others (Soares et al*.,* 2014).

The surinam cherry tree has many other uses besides as human food. It can be used to form living fences, for wood and as an ornamental plant (Dias et al., 2011). The leaves have pharmacological properties, characterized in the literature as antioxidant and antimicrobial (Soares et al., 2014), including activity against *Trypanosoma cruzi*, the protozoan that causes Chagas disease (Santos et al*.,* 2012a).

Knowledge of the physical and chemical characteristics of the fruits is necessary to identify the most appropriate potential uses. High pulp yield is attractive both for raw consumption and processing, as is the level of soluble solids, which enables more productive processing (Dias et al., 2011). The titratable acidity is an important factor affecting the conservation of food products, because high acidity combined with low pH inhibits the growth of microbes (Dias et al*.,* 2011).

The characterization of the genotypes of native fruit-bearing plants is of strategic importance, by allowing identification and selection of superior materials with promising traits for commercial exploitation as well as for genetic improvement programs (Farias et al., 2004). Despite the efforts of some researchers to find superior materials, studies related to surinam cherry are scarce compared to other tropical fruiting plants.

The first and only improved pitangueira cultivar in Brazil was launched in 2000, developed by the Pernambuco Agricultural Research Company, called the Agronomic Institute of Pernambuco until 1975, but the transformation maintained the acronym Pernambuco Agricultural Research Corporation [IPA] (2000). This cultivar was obtained from selecting genotypes with high productive potential and good agronomic characteristics (Bezerra et al., 2004). In the state of Bahia, cultivation of surinam cherry is rare, and is mainly concentrated in the state's southern region.

In light of this situation, the objective of this study was to select accessions of surinam cherry fruits with good potential for raw consumption and/or industrial processing, as well as for possible use in genetic improvement programs based on physical and chemical characterization from the germplasm collection of the Tropical Fruit Experimental Station of Empresa Baiana de Desenvolvimento Agrícola the Bahia Agricultural Development Agency [EBDA].

Material and methods

The study was conducted at the experimental station of EBDA, located in the municipality of Conceição do Almeida, Bahia, Brazil. Fruits were collected of 42 surinam cherry accessions in three consecutive years in four quadrants of a spherical portion of the tree crown (same plant). Twenty-five ripe fruits were collected randomly from each quadrant, for a total of 100 fruits per tree. The fruits were immediately evaluated for color (orange, red and purple) and sanitized for subsequent assessments.

Thirty fruits of each accessions were used to determine the following physical traits: longitudinal diameter – LD (mm); transversal diameter - TD (mm); TD/LD ratio; fruit weight (g); seed weight (g); pulp weight (g); percentage of seeds; and pulp yield percentage [PY(%)=100PW/FW]. The weights of the fruits and seeds were determined with an analytical scale and the pulp weight was calculated by the difference between the weight of each fruit and its seeds.

The fruits were pulped manually and the pulp was homogenized. The physico-chemical characteristics measured were: pH, using a potentiometer at a temperature of 25 ^{o}C and calibrated with buffer solutions of pH 4 and 7; and soluble solids (SS), determined with a refractometer, to obtain the ºBrix value at 25 ºC. The chemical properties ascertained were: titratable acidity (TA), expressed as percentage of citric acid; vitamin C (ascorbic acid), measured by the potassium iodide method, in mg of ascorbic acid/100 g of pulp Instituto Adolfo Lutz [IAL] (2008); total and reducing sugars, determined according to the method recommended by (IAL, 2008); non-reducing sugars, computed by the difference between total and reducing sugars; SS/TA ratio, determined mathematically by the quotient between the two measures; and technological index (TI), obtained by the equation: [IT = (soluble solids x pulp yield)/100].

That data were analyzed by descriptive statistics using the Genes 7.0 program (Cruz, 2008), to obtain measures of centrality and dispersion; minimum, mean and maximum values; and amplitude, standard deviation and coefficient of variation. Pearson correlation coefficients were calculated for the traits evaluated and their significance was measured by the t-test at 1% and 5% probability, with the Genes 7.0 software (Cruz, 2008).

The rank summation index technique of Mulamba e Mock (1978) was also employed to identify promising accessions, considering the variables of greatest interest for industrial processing. This index was obtained from the results of the physical (fruit weight, pulp yield and seed weight), physico-chemical (soluble solids) and chemical (titratable acidity) traits of the fruits.

