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GENETIC VARIABILITY OF ECONOMIC CHARACTERS IN 30 ACCESSIONS OF CUBIU (*Solanum sessiliflorum* DUNAL, SOLANACEAE) EVALUATED IN CENTRAL AMAZONIA

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ABSTRACT

Thirty accessions of cubiu (*Solanum sessiliflorum* Dunal) from the National Research Institute for Amazonia improvement program were evaluated in a completely randomized block design, with two repetitions, near Manaus. Fruit dimensions (longitudinal and transverse diameters, weight and quality characteristics (juice and Brix) and yield (number and total weight of fruits) were evaluated. The ratio of the error variance to the genetic variance among accessions confirms cubiu's autogamous habit. Heritability was shown to be high for fruit dimensions and intermediate for yield and Brix, indicating that selection can be fairly effective in the improvement of these traits.

INTRODUCTION

The cubiu (*Solanum sessiliflorum* Dunal), also called 'cocona' in Peru and Colombia, 'tupiro' in Colombia and Venezuela and 'orinoco apple' or peach-tomato in English, is native to western Amazonia, where it was domesticated by pre-Colombian Native Americans (Schultes, 1984). It is well adapted to the stressful edapho-climatic conditions of Amazonia (poor soils, high temperature and ample rainfall) and offers potential for modern agriculture in the region (Pahlen, 1977). Its fruit can be consumed fresh or in numerous culinary forms, both at home and industrially processed (Pahlen, 1977; Salick, 1989). The pulp has an agreeable flavor and is rich in iron (1.5 mg/100 g)

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and niacin (2.3 mg/100 g) (INN, 1945). This list of useful features made it an important domesticated plan in western Amazonia, but it's importance and use has diminished since pre-Colombian times.

Noda *et al.* (1991) report that cubiu is most commonly found as a subspontaneous crop and tolerated weed, which raises concern about genetic erosion in its domesticated populations. The introduction of the sour lime (*Citrus aurantifolia*) and tomato (*Lycopersicon esculentum*) appear to have contributed to this decline, because of the similarity of uses. Salick (1989) hypothesizes a general temperate zone bias since European contact with the Americas has also contributed strongly to this decline. The cubiu's evident potential and worries about genetic erosion of its pre-Colombian diversity are the main reasons that the National Research Institute for Amazonia (INPA) has taken an interest in this crop (Pahlen *et al.*, 1979; Noda *et al.*, 1984).

The INPA has studied cubiu since 1975 and currently maintains a collection with more than 50 accessions, collected from diverse areas of Brazil, Colombia and Peru. Pahlen (1977) developed and evaluated the early part of the collection and found significant variability and high heritability for fruit size and shape and for the presence of anthocianin in the stem. Unfortunately, much of this material was lost during the early 1980's when Brazil's scientific budget shrank.

Silva Filho *et al.* (1989) evaluated 12 accessions and Silva Filho *et al.* (1990) studied the relationship among the fruit characters of these 12 accessions. Estimated yields of 105 t/ha of edible pulp are significantly higher than previous estimates, though only organic matter and a light N dressing (as urea) was used. We report here on the genetic variability of another 30 accessions.

MATERIAL AND METHODS

Thirty accessions from diverse areas of cubiu's pre-Colombian and modern distribution (Figure 1) were sown at INPA's Vegetable Crops Research Station, km 14 AM 010, in Manaus, on a low nutrient, sandy textured, red-yellow podzol, in May 1988, with a final harvest in February 1989. The regional climatic type is "Afi", in Köppen's scheme, with 2,455 mm rainfall and 26°C temperature as yearly averages, and a dry season from July to September (Ribeiro, 1976). The seeds were sown in a germination bed previously treated with methyl bromide. One month later the seedlings were transplanted to polyethylene bags (1 kg) and after another month into the field at 1 x 1 mm spacing. The planting pits received 1 kg of organic compost. Fifteen days later, 10 g of ureia (45% N: 45 kg N/ha) were applied as a dressing around each plant, repeated at 15 day intervals for the first three months (total N: 270 kg/ha). A randomized complete block, with four repetitions and three plants/plot was sown, but two repetitions were lost when the irrigation system broke down during the dry season.

