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Multivariate analysis on dry mass variables in cupuassu progenies (*Theobroma grandiflorum*) in function of the plant age

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The aims of this study was to evaluate the dry matter production in different parts of cupuassu plant (*Theobroma grandiflorum*), such as leaves, stems, primary and secondary branches in progenies resistant to pests and diseases (Codajás and Manacapuru) in function of the plant age, through the application of multivariate statistical analysis. The experiment was conducted at Embrapa Amazônia Oriental for a period of four years, in a randomized design. Samples were taken of five trees of each progeny, resulting in a total of 40 plants, which were separated into leaves, stems, primary and secondary branches. In each group of variables, the assumptions of canonical correlation analysis were tested, such as multivariate normal, the homoscedasticity deviations, multicollinearity, linearity in the dry mass of plant parts and correlation matrices that test the significance of the experimental data. Plants of PMI186 and PMI215 showed significant canonical correlations between the most variable groups of leaves, stems, primary branches and secondary branches, indicating that the groups are not considered independent, showing a linear relationship between them. In the dry matter of leaves, stems, primary and secondary branches index showed a high degree of significance for the Pearson test when related to parts of cupuassu plants. The largest production of total dry matter was obtained in PMI186 with 4332.92 g plant^{-1} in secondary branches (4th year) and the lowest production showed in PMI215 with 4086.26 g plant^{-1} in the secondary branch (4th year).

Key words: Linear relationships, vegetative growth, cluster analysis.

INTRODUCTION

The cupuassu plant (*Theobroma grandiflorum*) shows social and economic importance in the state of Pará, especially in family farming in areas that has been improving their farms, with the introduction of consortium systems with other fruit trees, or through the introduction of agro-forestry systems involving planting a tree species, such as mahogany intercropped with cupuassu and other fruit trees (Vieira et al., 2007). The introduction of tree species in future shows as selling wood and seeds, while cupuassu plant are included as part of the system, enabling farmers to have the economic profitability in the short term, while the timber species is in vegetative development, producing shading for cupuassu (Vieira et al., 2007). In addition of high economic and social importance in the Amazon region, there is little research on the agronomic performance of cupuassu, limiting the expansion of the cultivated area in the region (Alfaia and Ayres, 2004). The plant has high potential, with average fruit yield around 16.8 and 13.1 fruits plant^{-1} for the PMI Codajás and PMI Manacapuru cultivars, respectively (Alves and Cruz, 2003). As a result of most soils in which the plantations are established in the Amazon region having low fertility (Vale Júnior et al., 2011), a research that takes into account this situation is needed to be carried out.

A proper mineral nutrition of cupuassu plants is critical to maintaining a vigorous growth and increase fruit yield (Ayres and Alfaia, 2007), since successive harvests, without the replacement of nutrients, promote soil depletion, resulting in low soil fertility, thus, decreasing the supply of nutrients to the culture. Although there are limitations due to the influence of other factors, unresolved, these influence the production, such as genetic (Alves et al., 2010), incidence of pests (Thomazini, 2002) and diseases (Alves et al., 2009), farmers whose economic activity with the cupuassu recognize the importance of fertilization to increase productivity, but find the problem of lack of research to enable the recommendation of agronomically correct and economically viable rates. Most of the information used for cupuassu cultivation comes from studies of cocoa by the proximity taxonomy of these plants (Alfaia and Ayres, 2004). However, this situation is reversed with fertilization and liming recommendations for the management of cupuassu plant (Viégas et al., 2010).

For the mass production of dry of cupuassu there is little information about which part of the plant could be used in order to study new mechanisms that relies not only on fruits to obtain any information about the plant nutrition, since although the study of the fruit is important, as well as accumulation and exportation of nutrients by fruit, it is important to report that it is not always possible to obtain this type of plant material on the occasion of not having control in the study of possible loss of fruit during the experiment period, such as stealing fruit.