The data were submitted to multivariate analysis using standardized means. The dissimilarity was measured by the mean Euclidian distance and groups were formed using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) (Sokal & Rohlf, 1962).

The groupings were validated by measuring the cophenetic correlation coefficient (CCC), according to Sokal e Rohlf (1962), and its significance was measured by Student t-test, at 5% probability, also utilizing the Genes 7.0 program (Cruz, 2008). Finally, the dendrogram was generated based on the distance matrix by the Genes 7.0 program (Cruz, 2008).

Results and discussion

All the variables studied showed low coefficient of variation of the means obtained from the fruits collected in the three years evaluated, using the mean values of each year (Tables 1 and 2). A good deal of variability was observed for the physical, physico-chemical and chemical traits of the surinam cherry fruits, with coefficients of variation ranging from 5.14% (transversal/longitudinal diameter ratio) to 32.75% (soluble solids/titratable acidity ratio), enabling identifying accessions with good potential for consumption of raw fruit and processing.

The transversal and longitudinal diameters (Table 1) varied from 12.99 mm to 19.11 mm and from 16.96 mm to 23.98 mm, respectively. The largest fruits were found in accessions SC-16, SC-23, SC-04, SC-05, SC-12, SC-20, SC-30 and SC-01 and the smaller in accessions SC-17, SC-28, SC-35 and SC-36. Dias et al. (2011) reported average transversal and longitudinal diameters of 19.27 and 14.18 mm, respectively, near those found in this study. The average ratio between the two diameters was 0.77, reflecting the typically flattened shape of the fruits. The coefficients of variation were lower than 6.31% for the three variables (Tables 1 and 2).

Table 1 - Means of the physical traits of surinam cherry fruits (*Eugenia uniflora* L.) collected in three consecutive years.

ACESSIONS	TD	LD	TD/LD	FW	SW	PW	PY	SP
SC-01	18.01	22.30	0.81	5.75	0.97	4.78	82.03	17.97
SC-02	15.09	19.84	0.76	3.53	1.16	2.37	67.33	29.34
SC-03	17.90	23.98	0.75	5.88	0.94	4.94	83.00	17.00
SC-04	18.27	23.40	0.78	5.69	1.02	4.67	80.76	19.24
SC-05	18.17	23.65	0.77	5.60	1.12	4.47	78.28	21.72
SC-06	15.80	21.91	0.72	4.80	0.93	3.87	79.13	20.87
SC-07	15.12	21.04	0.72	5.04	0.73	4.31	84.77	15.23
SC-08	16.12	22.00	0.73	4.52	1.06	3.47	74.27	25.73
SC-09	15.92	21.04	0.76	3.99	0.75	3.24	79.86	20.13
SC-10	16.78	23.03	0.73	4.84	1.06	3.78	75.86	24.14
SC-11	16.29	20.90	0.78	4.54	0.82	3.73	80.70	19.30
SC-12	18.12	23.76	0.76	5.73	1.22	4.50	76.67	23.32
SC-13	15.77	20.90	0.75	5.07	0.60	4.47	87.58	12.41
SC-14	15.91	23.06	0.73	5.48	0.98	4.50	80.70	19.30
SC-15	15.26	22.65	0.67	5.61	0.99	4.62	81.16	18.84
SC-16	19.11	22.42	0.85	5.44	0.95	4.49	81.29	18.71
SC-17	12.99	17.51	0.74	2.93	0.62	2.32	76.80	23.20
SC-18	14.64	16.96	0.86	2.68	0.60	2.08	75.29	24.71
SC-19	15.17	18.78	0.81	3.94	0.93	3.01	73.70	26.30
SC-20	18.04	23.68	0.76	6.44	0.99	5.44	83.69	16.31
SC-21	16.68	22.08	0.76	4.87	1.12	3.76	74.67	25.33
SC-22	17.20	22.82	0.75	5.49	0.91	4.58	82.31	17.68
SC-23	18.84	22.67	0.83	5.96	1.28	4.69	76.68	23.32
SC-24	14.16	19.59	0.72	3.39	0.81	2.58	73.43	26.57
SC-25	14.55	18.22	0.80	3.45	0.75	2.70	76.18	23.82
SC-26	15.80	20.53	0.77	4.57	0.92	3.65	78.22	21.78
SC-27	14.74	19.94	0.74	4.39	0.88	3.51	78.36	21.64
SC-28	13.11	17.75	0.74	3.14	0.68	2.45	76.22	23.78
SC-29	14.72	17.55	0.84	3.19	0.84	2.35	70.61	29.39
SC-30	18.02	23.31	0.77	5.91	1.21	4.70	77.68	22.32
SC-31	14.72	18.83	0.78	4.51	1.20	3.30	69.93	30.07
SC-32	15.51	19.85	0.78	4.64	0.83	4.09	80.85	19.15
SC-33	16.54	21.11	0.78	5.30	0.87	4.43	82.48	17.52
SC-34	15.96	20.59	0.77	5.09	1.17	3.92	74.72	25.28
SC-35	13.53	18.57	0.73	3.72	1.12	2.61	65.76	34.24
SC-36	13.86	18.69	0.74	3.04	0.64	2.41	77.18	22.82
SC-37	16.48	20.81	0.79	4.30	1.26	3.04	66.21	33.79
SC-38	15.60	18.97	0.82	3.65	0.80	2.85	76.08	23.92
SC-39	14.85	20.04	0.74	4.42	0.98	3.44	75.61	24.39
SC-40	15.48	20.62	0.75	4.54	0.93	3.61	77.84	22.16
SC-41	17.29	21.48	0.80	4.62	1.20	3.41	70.60	29.39
SC-42	14.80	20.67	0.72	3.95	0.72	3.23	80.41	19.59
Média	15.97	20.89	0.77	4.61	0.94	3.68	77.26	22.66
Mínimo	12.99	16.96	0.67	2.68	0.60	2.08	65.76	12.41
Máximo	19.11	23.98	0.86	6.44	1.28	5.44	87.58	34.24
CV (%)	3,42	2,87	1,97	4,53	2,46	5,80	4,55	17,20

