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Phenotypic stability of acerola genotypes evaluated in different times

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ABSTRACT - *Characteristics of acerola related to the levels of total soluble solids (TSS), total titratable acidity (TTA) and vitamin C (VC) are directly linked to the quality of the fruits, being influenced mainly by the genotype and climate. Climatic variations makes the amounts of SST, ATT and VC in the fruits not constant, so that eventually they do not meet the minimum demands of the consuming markets. This work had as objective to evaluate the differential response of acerola genotypes to the variation of the climatic conditions in fruits picked in three successive harvests in different seasons and also in the same season in successive years, by means of an analysis of phenotypic stability. In both situations, significant differences were observed among the genotypes in relation to the stability in the three variables assessed due to variations in the climatic conditions.*

Key words: *Malpighia emarginata* D.C., fruit characteristics, adaptability.

INTRODUCTION

The acerola (*Malpighia emarginata* D.C.) is a shrub especially cultivated in the Northeast of Brazil, whose commercial interest resides in the use of the fruits, which have high vitamin C content. Among the forms of commercialization of the product, stands out the frozen pulp, for the internal and external markets (Bliska and Milk 1995). Some minimum demands for the acerola export for the European and Japanese markets include total soluble solids content equal or superior to 7,0 °Brix and vitamin C content superior to 1000 mg ascorbic acid/100 g pulp (IBRAF 1995, Alves 1996). Nevertheless, the production of fruits that attend the minimum quality demands of the consumers is influenced by factors as variety and climate. Due to the climatic variations, the vitamin C and sugars contents in the fruits are not constant, being influenced mainly by the temperature and light exposure, associated directly to the photosynthetic activity, as well as by the rain that, in excess, reduces the content of sugars and vitamin C through the dilution of the cellular juice (Marino Netto 1986, Carvalho and Manica 1993). This work has as objective to evaluate the differential response of acerola genotypes to the variation of the climatic conditions in

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fruits picked in three successive harvests in different seasons and also in the same season in successive years, by means of an analysis of phenotypic stability using the method of Eberhart and Russel (1966).

MATERIAL AND METHODS

Mature fruits of 12 genotypes of the Active Acerola Germplasm Bank of Embrapa Cassava and Tropical Fruits, in Cruz das Almas, BA, Brazil were collected and evaluated in three successive harvests in different seasons, corresponding to the months of November-December/1999, January-February/2000 and March-April/2000. In a similar way, mature fruits of 13 genotypes were collected and evaluated in the same season in three successive years (1999, 2000 and 2001), in the month of November. The fruits were randomly collected from the inside and outside the plant canopy, in all sides, in a large number for subsequent selection for analysis of those with totally red skin, uniform ripening and without damages or injuries. The fruits were analyzed in the Laboratory of Science and Food Technology regarding to the contents of total soluble solids (TSS), in ºBrix, total titratable acidity (TTA), in % of malic acid, and vitamin C, in mg of ascorbic acid/100g pulp. The content of total soluble solids was measured with the use of a Brix refractometer. The total titratable acidity content was obtained by means of titration with NaOH 0.1 N, and the ascorbic acid content by using the method of Tillmans, with modifications. The analyses were accomplished in five samples, each sample constituted by nine fruits. The data were submitted to the analysis of variance, and for the analysis of stability the methodology described by Eberhart and Russell (1966) was used.

RESULTS AND DISCUSSION

Evaluation of fruits in successive harvests in different seasons

The characters evaluated in the fruits of the several genotypes, as well as the climatic conditions, varied according to the crop time. The summaries of the analyses of variance are presented in Table 1. It is observed that for all the variables studied, there was significance ($P < 0.01$) for genotypes, crop times and the interaction between them. The fact that the interaction has been significant suggests a differentiated behavior of the genotypes in relation to the different crop times. The low values of CV´s observed indicate good experimental precision.