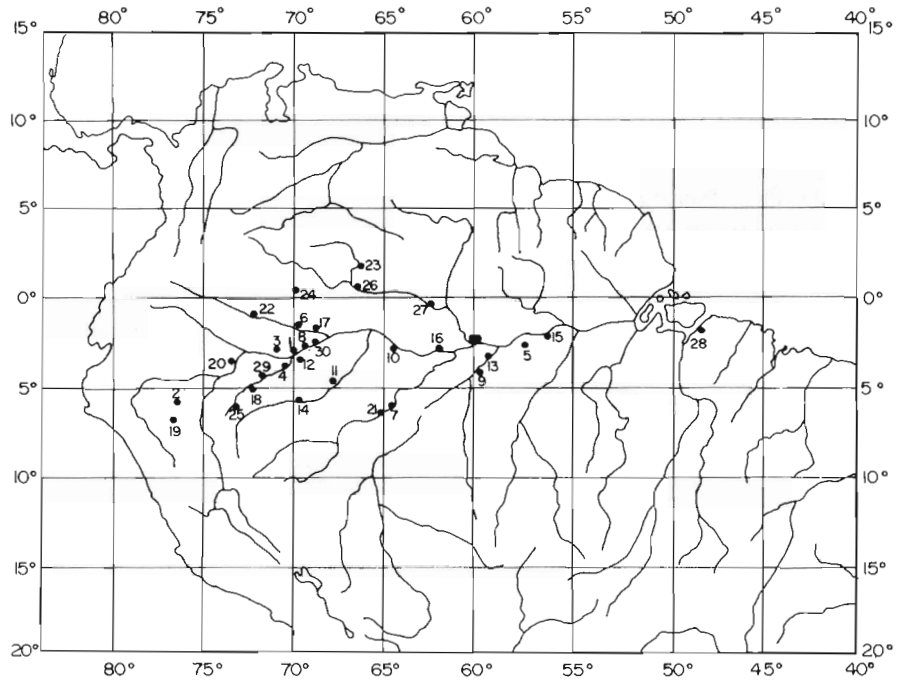

Figure 1 - Geographic origin of the 30 accessions of cubiu (*Solanum sessiliflorum*) evaluated at INPA, Manaus, in 1988-89: 1. Letícia (Colombia); 2. Yurimaguas (Peru); 3. Arara (Colombia); 4. Atalaia do Norte; 5. Ponta Alegre; 6. Ipiranga; 7. Canutama; 8. Umariaçu; 9. Borba; 10. Tefé; 11. Carnari; 12. Benjamin Constant; 13. Nova Olinda; 14. Eirunepé; 15. Parintins; 16. Coari; 17. Betânia; 18. Estirão do Equador; 19. Tarapoto (Peru); 20. Iquitos (Peru); 21. Lábrea; 22. Putamayo; 23. Cucuí; 24. Vila Bitencourt; 25. Palmeiras; 26. São Gabriel da Cachoeira; 27. Barcelos; 28. Belém; 29. Mayuruna (Peru); 30. São Paulo de Olivença.

The following fruit characters were measured on a randomly chosen sample of 10 fruits/plot: maximum fruit transverse and longitudinal diameters (mm); fruit weight (g); juice volume (ml) extracted from the locular cavity; total soluble solids (Brix) of the locular juice measured with a manual refractometer. The total fruit number and total fruit weight were evaluated until fruiting declined.

The variation observed was tabulated and graphed and then submitted to an analysis of variance. The magnitudes of the genetic parameters were estimated following Vencovsky (1987) and the broadsense heritability following Hanson *et al.* (1956), as outlined in Table I. The coefficients of genetic variation (Cvg) and experimental variation (CVe) were estimated from the following formulas (Vencovsky, 1987):

$$CVg = (\sqrt{\sigma_g^2} / \bar{x}) * 100$$

where σ_g^2 is the genetic variance and $\bar{x}$ is the experimental mean;

$$CVe = [\sqrt{(\sigma_d^2 + \sigma_e^2)} / \bar{x}] * 100$$

where σ_d^2 is the variance among individuals of the same progeny within plots; σ_e^2 is the plot-to-plot environmental variance response to environment and $\bar{x}$ is the overall mean.