Multivariate statistics in this evaluation process of dry matter production in the cupuassu progenies is an important tool in data analysis. The multivariate statistical consists of set of statistical methods allowing the confrontation of several variables of each sample element simultaneously. The technique aims to simplify or facilitate the interpretation of the phenomenon studied and its development has enabled the accurate study of complex phenomena, used in order to construct alternative indexes or variables and groups of sampling elements, analyze the dependence relationship of the variables and compare populations (Bakke et al., 2008).

The aims of this study was to evaluate the dry matter production in different parts of cupuassu plant, such as leaves, stems, primary and secondary branches in progenies resistant to pests and diseases (Codajás and Manacapurú) in function of the plant age, through the application of multivariate statistical analysis.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in Belém city, State of Pará, Brazil, in the Embrapa Amazônia Oriental, with coordinates 48° 26’ 55’’ and 48° 26’ 40’’ Latitude (North-South) and 01° 26’ 30’’ and 01° 26’ 10’’ Longitude (East-West) of Greenwich. The climate, according to Köppen classification, is the type Afi, characterized by being hot and humid, with annual average temperature of 26.7°C, relative humidity of 80% and average annual rainfall of 3,001 mm (Bastos et al., 2002).

Area preparation for planting

At the beginning of 2002 until the year 2003, soils were prepared with pit fertilizers, organic manure and coverered with triple superphosphate, castor bean, potassium chloride, urea, limestone and fertilizer with micronutrients (g plant^{-1}). In the experimental area, mowing and harrowing was practiced.

Study area

The area has 4300 m^2 with PMI186 (Codajás) and PMI215 (Manacapurú) progenies of cupuassu planted in alternating rows, with banana as temporary shading and açaí as permanent shade. The study was carried out during the four years, with annual evaluations of five plants of each progeny, totaling 40 plants.

Planting system

The planting system used was the cupuassu consortium with banana, açaí and mahogany. The cupuassu presented spacing of 5.0 × 5.0 m, the banana with 2.5 × 2.5 m and açaí with 5.0 × 5.0 m. Mahogany was located only on the sides of the experiment.

Plant material evaluations

The plant material used in the evaluations were leaves, stems, primary and secondary branches of half-brothers of cupuassu

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Table 1. Chemical characterization of soil before the implementation of the experiment, in the year of 2002.

Site	Depth (cm)	pH (H_2O)	P	K	Ca	Mg	Al
			-----mg dm^{-3}------		----------- $cmol_c$ dm^{-3}----------		
Yellow Latosol	0-20	4.3	4.0	19.0	0.4	0.2	0.8

progenies (PMI 186: Codajás; PMI 215: Manacapurú), from the Embrapa Amazônia Oriental.

Collection of plant material and determination of dry matter

Plant samples were collected from each cupuassu progeny (PMI186; PMI215) in the experimental area of Embrapa Amazônia Oriental, during the four years (2004 to 2007). The collected material was dried in a forced-air oven at 70°C and weighed on a digital scale to determine the dry mass of leaves, stems, primary and secondary branches.

Collection and determination of soil analysis

The soil of the experimental area was classified as Yellow Latosol (Embrapa, 2013). In the areas of cupuassu plants, two samplings were carried out, the first at the beginning of the experimental implementation in 2002, and the second during the conduct of the study in 2005. The soil sampling was performed at a depth of 0 to 20 cm (Tables 1 and 2) and then submitted to the laboratory for subsequent chemical analysis of the soil according to the methodology described by Embrapa (2009).

Experimental design

The experimental design was completely randomized in a factorial triple, 2 × 4 × 5, so specified: two half-brothers of cupuassu progenies (PMI186: Codajás; PMI215: Manacapurú); four years of evaluation (2004, 2005, 2006, 2007); five vegetative parts of cupuassu evaluated [leaves (F), stems (C), the primary branches (RP), secondary branches (RS) and total dry matter (MST)], with 5 replications, totaling 40 experimental units, in which each experimental unit consisted of one plant of each progenies.

