FOLIAR NUTRIENT CONTENTS AND FRUIT YIELD IN CUSTARD APPLE PROGENIES

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ABSTRACT – Foliar nutrient contents are evaluated in several fruit trees with many objectives. Leaf analysis constitutes a way of evaluating the nutritional requirements of crops. Due to the positive impact that fertilizers have on crop yields, researchers frequently try to evaluate the correlations between yield and foliar nutrient contents. This work's objective was to present fruit yields from the 4th to the 6th cropping seasons, evaluate foliar nutrient contents (on the 5th cropping season), and estimate the correlations between these two groups of traits for 20 half-sibling custard apple tree progenies. The progenies were evaluated in a random block design with five replicates and four plants per plot. One hundred leaves were collected from the middle third of the canopy (in height) of each of four plants in each plot. The leaves were collected haphazardly, i.e., in a random manner, but without using a drawing mechanism. In the analysis of variance, the nutrient concentrations in the leaves from plants of each plot were represented by the average of four plants in the plot. Fruit yield in the various progenies did not depend on cropping season; progeny A4 was the most productive. No Spearman correlation was found between leaf nutrient concentrations and fruit yield. Increased nutrient concentrations in the leaves were progeny-dependent, i.e., with regard to Na (progenies FE5 and JG1), Ca (progeny A4), Mg (progeny SM7), N (progeny A3), P (progeny M), and K contents (progeny JG3). Spearman's correlation was negative between Na-Mg, Na-Ca, and Mg-P contents, and positive between Mg-Ca and N-K contents.

Key words: _Annona squamosa_ L., correlation, bullock's heart, sweetsop,

TEORES DE NUTRIENTES FOLIARES E RENDIMENTO DE FRUTOS DE PROGÊNIES DE PINHEIRAS

RESUMO – A avaliação dos teores foliares de nutrientes em várias fruteiras é feita com vários objetivos. A análise foliar seria uma forma de avaliar as necessidades nutricionais das culturas. Devido ao impacto positivo que os fertilizantes têm sobre o rendimento das culturas, procura-se avaliar as correlações entre o rendimento e os teores foliares de nutrientes. O presente trabalho tem como objetivo apresentar os rendimentos de frutos da 4ª. à 6ª. Safras, avaliar os teores de nutrientes foliares (na 5ª. Safra) e estimar as correlações entre esses dois grupos de características, em 20 progênies de meias-irmãs da pinheira. As progênies foram avaliadas no delineamento de blocos completos casualizados com cinco repetições. Cem folhas foram coletadas do terço mediano (em altura) da copa de cada uma das quatro plantas de cada parcela. As folhas foram coletadas a esmo, isto é, procurou-se ser aleatório sem utilizar-se mecanismo de sorteio. Na análise de variância, as concentrações de nutrientes das plantas de cada parcela foram representadas pela média das plantas da parcela. O rendimento de frutos das progênies foi independente da safra e a progênie A4 foi a mais produtiva. A correlação de Spearman não existiu entre as concentrações de nutrientes e o rendimento de frutos. A maior concentração dos nutrientes dependeu da progênie, isto é quanto aos teores de Na (progênies FE5 e JG1), Ca (progênie A4), Mg (progênie SM7), N (progênie A3), P (progênie M) e K (progênie JG3). A correlação de Spearman foi negativa entre os teores Na-Mg, Na-Ca e Mg-P, e positiva entre Mg-Ca e N-K.

Palavras-chave _Annona squamosa_ L., correlação, ateira.

INTRODUCTION

Irrigated fruticulture is probably the most important current agricultural activity in the Brazilian Northeast; however, it is based on the exploitation of a small number of species. Because of the small number of species exploited, fruit growers find it hard to retain labor and consequently become subject to market fluctuations and problems with diseases and pests that frequently appear in monoculture crops. Concerned with these problems, some fruit growing companies started to diversify their exploiting activities. In this diversifying process, among some species that were taken into consideration, custard apple trees (*Annona squamosa* L.) deserved special attention because of their adaptation to the Semi-Arid region and because their fruit are delicious and have a pleasant and exotic smell.