Table I - Mathematical expectations for the mean squares [E(MS)] derived from the analysis of variance (Vencovsky, 1987).

Source of variation	g.l.	M.S.	E(MS)
Blocks	1 - (r-1)	-	-
Progenies	29 - (s-1)	MS_1	$\sigma_d^2 + n\sigma_e^2 + nr\sigma_g^2$
Error	29 - (r-1) (s-1)	MS_2	$\sigma_d^2 + n\sigma_e^2$
Within progenies	120 - [rs(n-1)]	MS_3	σ_d^2

$h^2_{(broad)} = \sigma_g^2 / (\sigma_d^2 + \sigma_e^2 + \sigma_g^2)$

r - no. blocks; s - no. of progeny (accessions); n - no. individuals/plot; σ_d^2 - variance between individuals of the same progeny within plots; σ_e^2 - plot-to-plot environmental variance; σ_g^2 - genetic variance among progenies; σ_p^2 - phenotypic variance - $\sigma_d^2 + \sigma_e^2 + \sigma_g^2$; broad-sense heritability - σ_g^2 / σ_p^2 (Hanson *et al.*, 1956).

RESULTS AND DISCUSSION

Experimental means are presented in Table II and frequency distributions of accession means are presented in Figure 2 (A-F) for each character evaluated. The estimated yields observed in this experiment were somewhat below those observed by Pahlen (1977), Silva Filho *et al.* (1989), and Salick (1989), probably because of the problems with the irrigation equipment that resulted in the total loss of two repetitions of the experiment (this also contributed to the high experimental CVs). Nonetheless, the maximum yield estimated was 32 t/ha, well above most fruit and vegetable crop yields in Central Amazonia.

The biomodal distribution of yield in Figure 2 is further examined in Figure 3. There are clearly two groups of accessions with distinct yield behaviors. This is not due

Table II - Experimental means, with standard deviations (SD), coefficients of variation, minimum and maximum observations, for each character evaluated in the 30 accessions of cubiu (*Solanum sessiliflorum*).

	Fruit			Juice volume	Degree	Fruit	Total weight
	Length cm	Width cm	Weight g	ml	Brix	number	kg
Mean	5.4	5.8	112.6	14.6	4.8	25.5	2.4
SD	1.2	1.5	66.5	7.9	0.5	12.4	0.7
CV	22.2	25.0	59.1	53.8	10.2	48.7	28.3
Min	3.6	3.3	26.2	4.1	3.6	12.5	1.5
Max	8.3	8.3	289.4	39.1	5.8	66.5	3.2

simply to higher or lower fruit numbers with larger or smaller fruit, as might be expected by the negative correlation (r = -0.47) between fruit number and fruit weight (Figure 3A). Some accessions have large fruit, but low yields, while others have large fruit and high yields (Figure 3B). The same is true for fruit number (Figure 3C).

The estimates of the genetic parameters and ratios are presented in Table III. The variance ratio σ_d^2/σ_g^2 were extremely low, except "Brix" which was estimated as 1.03. A low ratio suggests autogamy (Giannotti *et al.*, 1982; Vastano, 1984) and confirms previous observation on cubiu's autogamous habit (e.g. Pahlen, 1977; Salick, 1989). This contrasts with Storti (1988) who suggested a high degree of allogamy in cubiu, based upon floral biology and experiments with self and cross pollination.

The very high broad-sense heritabilities for fruit dimensions (Table III) confirm Pahlen's (1977) observations. They are also expected if Salick's (1989) hypothesis of maternal inheritance of fruit size and shape is true. Salick studied a 7x7 complete diallel cross and observed that the maternal characteristic was conserved regardless of the characteristics of the pollen parent.

Because one of the yield components (fruit weight) has a high heritability, yield has a moderate heritability under the agronomic conditions used (not especially favorable). Fruit number, the other component of yield, has a medium broad-sense heritability, as is common in most crops.