Data analysis

Initially, the assumptions of canonical correlation analysis were tested in each of the groups of variables, in the following order, multivariate normality, homoscedasticity of standard deviations, multicollinearity and linearity. Multivariate normality was measured by the Box Plot software (Mingoti, 2005); while the homogeneity of variances was made by check scatter diagrams and outliers (deviations > +5 or < -5) (Corrar et al., 2009), measured in Microsoft Office Excel 2007 spreadsheets; multicollinearity was calculated through the condition number (Montgomery and Peck, 1981), eliminating variables until getting the low degree of multicollinearity; linearity significance was calculated by the Pearson correlation coefficient, eliminating variables that showed no significant correlation coefficient or showed low correlation ($r < |0,3|$) (Carvalho et al., 2004), both by using the SPSS Statistics 17.0 software (Corrar et al., 2009). In the canonical correlation analysis were related in neighboring groups, that is, Group 1 with Group 2 and the Group 3, thus, consecutively. When a group showed significant canonical correlation to be related to the neighboring group, this has been correlated to the nearest second group etc. The canonical correlation analysis was performed by using SPSS Statistics 17.0 software (Corrar et al., 2009). The data were submitted to analysis of multivariate variance, Box plot figures and dendogram, selecting the variables leaves, stems, primary branches, secondary branches, and total dry mass in two half-brothers cupuassu progenies (PMI186: Codajás; PMI215: Manacapurú) (Silva et al., 2013).

RESULTS AND DISCUSSION

Multivariate analysis of variance

Table 3 shows a significant ordinal interaction, which carried out an assessment on both independent variables, such as X_{11}; X_{21}; X_{31}; X_{41}; X_{51}; X_{62}; X_{72}; X_{82}; X_{92} and X_{102} that showed significant main effects when considered simultaneously with the X_1 (A: PMI186 - Codajás) and X_2 groups (B: PMI215 - Manacapurú). Table 1 shows the results of the multivariate analysis of variance for the main purpose of X_1 and X_2 as well as the tests for the interaction effects, characterized significance for dependent variables, PMI186 (X_1) and PMI215 (X_2). The dependent variables X_1 (PMI186) and X_2 (PMI215) have significant impact (main effect) of the ten variables of the plant parts, both together as separately, according to the multivariate test. The impact of the ten independent variables resulted in the formation of combined groups, in which the multivariate model follows its normal size, both quadratic form as linear, but always explaining that two functions were formed that justified the formation of the canonical functions, dendograms and distance Euclidean two-dimension and correlations.

During the comparison of the dependent variable with any independent variable, the size of the effect attributable to the study the interaction effect (progeny*year*plant parts) is large, therefore, application of multivariate testing is possible. Thus, the effect of the difference between variables was the dry mass of each progeny produced, in which the PMI186 justifies the hypothesis of the study due to more productivity and which required larger amount of total dry mass in the leaves (FAT) with 3768.62 g $plant^{-1}$; 1666.44 g $plant^{-1}$ of total stem (CAT); 3017.02 g $plant^{-1}$ of total primary branch (RPAT); 4442.92 g $plant^{-1}$ of total secondary branch (RSAT); 12785.00 g $plant^{-1}$ of total dry matter (MSTA), compared to PMI215 which showed values of total dry mass in the leaves (FBT) of 3646.64 g $plant^{-1}$; 2183.82 g $plant^{-1}$ of total stem (CBT); 2634.28 g $plant^{-1}$ of total primary branch (RPBT); 4086.26 g $plant^{-1}$ of total secondary branch (RSBT); 12551.00 g $plant^{-1}$ of total dry

Table 2. Chemical and particle size characterization during the experimental period, in the year of 2005.