TD = transversal diameter of the fruit (mm); LD = longitudinal diameter of the fruit (mm); TD/LD = ratio of transversal and longitudinal diameters; FW = fruit weight (g); SW = seed weight (g); PW = pulp weight (g); PY = pulp yield (%); SP = seed percentage (%); CV = coefficient of variation.

Table 2 - Means of the physico-chemical and chemical traits of surinam cherry fruits (*Eugenia uniflora* L.) collected in three consecutive years.

ACESSIONS	pH	SS	TA	SS/TA	VC	TS	RS	NRS	TI
SC-01	2.99	12.67	0.94	13.92	20.71	5.51	4.16	1.35	10.40
SC-02	2.86	10.86	1.83	5.93	19.85	6.80	5.22	1.59	6.59
SC-03	3.07	13.18	1.03	12.81	20.46	6.89	5.51	1.37	10.94
SC-04	3.19	10.12	1.44	7.00	19.08	6.38	4.92	1.46	8.17
SC-05	3.23	7.81	1.76	4.43	18.59	4.40	2.69	1.71	6.11
SC-06	2.97	9.66	1.87	5.17	18.59	6.89	4.63	2.26	7.64
SC-07	2.99	10.15	1.56	6.49	32.81	6.79	5.31	1.49	8.60
SC-08	2.83	10.24	1.88	5.45	27.87	6.92	4.88	2.04	7.62
SC-09	2.92	9.92	1.56	6.34	29.22	6.92	5.51	1.41	7.93
SC-10	2.99	10.63	1.69	6.28	33.53	6.01	4.71	1.31	8.07
SC-11	2.64	11.89	1.31	9.11	35.37	6.35	4.65	1.70	9.60
SC-12	3.04	8.92	1.26	7.05	17.88	5.54	3.50	2.03	6.84
SC-13	2.57	11.93	1.91	6.24	17.93	6.53	4.94	1.59	10.45
SC-14	2.96	7.71	0.78	9.90	26.89	4.05	2.29	1.76	6.22
SC-15	2.63	12.89	1.13	11.43	21.31	6.38	4.83	1.54	10.46
SC-16	3.20	10.71	0.92	11.62	22.30	4.99	3.67	1.32	8.71
SC-17	2.86	6.61	1.46	4.54	21.08	6.83	5.62	1.21	5.08
SC-18	2.93	6.58	1.63	4.04	19.32	6.81	5.05	1.76	4.96
SC-19	2.97	8.23	2.03	4.06	18.59	3.88	2.50	1.38	6.07
SC-20	3.13	9.99	1.21	8.27	42.13	7.80	5.71	2.09	8.36
SC-21	2.65	9.56	1.99	4.79	22.30	4.30	2.69	1.61	7.19
SC-22	3.02	11.41	1.62	7.05	20.78	6.71	5.26	1.44	9.39
SC-23	3.13	11.15	1.44	7.73	24.32	5.98	4.84	1.14	8.55
SC-24	2.80	10.65	1.76	6.04	36.30	6.40	4.89	1.51	7.83
SC-25	3.22	9.94	1.45	6.88	26.50	4.05	2.38	1.67	7.58
SC-26	3.03	11.63	1.90	6.11	40.48	3.97	2.65	1.32	9.10
SC-27	3.11	7.94	0.79	10.09	47.17	5.60	4.33	1.27	6.23
SC-28	2.80	10.01	1.87	5.34	23.61	6.12	4.72	1.41	7.64
SC-29	3.28	9.15	1.24	7.35	19.06	6.73	5.60	1.05	6.47
SC-30	3.08	10.13	1.67	6.09	41.04	5.18	3.63	1.54	7.88