The estimates of the environmental indexes and the averages observed in each crop time are presented in Table 2. According to Cruz and Regazzi (1997), positive values of the environmental index identify the favorable environments, considered by the breeders as areas with edaphic and climatic conditions adapted to the culture. Negative values identify the unfavorable environments, usually associated to areas of adverse edaphic and climatic conditions. It is observed that for the variable TSS, the crop times 1 and 2 have the highest averages and positive indexes, indicating to be the most favorable times for the increment of total soluble solids. The crop time 1 also was shown to be favorable for the obtaining of high vitamin C content, with positive index and the highest average. Among the climatic factors involved, stood out the highest mean temperature and sunlight, as well as the smallest precipitation in the crop time 2 (Table 3). The positive results obtained in the crop time 1 can be partly attributed to the storage of carbohydrates by the plant in the period of May to October, when there was no production of fruits. The smallest means observed for the variables TSS, TTA

Table 1. Summary of the analyses of variance for three traits evaluated from fruits of 12 genotypes of acerola harvested in three successive crop times

Sources of variation	df	Mean Square		
		TSS[1]	TTA	VC
Genotypes	11	6.1863**	1.2887**	747754.1604**
Crop Times	2	54.1681**	1.3184**	1609124.8233**
Genotypes x Crop Times	22	1.5313**	0.1337**	117180.6326**
Error	142	0.0036	0.0002	6076.4683
C.V. (%)		0.91	1.21	6.29
Mean		6.62	1.21	1239.68

[1]TSS: total soluble solids, in ºBrix; TTA: total titratable acidity, in % of malic acid and; VC: vitamin C, in mg ascorbic acid/100g pulp
** $P < 0.01$

Table 2. Means and environmental index values for three traits evaluated from fruits of 12 genotypes of acerola harvested in three successive crop times

Crop Times	TSS[1]		TTA		VC	
	Mean	Index	Mean	Index	Mean	Index
Nov-Dec/1999	7.42	0.81	1.37	0.16	1434.07	190.70
Jan-Feb/2000	6.83	0.22	1.18	-0.03	1180.10	-63.27
Mar-Apr/2000	5.58	-1.03	1.08	-0.13	1115.93	-127.44

[1]Coded as in the Table 1

Table 3. Climatic data from the weather station of Embrapa Cassava and Tropical Fruits

Crop Times	Period	Mean Temperature °C	Precipitation mm	Sunlight hours
1	Nov-Dec/1999	24.3	142.7	169.4
2	Jan-Feb/2000	25.4	69.2	222.4
3	Mar-Apr/2000	24.8	128.3	195.5

Table 4. Estimates of the parameters β_0 and β_1 of the regression model proposed by Eberhart and Russel (1966) for three traits evaluated from fruits of 12 genotypes of acerola harvested in three successive crop times

Genotype	Name	TSS[1]		TTA		VC	
		β_0	β_1	β_0	β_1	β_0	β_1
1	CMF002	6.2667	1.0012	0.8733	0.2217**	1059.4000	0.9589
2	CMF005	7.0533	1.0496*	1.6100	1.4614**	1541.0567	1.0452
3	CMF006	7.7067	1.4067**	1.6800	0.1652**	1567.2167	0.2933**
4	CMF017	6.5333	0.7342**	1.0567	1.8356**	1202.0667	1.1394
5	CMF022	6.0933	1.1046**	1.2967	2.3076**	1262.2000	2.5760**
6	CMF024	6.4000	0.5507**	1.1900	0.1301**	953.7333	0.4707**
7	CMF034	6.8667	0.5173**	0.9033	-0.3153**	957.6433	-0.3598**
8	CMF040	7.0267	1.3799**	1.0233	1.1935**	1093.1333	0.7803
9	CMF055	6.8133	0.7192**	0.8200	0.2830**	1128.1333	1.5262**
10	CMF111	7.2867	1.5043**	1.5300	2.3847**	1515.8667	1.2873*
11	CMF113	5.4800	1.1614**	1.1600	1.7248**	1206.7333	1.7956**
12	CMF144	5.8267	0.8710**	1.3767	0.6076**	1433.2000	0.4867**

[1]Coded as in the Table 1
** P < 0.01; * P < 0.05

and VC in the crop time 3 support this assumption, which could be partly a consequence of the depletion of the plant reserves. For the variable TTA, as the reduction of the acidity is desired, the crop time 3 was the most favorable having the smallest mean and negative environmental index.