Site	Depth cm	Granulometry (g kg^{-1})			
		Coarse sand	Fine sand	Silt	Clay
PMI186	0-20	605	265	31	100
PMI215	0-20	649	231	41	80

Site	Depth	pH	OM	P	K	Na	Ca	Mg	Al	H+Al
	cm	H_2O	g kg^{-1}	---- mg dm^{-3}----		---- cmol$_c$ dm^{-3}----				
PMI186	0-20	4.2	8.36	193	49	16	0.8	0.5	0.9	3.96
PMI215	0-20	4.0	8.91	206	61	21	1.0	0.7	1.1	5.45

Table 3. Multivariate Analysis of variance of the results of measurements of plant parts: leaves (F), stem (CA), primary branches (RP), secondary branches (RS) and total dry matter (MST) (X_{11}; X_{21}; X_{31}; X_{41}; X_{51}; X_{62}; X_{72}; X_{82}; X_{92}; X_{102}) to X_1 group (A = PMI186: Codajás) and X_2 group (B = PMI215: Manacapurú).

Independent variable	Combined groups (PMI186*PMI215*age)	Sum of squares	df	Mean square	Sig.
X_{11} (FA)	Linear	119475.64	2	59737.82	**
	Quadratic	46.976.76	1	46976.76	**
X_{21} (CA)	Linear	47451.38	2	23725.69	**
	Quadratic	1575.27	1	1575.27	**
X_{31} (RPA)	Linear	10607.11	2	5303.56	**
	Quadratic	27.40	1	27.40	**
X_{41} (RSA)	Linear	482268.35	2	241134.17	**
	Quadratic	1672.35	1	1672.35	**
X_{51} (MSTA)	Linear	95054.12	2	47527.06	**
	Quadratic	87225.04	1	87225.04	**
X_{62} (FB)	Linear	15354.36	2	7677.18	**
	Quadratic	2834.32	1	2834.32	**
X_{72} (CB)	Linear	22630.60	2	11315.30	**
	Quadratic	17977.15	1	17977.15	**
X_{82} (RPB)	Linear	17300.48	2	8650.24	**
	Quadratic	2657.38	1	2657.38	**
X_{92} (RSB)	Linear	237009.68	2	118504.84	**
	Quadratic	906.80	1	906.80	**
X_{102} (MSTB)	Linear	78546.94	2	39273.47	**
	Quadratic	38206.52	1	38206.52	**

matter (MSTB). The results obtained in this study are in agreement with Alves and Cruz (2003) who in studies with cupuassu progenies observed that the Codajás (PMI186) showed higher production of fruits than the

Manacapurú (PMI215).

In studies with *Eucalyptus grandis* presenting age of 4.3 years were founded values of 3047.53 g plant^{-1} dry mass of stems; 2475.00 g plant^{-1} dry mass of leaves; 2182.10 g plant^{-1} dry mass branches (Bellote et al., 1980). Compared to progeny cupuassu, PMI186 and PMI215, dry mass value was lower, featuring their quality probably attributed to greater leaf area of cupuassu plant, which promoted increments in the production of assimilates and plant biomass accumulation (Nunes et al., 2013).

Correlation matrices of PMI186 (Codajás) and PMI215 (Manacapurú)

To the values of the correlation matrices of PMI186 (Codajás) and PMI215 (Manacapurú) observed a high correlation index (≥ 0.90) between the indicators (Table 4), enabling visualization of the explanatory power of the factors (MSF; MSC; MSRP; MSRS and MST) in each of the variables analyzed. These factors are represented by values (1.00) founded on the main diagonal which are indicated by colors, in which the pink color characterizes the correlations of parts of cupuassu with the PMI186, and green colors characterize the parts of cupuassu with the PMI215, while colors isolated demonstrate the interrelationships between the progeny and parts of plant (RPA*FB), (RPA*RPB) and (RPB*FB). The results obtained of the interrelationships between progeny and parts of plant observed a well-adjusted correlation, in which the adjustment explains that primary branch of PMI186 with the leaf PMI215 (RPA*FB); primary branch of PMI186 with primary branch of PMI215 (RPA*RPB); primary branch of PMI215 with a leaf of the same progeny (RPB*FB) showed increments of dry matter, a fact that, probably, is related to constant releases of leaves and branches by cupuassu plant. In the present study were not observed values lower than 0.50 in the correlation matrix, which is considered that a small data measurement (Corrar et al., 2009) should be removed from the analysis.