SC-31	3.01	10.10	1.44	7.02	18.48	5.49	4.10	1.39	7.08
SC-32	2.72	12.85	1.14	11.28	32.38	7.04	5.70	1.33	10.39
SC-33	2.88	13.24	1.43	9.23	29.67	7.40	5.79	1.61	10.92
SC-34	2.89	12.19	1.91	6.39	27.83	6.64	5.33	1.31	9.12
SC-35	3.01	11.03	2.03	5.42	20.10	4.26	3.05	1.21	7.27
SC-36	2.85	12.38	1.71	7.24	14.04	5.61	3.28	2.33	9.56
SC-37	2.82	10.24	1.87	5.47	18.60	5.56	3.75	1.82	6.80
SC-38	2.73	10.85	1.66	6.53	17.60	6.48	4.75	1.73	8.26
SC-39	2.82	8.90	0.91	9.75	33.41	6.58	5.09	1.49	6.74
SC-40	2.87	9.64	0.92	10.45	26.95	6.79	5.28	1.51	7.51
SC-41	2.95	9.48	0.94	10.03	34.58	5.54	3.53	2.01	6.70
SC-42	2.91	10.59	1.52	6.98	35.58	7.19	5.87	1.32	8.52
Média	2.94	10.33	1.49	7.46	26.06	6.01	4.45	1.56	7.99
Mínimo	2.57	6.58	0.78	4.04	14.04	3.88	2.29	1.05	4.96
Máximo	3.28	13.24	2.03	13.92	47.19	7.80	5.87	2.33	10.94
CV (%)	1,24	4,15	1,56	3,77	3,17	1,33	1,42	3,48	8,28

pH = hydrogen potential; SS = soluble solids (°Brix); TA = titratable acidity (% of citric acid); SS/TA = soluble solids/titratable acidity ratio; VC = vitamin C; TS = total sugars (% glucose); RS = reducing sugars (% glucose); NRS = non-reducing sugars; TI = technological index; CV = coefficient of variation.

The fruit weight varied from 2.68 g for accession SC-18 to 6.44 g for accession SC-20, with mean of 4.61 g. Dias et al. *(*2011), studying surinam cherry accessions grown in the Recôncavo da Bahia region, observed a larger amplitude between the accessions characterized, ranging from 1.28 g to 6.52 g, and average weight (2.69 g) much lower than found in this study. The pulp weight was the variable presenting the largest amplitude of variation, with a coefficient of variation of 5.80% (Table 1).

The seed weight varied from 0.60 g in accession SC-18 to 1.28 g in accession SC-23, with an average of 0.94 g and coefficient of variation of 2.46% (Table 1). These results differ from those of Dias et al*.* (2011), who obtained a seed weight variation from 0.15 g to 1.12 g with mean of 0.58 g and coefficient of variation of 40.79%. These same authors suggesting the existence of diversity among accessions also for this trait.