Pahlen (1977) had reported on cubiu's maintenance of fruit size under extremely variable agronomic conditions, not commonly observed in most crops. The low h^2 for fruit number suggests that cubiu maintains its fruit size under extreme environmental

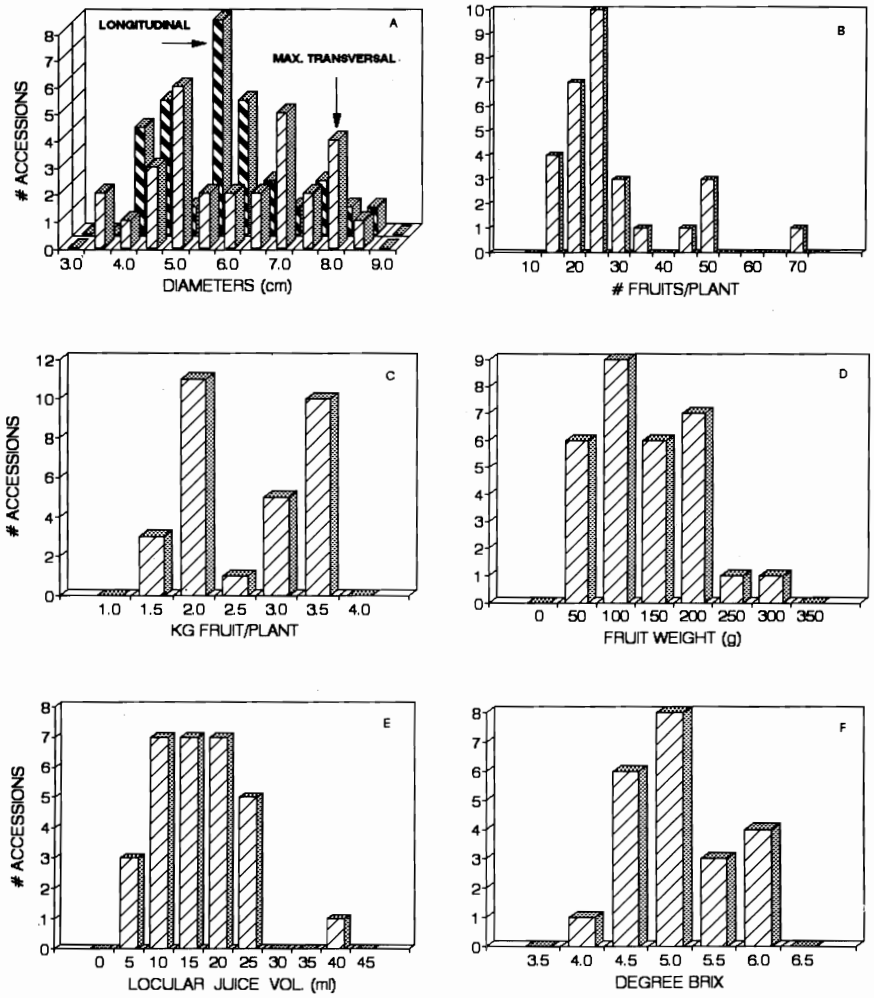

Figure 2 - Frequencies of the means of 30 accessions of cubiu (*Solanum sessiliflorum*) evaluated in Central Amazonia. (A) Maximum longitudinal and transverse diameters (cm); (B) number of fruits per plant; (C) yield as kg fruit/plant; (D) fruit weight (g); (E) volume of locular juice (ml); (F) degree Brix.

variation by partitioning photosynthesates to fewer fruit, while each fruit receives enough to attain its full genetic expression. The moderate heritability for yield and the high heritability for fruit weight, combined with the moderate to high genetic coefficients of variation, should allow for rapid improvement under selection.