The values obtained in this study are above 0.90 and considered ideal for the analysis, thus, without removing any variable statistical context, enabling high power of explanation of indicators, taking into account all factors obtained (commonalities).

Scores of the dry mass of cupuassu progenies in relation to two canonical variables

To obtain a satisfactory interpretation of the variability manifested among Progenies *Parts of plant* years it would be necessary that the first two canonical variables allow a minimum estimate of 80% of the total variance contained in the data set, and in this study the two canonical variables were explained for about 99.33% of the variance (Table 5). By using the scores of the first and second canonical variable Figure 1 was obtained with two-dimensional display (model of Euclidean distance) of PMI's analyzed. The dispersion allowed the separation of the progenies in groups with parts of interrelated plants in the years 1, 2, 3 and 4, providing a strategy to select the progeny and plant part of this divergent progeny used to quantify the contribution of dry matter accumulation.

Model of Euclidean distance of dry matter production

Figure 1 shows the selection of significant variables constituting part of a factor, selected based on the magnitude of factor loadings. Initially, a cutoff point was adopted, considering only the loads above 0.50. Subsequently, the significant variables were selected and chosen to the factor loadings of greater value. Later, this process was made to Figure 1, in which the observed Factor 1 showed two significant loads, and the Factor 2 showed eight loads. In the Factor 1, secondary branch of PMI186 (RSA) and secondary branch of PMI215 (RSB), both with positive signs, demonstrating the occurrence of variation, showed consistency with the dry matter production process [4332.92 g plant^{-1} of RSA in the 4th year (PMI 186); 4086.26 g plant^{-1} of RSB in the 4th year (PMI 215)]. The increase in the secondary branch provided an increase in dry matter yield of the progenies 186 (Codajás) and 215 (Manacapurú), possibly, due to increased formation of conducting vessels, which directly influenced the plant production capacity, with greater expressiveness in PMI186. In Factor 2, the progeny 186 and 215 of cupuassu, the variables (CB, RPA, CA, RPB, FA, FB) showed the better adjustment in the same quadrant, and away from Factor 1, which means that the isolation of Factor 2 has a higher power of explanation in comparison to Factor 1, by having a greater involvement on the dry mass production. Although its effects are visible when comparing high-yielding progenies, thus, the PMI186 showed higher production of total dry matter compared to progeny PMI215, during the trial period of four years. The difference in yield of progenies is related to genetics of plant and its nutrient absorption capacity of the soil.

Dendogram of Ward's clustering method

The average distance of Mahalanobis between progenies and their plant parts (F, C, RP, RS, MST) according to the age (D^2=5.3) was used as a criterion for the formation of groups, as well as applied to bean cultivars (Cargnelutti Filho et al., 2009). By dendogram information shown in Figure 1, the formation of three groups was observed, the first group consisted RPA, FB and RPB, the second group consisted MSTA and MSTB, while the third group consisted the variables CB, FA, CA, RSA and RSB.

Table 4. Matrix of correlation between the half-brothers progenies of PMI186 (Codajás) and PMI215 (Manacapurú) of cupuassu plant (*Theobroma grandiflorum*), according to the age.

	FA	CA	RPA	RSA	MSTA	FB	CB	RPB	RSB	MSTB
FA	-	0.99	0.99	0.96	0.99	0.99	0.98	0.99	0.97	0.99
CA	0.99	-	0.99	0.93	0.98	0.99	0.97	0.99	0.95	0.98
RPA	0.99	0.99	-	0.97	0.99	1.00	0.99	1.00	0.98	0.99
RSA	0.96	0.93	0.97	-	0.98	0.97	0.98	0.97	0.99	0.98
MSTA	0.99	0.98	0.99	0.98	-	0.99	0.99	0.99	0.99	0.99
FB	0.99	0.99	1.00	0.97	0.99	-	0.99	1.00	0.98	0.99
CB	0.98	0.97	0.99	0.98	0.99	0.99	-	0.99	0.99	0.99
RPB	0.99	0.99	1.00	0.97	0.99	1.00	0.99	-	0.98	0.99
RSB	0.97	0.95	0.98	0.99	0.99	0.98	0.99	0.98	-	0.99
MSTB	0.99	0.98	0.99	0.98	0.99	0.99	0.99	0.99	0.99	-