Foliar nutrient contents are evaluated in several fruit trees with many objectives. These include predictions on the variability that exists between plants (Souza et al., 1997), assessments of the influence of cultural practices on those contents (CARVALHO et al., 2001), and the identification of genotypic differences (GAZEL FILHO et al., 1994). Leaf analysis constitutes a way of evaluating the nutritional requirements of crops (SOUZA et al., 1997). Such studies have been conducted on several fruit trees, including apple (KAITH & AWASTHI, 1998), mango (Silva & Lima, 2001) and soursop trees (GAZEL FILHO et al., 1994), passion fruit vine (CARVALHO et al., 2001), and pineapple plants (Kar et al., 1992), but nothing was found in the consulted literature on custard apple trees. Due to the positive impact that fertilizers have on crop yields, researchers frequently try to evaluate the correlations between yield and foliar nutrient contents (ESTRADA et al., 1998).

There are genotypic differences with regard to the acquisition (ARÃO et al., 2003; MARSCHNER et al., 2007), assimilation (CABA et al., 1993), distribution (WU et al., 2007) and effectiveness in the use (GEORGE ET al., 2002; Inthapanya et al., 2000) of nutrients. Then there would be genotypic differences among custard apple tree progenies with regard to leaf nutrient contents. This hypothesis founds support in other research works. According to Lima *et al*. (2007), there were genotypic differences among leaf nutrient concentrations in Barbados cherry (*Malpighia emarginata* DC.) plants, although with some seasonal variations in such concentrations. Moreover, fruit yield, of course, must also depend on the plant nutrient content in order to generate correlation between fruit yield and leaf nutrient content, as has been evidenced in apple (SHARMA & BHANDARI, 1992). Finally, there are nutrient interactions in the plant (CHEN et al., 2007), a finding that stimulates to hypothesize that there exist correlations between nutrients inside the leaf tissues. This work tests the three hypotheses mentioned above.

This work's objectives was to present fruit yields from the 4th to the 6th cropping seasons, evaluate foliar nutrient contents (on the 5th cropping season), and estimate the correlations between these two groups of traits for 20 half-sibling custard apple tree progenies. Data on the yield and quality of fruits obtained in the first three cropping seasons have been presented by other authors (ANONYMOUS, 2007).

MATERIAL AND METHODS

The experiment was conducted at the “Rafael Fernandes” Experimental Farm (latitude 5° 11’S, longitude 37° 20’W, and 18m elevation). Data on the climatic conditions during the period when the experiment was conducted can be obtained from http://www.ufersa.edu.br

The progenies were obtained in home orchards in the municipal districts of Aracati-CE, Mossoró-RN, and Serra do Mel-RN. Based on plant health and vigor and their apparent fruit yield, 25 matrices were selected. The seeds were sown in black perforated plastic bags, 32 cm tall and 25 cm in diameter. The bags were filled with a substrate consisting of 1,800 L cattle manure, 3,600 L Red-Yellow Argisol (RYA) (EMBRAPA, 1999), 1,080 g potassium chloride, and 1,620 g single superphosphate. At 23 and 25 days after sowing, the seedlings received an application of the product Mastermins (with the following percentage contents: 14 N, 9 P2O5, 6 K2O, 08 S, 1.5 Mg, 2 Zn, 0.1 B, 1.5 Mn, and 0.05 Mo). Among the 25 progenies, 20 were selected based on their vigor.

The planting pits were opened in October/00, measuring 60 cm × 60 cm × 60 cm, at a spacing of 5.0 m × 4.5 m. The experimental soil was classified according to the Brazilian Soil Classification System as Argissolo Vermelho-Amarelo Eutrófico (EMBRAPA, 1999) and as a Ferric Lixisol according to the Soil Map of the World (FAO, 1988). Analysis of this soil showed the following results: pH = 6.6, Ca + Mg = 4.20 $cmol_c\ dm^{-3}$, P = 25mg dm^{-3}, K = 0.28 $cmol_c\ dm^{-3}$, Na = 0.07 $cmol_c\ dm^{-3}$, Al = 0.02 $cmol_c\ dm^{-3}$, and organic matter = 10.40 g kg^{-1}. Eighteen liters of rotted cattle manure, in addition to 240 g ammonium sulfate (80 kg N ha^{-1}), 2,340 g single superphosphate (80 kg P_2O_5 ha^{-1}) and 60 g potassium chloride (60 kg K_2O ha^{-1}) per pit were used as planting fertilization. The above-mentioned fertilization, with the exception of manure, was repeated on the twentieth of February, April, June, August and October, from 2001 to 2004.