In a statistical point of view, Eberhart and Russell (1966) consider that the ideal genotype should present high mean production (β_0), regression coefficient (β_1) equal to 1.00 and deviations of the regression (σ^2_D) as small as possible. It is observed in the Tables 4 and 5 that the genotype 3 presented high means for TSS (7.71 ºBrix) and VC (1567 mg/100g pulp), and specific adaptability to the favorable times (β_1>1) for these variables, but its disadvantage is to present high means for TTA (1.68% of malic acid), besides the verification of the low predictability of behavior ($\sigma^2_D \neq 0$) and the low values of R^2 (4.26 and 12.20%) for the variables TTA and VC. The genotypes 2 and 10 had similar behavior, high means for TSS (7.05 and 7.29 ºBrix) and VC (1541 and 1516 mg/100g pulp) and specific adaptability to the favorable times (β_1>1), except for the significance of β_1 in the variable VC of the genotype 2, that presented general adaptability. The genotype 2 presented low deviations of the regression and high R^2 (99.42%) for TSS, indicating good predictability of behavior. Both genotypes had high averages for TTA (1.61% and 1.53% of malic acid). It was observed that the genotypes 1,7 and 9 had the smallest averages for TTA (0.87, 0.90 and 0.82% of malic acid, respectively) and specific adaptability to the environments that favor the reduction of that variable, although the genotypes 1 and 7 have low predictability of behavior for that variable with low values of R^2, 16.26 and 51.42%, respectively.

Evaluation of fruits in successive years in the same season

The characteristics of the fruits varied among years, possibly influenced by variations in the climatic conditions, with influence also of the genotype. The summary of the analyses of variance is presented for the variables studied in Table 6. It is observed that the effects of genotypes, years and the interaction between them was highly significant (P < 0.01). The significant interaction

Table 5. Estimates of the variance deviations (σ^2_D) and the coefficients of determination (R^2) according to the regression model proposed by Eberhart e Russel (1966) for three traits evaluated from fruits of 12 genotypes of acerola harvested in three successive crop times

Genotype	Name	TSS[1]		TTA		VC	
			R^2 (%)	σ^2_D	R^2 (%)	σ^2_D	R^2 (%)
1	CMF002	0.0190**	98.89	0.0116**	16.26	18446.4125**	72.77
2	CMF005	0.0104**	99.42	0.0114**	89.51	12361.4102**	82.20
3	CMF006	0.0516**	98.52	0.0281**	4.26	34027.3790**	12.20
4	CMF017	0.7556**	55.68	0.0129**	92.26	3298.2520*	94.44
5	CMF022	0.0285**	98.65	0.0251**	90.68	10818.7231**	96.94
6	CMF024	0.4246**	55.68	0.0000[ns]	97.06	1953.0659	80.79
7	CMF034	0.2742**	63.16	0.0043**	51.42	2741.8352	66.02
8	CMF040	2.5190**	57.12	0.0195**	76.96	15030.9893**	68.21
9	CMF055	0.0805**	91.81	0.0005**	87.42	5302.3282*	95.42
10	CMF111	1.0473**	79.19	0.0058**	97.80	14751.5142**	85.60
11	CMF113	0.1081**	95.62	0.0036**	97.43	18665.4966**	90.26
12	CMF144	0.0741**	94.70	0.0403**	29.56	26891.0962**	32.45

[1]Coded as in the Table 1
** P < 0.01; * P < 0.05

Table 6. Summary of the analyses of variance for three traits evaluated from fruits of 13 genotypes of acerola harvested in three years