FA (Leaves of PMI186); CA (stem of PMI186); RPA (primary branches of PMI186); RSA (secondary branches of PMI186); MSTA (total dry matter of PMI186); FB (Leaves of PMI215); CB (stem of PMI215); RPB (primary branches of PMI215); RSB (secondary branches of PMI215); MSTB (total dry matter of PMI215).

Table 5. Scores of the dry mass of progenies cupuaçu (*Theobroma grandiflorum*) for the two canonical variables obtained in the evaluation of dissimilarity of PMI186 and PMI215 with plant parts, according to the age.

Progenies*Plant parts*Years	Canonical variables	
	1°	2°
FA	0.4142	-0.1062
CA	1.2014	-0.0980
RPA	0.7225	-0.0495
RSA	0.3833	0.3142
MSTA	-2.8664	0.0286
FB	0.4704	-0.1088
CB	1.0429	-0.0386
RPB	0.8578	-0.0696
RSB	0.4330	0.2102
MSTB	-2.6599	-0.0824
Variance (%)	98.36	99.33
Accumulated variance (%)	98.36	99.33

The MSTA and MSTB access (GII) highlights compared to the others showing increased production of dry matter, due to the total dry weight of the progeny A (PMI 186) and progeny B (PMI 215) is the sum of leaves (F), stems (C), primary branches (RP) and secondary (SR) within each progeny. The total dry mass of the PMI186 corresponds to a production of 486.78 g plant^{-1} (1th year), 1214.68 g plant^{-1} (2th year), 5080.71 g plant^{-1} (3th year), 12785.00 g plant^{-1} (4th year), while PMI215 obtained a production in total dry mass of 610.18 g plant^{-1} (1th year), 1847.16 g plant^{-1} (2th year), 4799.36 g plant^{-1} (3th year), 12164.54 g plant^{-1} (4th year).

The first group (GI), which corresponds to RPA (primary branch of PMI186), FB (leaf of PMI215) and RPB (primary branch of PMI215) showed the order of placement due the similarities between them (Figure 2), such as the total dry matter production, the GI showed increase from the second year, checking that the RPA showed an increase of 429.54 g plant^{-1} (1th year) to 3017.02 g plant^{-1} (4th year); the variable FB showed the same tendency of dry matter increase from the second year with values of 677.12 g plant^{-1} reaching values in the fourth year of 1688.04 g plant^{-1}; RPB showed higher dry matter yield in the second year (461.08 g plant^{-1}) until the fourth year (2634.28 g plant^{-1}).

The third group (GIII) of dendrogram consisting CB, FA, CA, RSA, RSB showed a satisfactory level of explanation that the positions on the same set (Figure 2), due to the