The progenies were evaluated in a random block design with five replicates and four plants per plot, irrigated with a microsprinkler system**.** In characteristics evaluated for periods longer than a year, a split-plot design was adopted, with progenies considered as plots and annual cropping seasons as subplots. Each custard apple tree was associated with a microsprinkler placed near the stem, with a flow of approximately 50 L h^{-1}. Each plant received about 100 L water day^{-1}, 3 days a week. Due to water limitations, a greater amount of water could not be applied.

Fruit yield was evaluated during the 2004/05, 2005/06, and 2006/07 cropping seasons, that is, from the 4th to the 6th harvests, respectively. The fruits were harvested manually every two days, throughout the production period. Foliar nutrient contents were evaluated on the 5th cropping season. One hundred leaves were collected in March 2006 from the middle third of the canopy (in height) of each of four plants in each plot. The leaves were collected haphazardly, i.e., in a random manner, but without using a drawing mechanism. During collection, apparently adult, non-senescent leaves without signs of attack by diseases and pests were harvested. The leaves of each plant were analyzed for nutrient contents according to recommendations by EMBRAPA (1999).

The statistical analyses were performed using software GENES developed by Universidade Federal de Viçosa (CRUZ, 2006). The following model was adopted for characteristics evaluated in a single year: $Y_{ij} = \mu + G_i + B_j + E_{ij.}$ For characteristics evaluated during three years, the treatment design adopted consisted of split-plots. with random G and fixed A, according to the model $Y_{ijk} = \mu + B_j + G_i + (BG)_{ij} + A_k + GA_{ik} + E_{ijk.}$ In the analysis of variance, the nutrient concentrations in the leaves from plants of each plot were represented by the average of four plants in the plot. The means were compared at 5 % probability by Duncan test (1974). Spearman's coefficient of correlation was also calculated between the yield data (obtained for each cropping season) and the foliar nutrient data, as well as between individual nutrients. The values obtained for this coefficient were tested at 5% (CAMPOS, 1979).

RESULTS AND DISCUSSION

There was an effect of cropping seasons (S) and progenies (P), but no effect was observed for the S × P interaction on fruit yield (Table 1). Yield in cropping season 6 (4471 kg ha^{-1}) was higher than in cropping seasons 4 (3484 kg ha^{-1}) and 5 (1819 kg ha^{-1}). On average, cropping season 5 produced less than cropping season 4. The FJ2 progeny was the most productive, although without difference from progenies A2, A4, and FJ1. In the evaluation of the three initial cropping seasons, there was an effect of the S × P interaction and, in general, the most productive progenies were A3 and A4 (SILVA et al., 2007). Such discrepancy between results for the first three cropping seasons and for the last three cropping seasons indicates the importance of evaluating perennial plants for an extended number of years, so that the inference of conclusions can be done safely.

Table 1. Fruit yield at three cropping seasons of custard apple progenies.

	Fruit yield (kg ha^{-1})			
	Cropping seasons			
Progenies	Fourth	Fifth	Sixth	Means
M	1861	1052	2.981	1965 i
A2	3842	2043	5.698	3861 abc
A3	2768	2073	4.727	3190 defg
A4	4103	2343	5.725	4057 ab
A5	3437	2193	3.466	3032 fgh
A6	4037	2409	4.400	3615 bcd
FE1	3511	1071	3.986	2856 fgh
FE3	3215	1178	4.028	2807 gh
FE4	3613	1104	4.566	3094 fg
FE5	3551	2073	3.807	3144 efg
FJ1	4743	2172	4.916	3944 abc
FJ2	4455	2512	5.607	4191 a
JG1	3847	2154	4.863	3621 bcd
JG2	3917	1939	5.391	3749 bc
JG3	3283	1445	4.095	2941 fgh
JG4	2992	1423	4.808	3074 fg
SM1	2865	1199	3.688	2584 h
SM3	2131	1793	3.849	2590 h
SM7	3732	2409	4.556	3566 cde
SM8	3779	1800	4.262	3280 def
CV, %	CVa = 39; CVb = 55			

[1] Means followed by the same letter are not different from each other at 5% probability, by Duncan test.