The pulp yield is one of the most important traits for consumption of raw fruit and processing and is related to the size of the fruits and of the seeds (Nascimento & Cocozza, 2015). More than 70% of the accessions presented pulp yield above 75%, with an average of 77.26%. Similar results were found by Bezerra et al. (2004) and Dias et al. (2011), who obtained an average of 80.0% and 79.46%, respectively, and higher than reported by Lopes et al. (2013) with 66.64%. Yields greater than 80% were observed for accessions SC-13 (87.58%), SC-07 (84.77%) and SC-20 (83.69%), and lower than that for accessions SC-35 (65.76%), SC-37 (66.21%), SC-02 (67.33%) and SC-31 (69.93%) (Table 1).

The physical variables are all important for marketing of fruits, because the higher the pulp weight and the lower the seed percentage, the larger the fruits tend to be, making them more attractive to consumers and processors (Nascimento & Cocozza, 2015).

Among the physico-chemical traits, pH was the most homogeneous among the accessions and thus showed the smallest coefficient of variation (1.24%), with values ranging between 2.57, for accession SC-13, and 3.28, for accession SC-29 (Table 2). These results are near those observed by Dias et al. (2011), who measured a variation from 2.61 to 3.07 and a coefficient of variation of 3.31%. Low pH favors conservation, by hindering the development of microorganisms during transport and processing, besides needing less or no addition of citric acid when making processed products (Lima et al*.,* 2002), although higher pH values (lower acidity) are generally preferred by consumers of raw fruits.

The level of soluble solids (SS) varied from 6.58 ºBrix for accession SC-18 to 13,24 ºBrix for accession SC-33, with mean of 10.32 ºBrix (Table 2). The average among all the genotypes is in accordance with the finding of Dias et al. (2011), which was 10.88 ºBrix, but above that reported by Oliveira et al. (2006), of 7,00 °Brix. All the accessions presented ºBrix values established by the Brazilian Ministry of Agriculture (Brasil, 1999) for surinam cherry pulp in relation to soluble solids, which sets a minimum of 6.00 °Brix. Higher levels of soluble solids are desirable in fruits in general, both by consumers of raw fruits and for processing, in the latter case because the yield is greater, there is less need to add sugar and processing time is shorter, thus reducing energy costs (Dias et al., 2011).

The titratable acidity (TA) of the fruits, expressed in terms of citric acid, varied from 0.78% for accession SC-14 to 2.03% for accession SC-19, with a mean of 1.49% and coefficient of variation of 1.56% (Table 2). The accessions with titratable acidity above 1.00% are more attractive to processing companies, because of the lesser need to add acids for conservation of the pulp to hinder the development of microorganisms (Lima et al*.,* 2002). Oliveira et al. (2006), investigating surinam cherry fruits grown in the region of Campina Grande, Paraiba state, observed average titratable acidity of 2.23%, well above that found in this study. However, only three of the accessions among those evaluated here (SC-14, SC-27 and SC-39), did not meet the requirements of the Ministry of Agriculture for surinam cherry pulp, which is at least 0.92% (Brasil, 1999).

The ratio between soluble solids and titratable acidity (SS/TA) permits inferring the quality (flavor) and ripeness point of the fruits (Lima et al., 2002). Among the 42 accessions analyzed, the values varied from 4.04 in accession SC-18 to 13.92 in accession SC-01, with an average of 7.46 (Table 2), higher than the values found by Dias et al. (2011), who measured an average of 5.85 and maximum value of 7.31. This ratio in ripe fruits reveals the balance between sugars and acidity, with higher values indicating the presence of more soluble solids as a result of transformation of insoluble polysaccharides into soluble sugars (Santos et al*.,* 2012b).

The concentrations of vitamin C in the accessions varied from 14.04 to 47.19 mg of ascorbic acid/100 g of pulp, with an average of 26.06 mg of ascorbic acid/100 g of pulp. The highest values were obtained for accessions SC-27, SC-20. SC-30 and SC-26, with levels above 40 mg of ascorbic acid/100 g of pulp. Nzeagwu e Onimawo (2010), studying surinam cherry fruits harvested in Nigeria, observed values near 27.6 mg of ascorbic acid/100 g of pulp. All accesses evaluated in the present study had levels considered high when compared to the Brazilian table of food composition according to Center for Studies and Research in Food [Nepa] (2011) for surinam cherry, which sets a minimum level of 8.1 mg of ascorbic acid/100 g of pulp. High vitamin C levels naturally present in fruits intended for raw consumption have high antioxidant power, helping to prevent and fight various diseases (Chitarra & Chitarra, 2005).