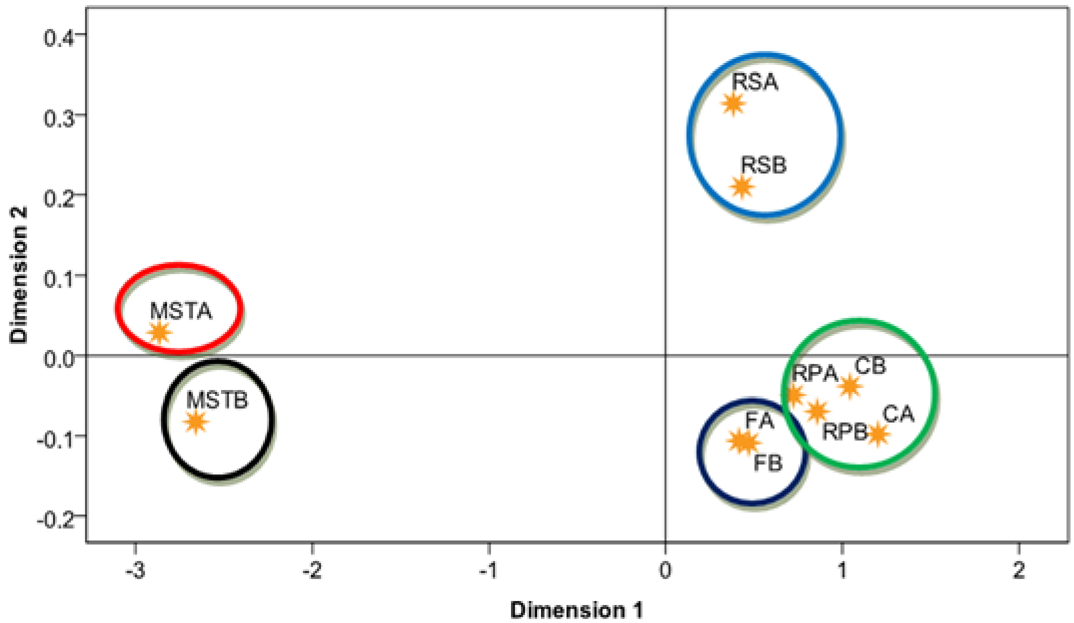

Figure 1. Euclidean distance model of the dry mass production (g kg^{-1}) of PMI186 (Codajás) and PMI215 (Manacapurú) in cupuassu plant (*Theobroma grandiflorum*), according to the age.

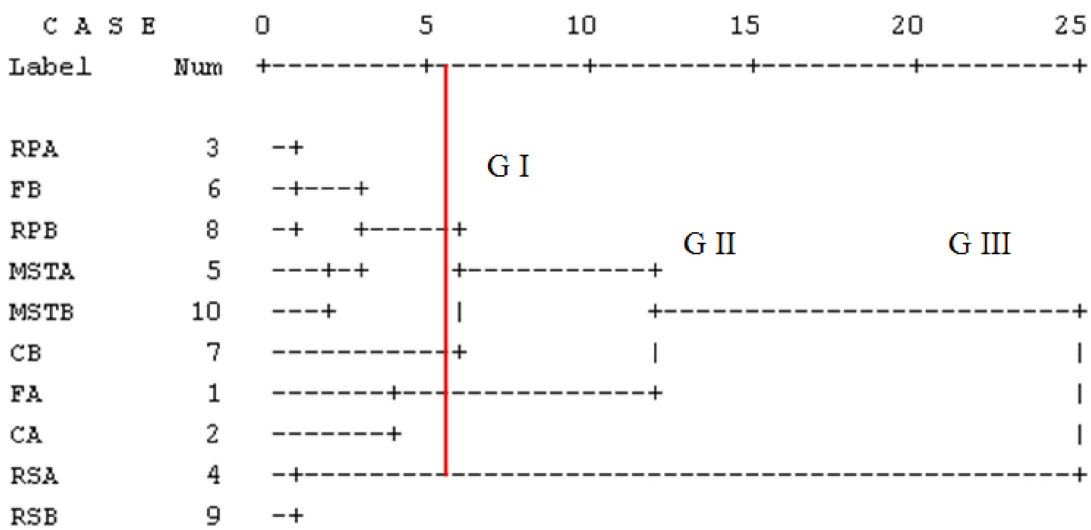

Figure 2. Dendogram of Ward's clustering method, obtained in two half-brothers progeny (A, B) of cupuassu plant (*Theobroma grandiflorum*), PMI186 and PMI215, according to age, from the Mahalanobis distance with parts of the plant (F, C, RP, RS, MST).

variables from the second year present a dry matter yield more than five times compared to any components of cupuassu plants, such as FA in the second year which were of 396.14 g $plant^{-1}$ and the fourth year of 3768.62 g $plant^{-1}$; CA in the second year were of 304.02 g $planta^{-1}$ and the fourth year of 1666.44 g $planta^{-1}$; RSA in the second year were of 84.98 g $planta^{-1}$ and the fourth year 4332.92 g $planta^{-1}$; CB in the second year were 501.52 g $planta^{-1}$ and the fourth year 2183.82 g $planta^{-1}$; and RSB in the second year were of 207.32 g $planta^{-1}$ and the fourth year 4086.26 g $planta^{-1}$.