		Mean Square		
Sources of variation	df	TSS[1]	TTA	VC
Genotypes	12	6.6865**	1.0166**	1093573.9200**
Years	2	253.1836**	1.1328**	819294.7700**
Genotypes x years	24	5.5642** σ^2_D	0.1638**	642352.7900**
Error	156	0.0045	0.0002	3582.1400
C.V. (%)		0.7932	1.2109	4.4031
Mean		8.4631	1.2517	1359.2950

[1]Coded as in the Table 1
** P < 0.01; * P < 0.05

Table 7. Means of years and environmental index values for three traits evaluated from fruits of 13 genotypes of acerola harvested in three years

Years	TSS[1]		TTA		VC	
	Mean	Index	Mean	Index	Mean	Index
Nov/1999	7.4354	-1.0277	1.3554	0.1036	1378.5538	19.2585
Nov/2000	7.2154	-1.2477	1.1046	-0.1472	1238.6431	-120.6523
Nov/2001	10.7385	2.2754	1.2954	0.0436	1460.6892	101.3938

[1]Coded as in the Table 1

Table 8. Climatic data from the weather station of Embrapa Cassava and Tropical Fruits

Years	Period	Mean Temperature °C	Precipitation mm	Sunlight hours
1	Nov/1999	23.8	103.1	154.6
2	Nov/2000	24.9	121.9	207.0
3	Nov/2001	25.2	39.0	236.2

indicates the differentiated behavior of the genotypes in relation to the years of harvest. The experiment had good precision considering the low values of CV obtained.

The estimates of the environmental indexes and the averages observed in every year of harvest are presented in Table 7. It is observed that for the variables TSS and VC, the year 3 had the highest averages and positive index, indicating to be the most favorable year for the increment in the contents of total soluble solids and vitamin C, possibly influenced by the smallest precipitation and highest sunlight (Table 8). For the variable TTA, as the reduction of acidity is desirable, the year 2 was the most favorable by having the smallest average and negative environmental index, perhaps due to the highest precipitation, that may have caused a dilution of the juice present in the pulp.

It is observed in Tables 9 and 10 that for the variable TSS the genotype 11 presented the highest average (10.02 ºBrix), wide adaptability ($\beta_1 = 1$) and high predictability ($\sigma^2_D = 0$), being considered as the ideal genotype for that characteristic, but its disadvantage is presenting high average for TTA (1.57% of malic acid). For the other genotypes, values ranging from 7.33 to 8.84 ºBrix were found. The genotypes 8 and 9 had the smallest

Table 9. Estimates of the parameters β_0 and β_1 of the regression model proposed by Eberhart and Russel (1966) for three traits evaluated from fruits of 13 genotypes of acerola harvested in three successive years

Genotype	Name	TSS[1]		TTA		VC	
		β_0	β_1	β_0	β_1	β_0	β_1
1	CMF001	8.7200	1.3714*	1.2267	0.6836	1537.8200	-3.6327**
2	CMF002	7.8000	1.4246**	0.9367	0.7105	1243.0800	0.4592**
3	CMF005	8.7867	0.6158*	1.5067	3.0267	1361.5567	3.3668**
4	CMF006	8.8400	0.7926	1.4833	0.7727	1263.7667	2.9179**
5	CMF017	8.6667	0.9347	1.2567	1.4386	1845.8967	-3.4194**
6	CMF022	7.6933	1.0258	1.4133	2.4465	1419.7500	2.6062**
7	CMF030	7.3333	0.2016**	1.0633	0.1352	1054.2567	0.1888**
8	CMF031	8.2800	0.6524*	0.9400	-0.3706	967.8633	1.1549**
9	CMF034	8.0667	0.4824**	0.8400	-0.1144	955.8233	0.2727**
10	CMF040	8.5600	0.7960	1.0467	0.7154	1301.1300	-0.6494**
11	CMF111	10.0200	1.3206	1.5733	1.5358	1567.4333	2.7074**
12	CMF113	8.6933	1.8795**	1.4700	1.8183	1453.6967	0.8325**
13	CMF144	8.5600	1.5026**	1.5167	0.2017	1698.7667	6.1952**