[2] Source of progenies: M = city of Mossoró-RN; A = Ema Brandl's ranch, town of Aracati-CE; FE = UFERSA Experimental Farm, Mossoró-RN; FJ = Francisca Jales' ranch, Mossoró-RN; João Jerônimo's ranch, Mossoró-RN; SM = town of Serra do Mel-RN.

The highest foliar Na content means were obtained with progenies FE5 and JG1 (Table 2). As to the leaf contents of Ca, Mg, N, P, and K, the highest means were observed in progenies A4, SM7, A3, M, and JG3, respectively (Table 2). These genotypic differences regarding foliar nutrient concentrations were observed by other authors in perennial species such as soursop (GAZEL FILHO et al., 1994). In this fruit tree, however, which is an annonaceous plant, just like custard apple, there were differences between cultivars only with respect to Ca content. Variability in foliar nutrient contents also exists between Pêra orange plants (SOUZA et al., 1997).

Table 2. Foliar nutrient contents (in the beginning of second cropping season) of custard apple progenies.

	Foliar nutrients content					
	g kg^{-1}					
Progenies	Na	Ca	Mg	N	P	K
M	1.82 def	19.65 abc	7.24 abc	19.16 abc	0.412 a	7.32 bcdef
A2	2.66 abcdef	16.83 bcde	7.13 abc	16.87 bcd	0.287 cd	7.40 abcdef
A3	1.98 cdef	18.22 abcd	7.93 ab	20.20 a	0.328 abcd	8.92 ab
A4	1.98 cdef	23.30 a	6.78 abc	19.74 ab	0.305 bcd	5.91 f
A5	3.61 ab	16.04 bcde	6.85 abc	15.37 d	0.313 bcd	7.32 bcdef
A6	3.45 abc	19.78 abc	7.66 ab	16.87 bcd	0.296 cd	7.59 abcdef
FE1	1.74 def	19.67 abc	7.27 abc	18.41 abcd	0.289 cd	7.47 abcdef
FE3	3.00 abcde	16.34 bcde	6.74 bc	16.94 bcd	0.322 abcd	7.90 abcde
FE4	1.58 ef	16.85 bcde	7.77 ab	17.15 abcd	0.338 abcd	8.29 abc
FE5	3.91 a	15.84 bcde	5.94 c	16.80 bcd	0.341 abcd	7.70 abcde
FJ1	3.63 ab	14.06 cde	6.85 abc	19.04 abc	0.345 abcd	7.18 bcdef
FJ2	2.58 abcdef	13.03 de	6.56 bc	17.29 abcd	0.399 ab	7.35 bcdef
JG1	3.81 a	12.18 e	6.58 bc	16.52 cd	0.325 abcd	7.48 abcdef
JG2	2.09 bcdef	17.30 bcde	7.08 abc	18.83 abc	0.294 cd	7.88 abcde
JG3	3.33 abcd	15.29 cde	6.72 bc	18.90 abc	0.349 abcd	9.14 a
JG4	2.75 abcdef	16.50 bcde	7.02 abc	18.68 abc	0.283 cd	8.58 abc
SM1	2.40 abcdef	16.59 bcde	7.62 ab	17.01 bcd	0.340 abcd	6.13 ef
SM3	1.92 cdef	16.86 bcde	6.52 bc	18.13 abcd	0.378 abc	8.05 abcd
SM7	1.30 f	21.80 ab	8.20 a	17.25 abcd	0.251 d	6.99 cdef
SM8	2.40 abcdef	77.82 abcde	5.93 c	18.59 abc	0.342 abcd	6.43 def
CV, %	56	31	19	16	27	21

[1] Means followed by the same letter are not different from each other at 5% probability, by Duncan test.
[2] Source of progenies: M = city of Mossoró-RN; A = Ema Brandl's ranch, town of Aracati-CE; FE = UFERSA Experimental Farm, Mossoró-RN; FJ = Francisca Jales' ranch, Mossoró-RN; João Jerônimo's ranch, Mossoró-RN; SM = town of Serra do Mel-RN.