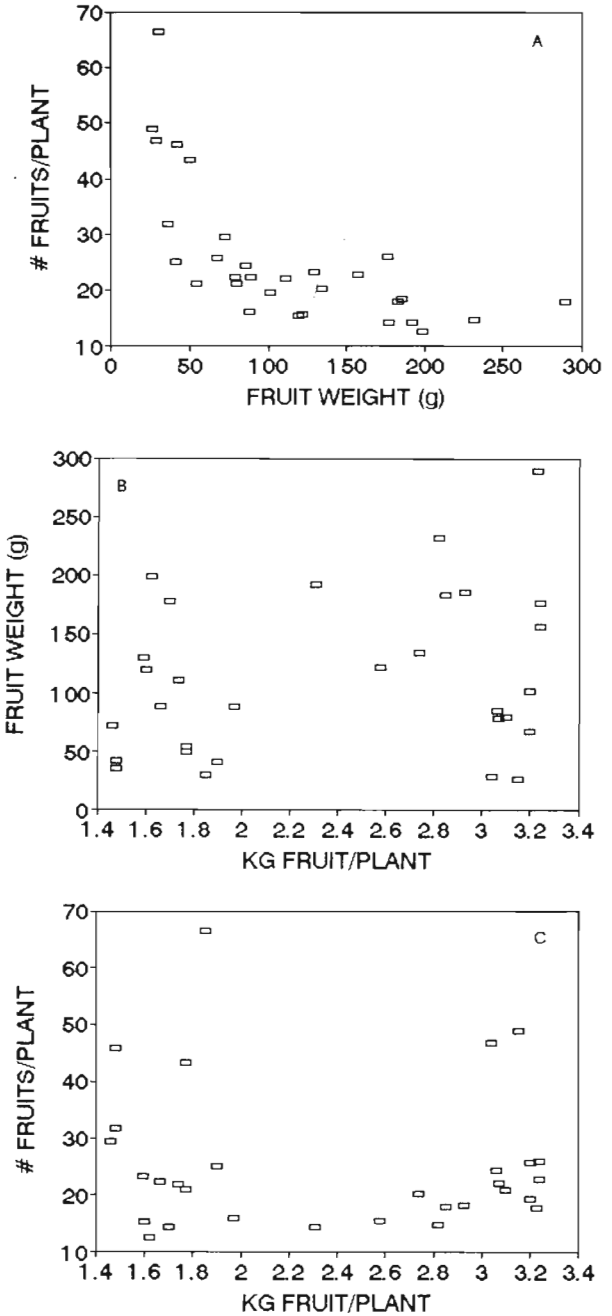

Figure 3 - The relationships between yield and its components. (A) number of fruit/plant with weight (g); (B) fruit weight with yield; (C) number of fruit/plant with yield.

Table III - Estimates of the variances obtained by decomposition of the ANOVA following Vencovsky (1987), with estimates of genetic and experimental coefficients of variation, broad-sense heritabilities (Hanson *et al.*, 1956) and the ratio σ_d^2/σ_g^2.

Characters	Variances			C.V.		h^2	σ_d^2/σ_g^2
	d	e	g	g	e		
Long. diam.	0.165	0.123	1.412	21.95	7.80	0.93	0.12
Max. tra. diam.	0.187	0.064	2.106	25.01	18.72	0.97	0.09
Fruit weight	513.337	384.314	4300.302	58.24	20.93	0.95	0.12
Juice volume	13.445	8.545	57.430	51.96	24.75	0.92	0.23
Degree Brix	0.175	0.091	0.170	8.58	8.06	0.74	1.03
No. fruits	57.628	103.856	97.659	38.77	43.52	0.69	0.59
Kg fruit/pl.	0.342	0.298	0.650	35.68	28.42	0.81	0.53

RESUMO

O cubiu (*Solanum sessiliflorum* Dunal) foi domesticado pelos Ameríndios pré-Colombianos na Amazônia ocidental. Quase esquecido até recentemente, sua produtividade potencial e sabor agradável têm chamado a atenção da pesquisa na Amazônia e em outras áreas nas últimas décadas. Trinta introduções do programa de melhoramento genético do Instituto Nacional de Pesquisa da Amazônia foram avaliadas num desenho de blocos inteiramente casualizados, com duas repetições, perto de Manaus. As dimensões (diâmetro longitudinal e transversal (mm), peso (g)) e caracteres de qualidade (suco (ml), Brix) dos frutos, e a produtividade (número e peso total dos frutos) foram avaliadas. A razão da variância entre plantas dentro das parcelas à variância genética entre introduções confirma o hábito autógamo do cubiu. As dimensões dos frutos apresentaram herdabilidades altas, enquanto a produtividade e o Brix foram medianos. Ganhos expressivos no programa de melhoramento com este material podem ser esperados.

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