The concentrations of total sugars ranged from 3.88% in accession SC-19 to 7.80% in accession SC-20. With respect to reducing sugars, the minimum level found was 2.29% in accession SC-14 and the maximum was 5.87% accession SC-42. The Ministry of Agriculture does not set a minimum standard for total sugars in surinam cherry pulp, but does establish a maximum of 9.50% (Brasil, 1999). Among the accessions evaluated, 62% presented percentages of reducing sugars higher the 4.5%. The reducing sugars are the most important sugars in relation to flavor (Chitarra & Chitarra, 2005).

The technological index (IT), or industrial yield, measures the yield from raw material after industrial processing of fruits, using as parameters pulp yield and soluble solids levels of fruits (Pinto et al., 2003). For the accessions evaluated, the average value was 7.99, with variation from 4.96 in accession SC-18 to 10.94 in accession SC-03. All the accessions had values above the standard for industrial acceptance, according to Chitarra e Chitarra (2005), which is an index above 4.4. In the fruit processing business, higher technological indices are desirable, because this means greater possibility for concentration of soluble solids (Dias et al*.,* 2011). Processing companies tend to pay more when this index is high, as long as other attributes are also acceptable, such as soluble solids. Therefore, these two attributes can be used to select accessions for genetic improvement programs.

By applying the rank summation index technique of Mulamba e Mock (1978), and considering the highest values of pulp weight, pulp yield, soluble solids, titratable acidity, SS/TA ratio and pH level, the accessions SC-01, SC-03, SC-04, SC-13, SC-15, SC-16, SC-22, SC-23, SC-32 and SC-33 can be recommended both for industrial use and sale of raw fruits directly to consumers.

Considered to be an important tool for genetic improvement programs, analysis of correlations between traits is particularly used when the objective is to improve the material for a set of traits simultaneously (Dias et al., 2011). Ten highly significant correlations (above 0.7 or below -0.7) were obtained, mainly between the physical variables (Table 3). The correlations strongest were obtained between seed percentage and pulp yield (-0.988) and pulp weight and fruit weight (0.979), both involving physical traits related to production. Among the chemical characteristics, the highest correlations were between reducing sugars and total sugars (0.960) and titratable acidity and the soluble solids/titratable acidity ratio (-0.844). The technological index presented a significant correlation only with soluble solids, with value of 0.919. Dias et al. (2011), characterizing surinam cherry genotypes in the Recôncavo da Bahia region of the state, also observed high correlations between the physical traits, such as fruit weight, seed weight, pulp weight and longitudinal and transversal diameters of the fruits. These variables are very important sale for consumption of raw fruit, because they make the fruits more attractive to consumers. Correlations near zero or slightly negative demonstrate that the selection for the traits in question can be independent, without a correlated response.