[1]Coded as in the Table 1
** P < 0.01; * P < 0.05

Table 10. Estimates of the variance deviations (σ^2_D) and the coefficients of determination (R^2) according to the regression model proposed by Eberhart e Russel (1966) for three traits evaluated from fruits of 13 genotypes of acerola harvested in three successive years

Genotype	Name	TSS[1]		TTA		VC	
		σ^2_D	**R²** (%)	σ^2_D	**R²** (%)	σ^2_D	**R²** (%)
1	CMF001	0.7932*	94.8590	0.0004	97.1108	46182.0259**	87.6444
2	CMF002	0.8293*	95.0106	0.0139	55.3038	-492.7236**	95.9614
3	CMF005	0.0698	97.6614	0.0101	96.8731	168353.8208**	62.8275
4	CMF006	0.9073*	84.3458	0.0264	43.6549	114472.1377**	65.0748
5	CMF017	0.0203	99.6889	0.0007	98.9829	187656.7710**	61.0095
6	CMF022	0.3652	95.7253	0.0080	96.2287	137753.2042**	55.2874
7	CMF030	0.0291	91.3522	0.0078	7.3730	3738.5889**	16.7878
8	CMF031	0.6099	84.4442	0.0567	7.6694	19888.9794**	62.0010
9	CMF034	0.6128	74.7104	0.0049	8.3111	5270.4437**	23.8472
10	CMF040	0.4010	92.4711	0.0099	63.8232	6051.1212**	61.1015
11	CMF111	0.2961	97.8608	0.0794	50.4587	22198.3442**	88.9669
12	CMF113	0.4362	98.4365	0.1112	50.4795	15014.1811**	52.6227
13	CMF144	0.2114	98.8075	0.0391	3.4459	154467.3221**	86.1776

[1]Coded as in the Table 1
** P < 0.01; * P < 0.05

averages for TTA, although their predictability was low due to the low values of R^2 observed, 7.67 and 8.31%, respectively. For the variable VC, the genotypes 5, 13 and 11 had the highest values, 1845.90, 1698.77 and 1567.43 mg/100g pulp, respectively, so that the genotype 5 presented specific adaptability to unfavorable environments (β_1<1) and the genotypes 11 and 13 presented specific adaptability to favorable environments (β_1>1). The three genotypes had low predictability of behavior ($^{2}_{D}$ 0).

CONCLUSIONS

For the factor harvests in different seasons, all the evaluated genotypes have low stability for the characteristics TSS, TTA and VC, except the genotype CMF024 regarding TTA and VC and the genotype CMF034 for VC.

For the factor same season in successive years, the genotypes CMF001, CMF002 and CMF 006 form a group with smaller stability in relation to the TSS content in the fruits; with regard to TTA and VC content, all the evaluated genotypes have high and low stability, respectively.

Estabilidade fenotípica de genótipos de acerola avaliados em diferentes épocas

RESUMO - *Características da acerola referentes aos teores de sólidos solúveis totais (SST), acidez total titulável (ATT) e vitamina C (VC) estão diretamente ligadas à qualidade dos frutos, sendo influenciadas principalmente pelo genótipo e clima. Variações climáticas fazem com que os teores de SST, ATT e VC nos frutos não sejam constantes, de forma que eventualmente podem deixar de atender as exigências mínimas dos mercados consumidores. Este trabalho teve como objetivo avaliar a resposta diferencial de genótipos de acerola à variação das condições climáticas em frutos colhidos em três safras sucessivas em épocas diferentes e também na mesma época em anos consecutivos, mediante uma análise de estabilidade fenotípica. Em ambas as situações, foram observadas diferenças significativas entre os genótipos em relação à estabilidade nas três variáveis avaliadas em virtude de variações nas condições climáticas.*

Palavras-chave: *Malpighia emarginata* D.C., características do fruto, adaptabilidade.

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