Although significant correlations do not necessarily indicate a cause and effect relationship, some Spearman's coefficient of correlation values obtained in the present work are worth noting (Table 3). There was a positive correlation between yields in the three cropping seasons, supporting the lack of a progenies × cropping seasons interaction. In other words, this indicates that the progenies' behavior was consistent in the three cropping seasons. There was no correlation between fruit yield and foliar nutrient concentrations in the progenies (Table 3). Various authors disagree with regard to the existence of correlation between leaf nutrients and fruit yield. A positive correlation was obtained in apple (SHARMA & BHANDARI, 1992), but not in mango trees (ESTRADA et al., 1998). May be this discrepancy is associated, at least in part, with the season during which the leaves are sampled, as observed in passion fruit vine (CARVALHO et al., 2001) and pineapple (KAR et al., 1992). In fact, it seems unlikely that a correlation will always exist between the yield of fruits produced almost throughout the year in irrigated perennial crops, and concentrations of leaf nutrients, evaluated at a given season of the year. This is true especially considering the great environmental influence that affects foliar nutrient contents (CARVALHO et al., 2001; KAITH & AWASTHI, 1998).

Table 3. Spearman's coefficient of correlation between fruit yield in three cropping seasons (fourth, fifth and sixth) and foliar nutrient contents in the fifth cropping season, for 20 custard apple progenies.

Traits	RPS	RSS	RTS	Na	Mg	Ca	N	P	K
Yield in fourth cropping season (RPS)	-	0.66*	0.71*	0.27	-0.13	-0.18	-0.10	-0.18	-0.38
Yield in fifth cropping season (RSS)	-	-	0.46*	0.33	-0.11	-0.07	-0.20	-0.15	-0.34
Yield in sixth cropping season (RTS)	-	-	-	0.02	0.03	-0.03	0.25	-0.32	-0.02
Na content	-	-	-	-	-0.50*	-0.71*	-0.43	0.11	0.09
Mg content	-	-	-	-	-	0.53*	0.12	-0.47*	0.02
Ca content	-	-	-	-	-	-	0.35	-0.38	-0.22
N content	-	-	-	-	-	-	-	0.22	0.57*
P content	-	-	-	-	-	-	-	-	0.02

* Significant at 5% probability

There was a negative relationship between Na content and Mg and Ca contents (Table 3). The correlation between Mg and P contents was also negative, but the correlations between Mg and Ca and between N and K were positive (Table 3). The interactions between leaf nutrients also observed by other authors (CARVALHO et al., 2001; MELGAR et al., 2006) vary with crop development stage (LIU et al., 2003), nutrient type, plant part, and genotype (Zhang et al., 2002). These interactions would be the result of interactions in the absorption and translocation of nutrients (LIU et al., 2003) and other processes such as retranslocation and effectiveness in the use of nutrients by the plant. For example, in the case of the interaction between Na and Ca, the effect of Ca on Na would mainly occur by preventing sodium translocation and not restricting its absorption (MELGAR et al., 2006).

CONCLUSIONS

Fruit yield in the various progenies did not depend on cropping season; progeny A4 was the most productive. No Spearman correlation was found between leaf nutrient concentrations and fruit yield. Increased nutrient concentrations in the leaves were progeny-dependent, i.e., with regard to Na (progenies FE5 and JG1), Ca (progeny A4), Mg (progeny SM7), N (progeny A3), P (progeny M), and K contents (progeny JG3). Spearman's correlation was negative between Na-Mg, Na-Ca, and Mg-P contents, and positive between Mg-Ca and N-K contents.

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