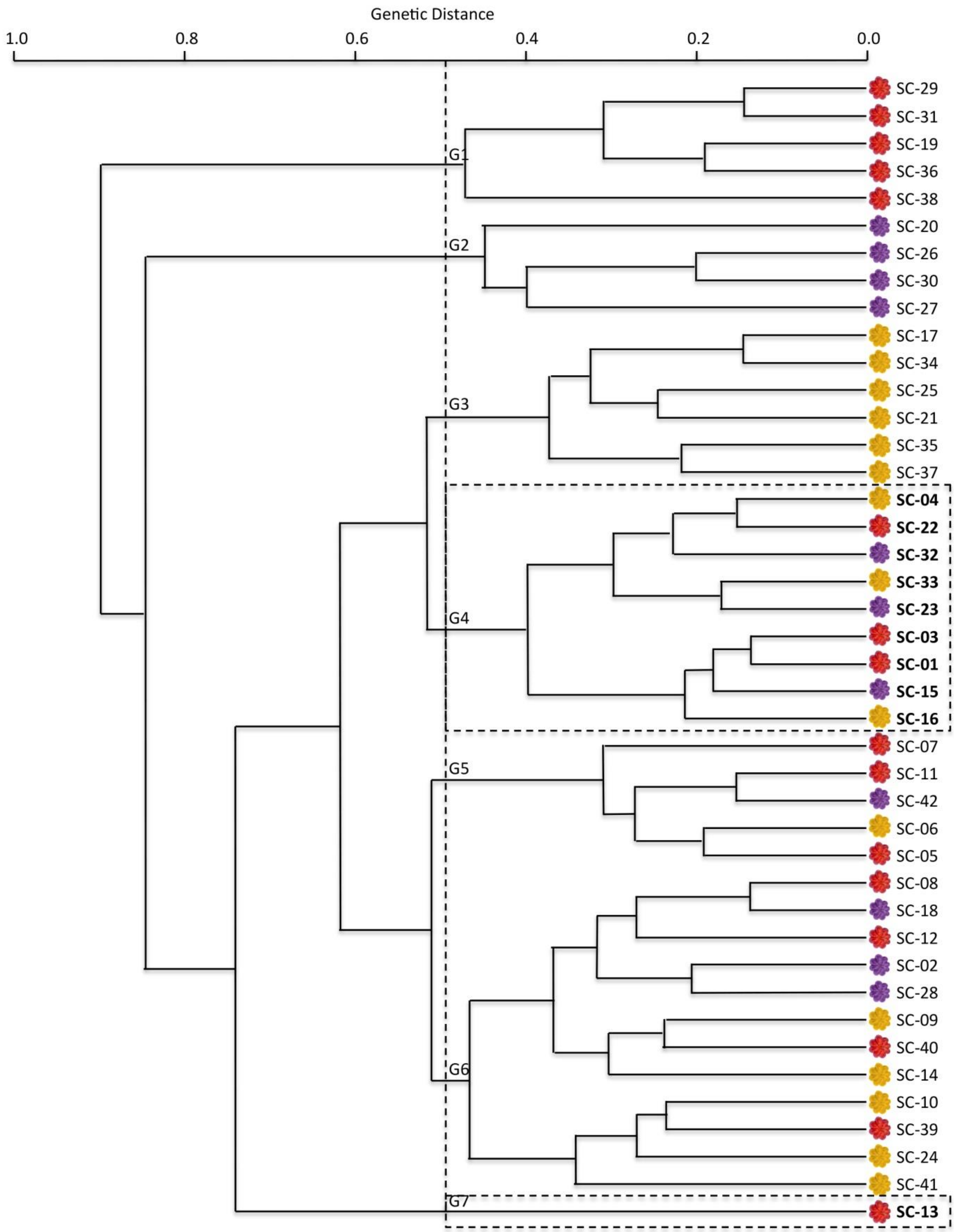
Table 3 - Linear correlation coefficients between physical, physico-chemical and chemical traits of surinam cherry fruits (*Eugenia uniflora* L.) collected in three consecutive years.

	FW	LD	TD	TD/LD	SW	PW	PY	SP	pH	SS	TA	VC	SS/TA	TS	RS	NRS
LD	**0.898****															
TD	**0.821****	**0.856****														
TD/LD	-0.061	-0.178*	0.329**													
SW	0.524**	0.517**	0.545**	0.079												
PW	**0.979****	**0.864****	**0.776****	-0.079	0.353**											
PY	0.488**	0.470**	0.389**	-0.087	-0.330**	0.609**										
SP	-0.475**	-0.464**	-0.381**	0.090	0.322**	-0.593**	**-0.988****									
pH	0.231**	0.208*	0.381**	0.357**	0.259**	0.188*	0.039	-0.030								
SS	0.310**	0.246**	0.212*	-0.115	0.052	0.341**	0.290**	-0.298**	-0.258**							
TA	-0.311**	-0.232**	-0.243**	-0.092	-0.008	-0.344**	-0.278**	0.270**	-0.217*	0.046						
VC	0.163	0.146	0.038	-0.197*	0.002	0.183*	0.169	-0.161	0.051	0.004	-0.265**					
SS/TA	0.441**	0.338**	0.331**	0.026	0.061	0.480**	0.366**	-0.363**	0.037	0.452**	**-0.844****	0.198*				
TS	-0.007	0.003	-0.053	-0.147	-0.296**	0.064	0.243**	-0.258**	-0.246**	0.222*	-0.132	0.104	0.139			
RS	-0.023	-0.052	-0.082	-0.111	-0.301**	0.049	0.227*	-0.241**	-0.191*	0.235**	-0.154	0.136	0.171	**0.960****		
NRS	0.053	0.195	0.107	-0.119	0.038	0.049	0.035	-0.037	-0.177*	-0.067	0.089	-0.121	-0.129	0.065	-0.216*	
TI	0.446**	0.377**	0.324**	-0.116	-0.100	0.522**	0.624**	-0.606**	-0.197*	**0.919****	-0.079	0.067	0.515**	0.267**	0.273**	-0.045

(**), (*) = Significant at 1% and 5% probability by the t-test. **Values in boldface** = correlations above 0.7 or below -0.7. FW = fruit weight (g); TD = transversal diameter of the fruit (mm); LD = longitudinal diameter of the fruit (mm); TD/LD = transversal diameter/longitudinal diameter ratio; SW = seed weight (g); PW = pulp weight (g); PY = pulp yield (%); SP = seed percentage (%); pH = hydrogen potential; SS = soluble solids (°Brix); TA = titratable acidity (% citric acid); VC = vitamin C; SS/TA = soluble solids/titratable acidity ratio; TS = total sugars (% glucose); RS = reducing sugars (% glucose); NRS = non-reducing sugars; TI = technological index.

The multivariate analysis carried out with the 42 accessions led to the formation of seven groups (Figure 1) by the UPGMA method, based on mean Euclidian distance, using as cutoff point genetic dissimilarity of *D dg* = 12.

Figure 1 - Genetic dissimilarity dendrogram generated by the UPGMA algorithm based on the mean Euclidian distance of the set of physical, physico-chemical and chemical data of the fruits from 42 surinam cherry trees (*Eugenia uniflora* L.) collected in three consecutive years. CCC (Cophenetic Correlation Coefficient) = 0.73.



The cophenetic correlation coefficient of the dendrogram (r=0.73) revealed a good fit between the graphical representation of the distances and their original matrix, reflecting good concordance with the genetic dissimilarity values.

Group G1 was composed of five accessions, all having fruits with reddish color (SC-29, SC-31, PIT19, SC-36 and SC-38), along with similar values for longitudinal diameter and vitamin C content. Group G2 was composed of accessions SC-20. SC-26, SC-27 and SC-30, with fruits having purple color and sharing similar values of transversal/longitudinal ratio, pulp yield and seed percentage. Group G3 was formed of six accessions, with orange colored fruits (SC-17, SC-21, SC-25, SC-34, SC-35 and SC-37), sharing characteristics of pulp yield and seed percentage.

Group G4 was composed of nine accessions, all recommended both for processing and raw consumption, with high values of fruit weight, pulp weight, pulp yield, soluble solids, titratable acidity and soluble solids/titratable acidity ratio. Groups G5 and G6 included the other accessions, with varied colors and traits. Finally, group G7 was formed only of accession SC-13, which presented the highest pulp yield and one of the highest technological indices. This accession also can be recommended for processing, raw consumption and can be cloned via grafting or used in breeding programs to obtain superior hybrids.

As in this study several others have collaborated with information on the phenotypic divergence in different plants species and with different purposes (Carpentieri-Pípolo et al., 2000, Souza et al., 2012a, Souza et al., 2012b, Santos et al., 2015 & D'Abadia et al. 2020). Souza et al. (2012a) performed the selection of different accessions of pineapples with ornamental potential and for use in the breeding program from the studies of phenotypic diversity. Other authors with this same objective also selected accessions of banana (Souza et al., 2012b) and citrus (Santos et al., 2015) with ornamental potential. Regarding the selection of parental genotypes, from studies of genetic divergence based to fruit quality, Carpentieri-Pípolo et al. (2000) selected eight West Indian Cherry genotypes due to the high content of vitamin C. A recent study of genetic diversity in *Passiflora alata* Curtis. carried out by D'Abadia et al. (2020) allowed the identification of two elite genotypes for use in breeding programs.

Conclusions

Wide phenotypic diversity was found among the 42 surinam cherry accessions evaluated by characterization of fruits and can be used in genetic improvement programs.

The fruits of all the accessions showed traits attractive for commercial exploitation, with pulp yield higher than 65%.

The fruits of accessions SC-01, SC-03, SC-04, SC-13, SC-15, SC-16, SC-22, SC-23, SC-32 and SC-33 presented the best agronomic traits for raw consumption, industrial processing and can be cloned via grafting or used in breeding programs to obtain superior hybrids.

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