The formation of three groups was due to the characteristics already mentioned which indicate the similarity between the variables. The formation of two

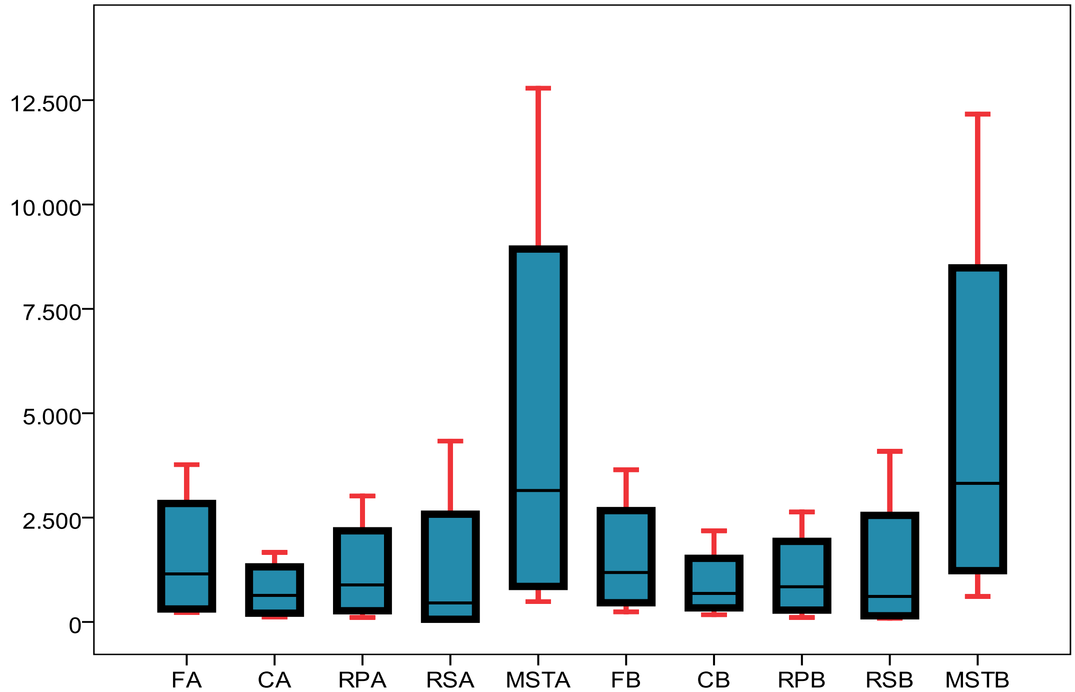

Figure 3. Box plot of dry mass production (g kg^{-1}) in cupuassu plant (*Theobroma grandiflorum*), PMI186 and PMI215, according to the age.

groups obtained in this study are consistent with those obtained by Bento et al. (2007), in a study of phenotypic variability in *Capsium annum*, that observed differences in the number of groups formed. In this study, the formation of groups constituted to multicategoric data related to Years*Progeny*Plant parts, while for Sudré et al. (2006) characterized the collection of data as multicategoric practice to demand less time in the studies with pepper and chili.

Box plot of dry matter production

Figure 3 shows the box plot analysis of PMI186 (Codajás) and PMI215 (Manacapurú) cupuassu of plants, which represents the degree of variation between the groups (FA, CA, RPA, RSA, MSTA, FB, CB, RPB, RSB and MSTB) for a qualitative or categorical variable (PMI186 or PMI215), therefore, the length of the box and its extensions describe the variation of the data within each progeny. The information obtained, found that PMI186 showed the highest amount of MST compared to PMI215, the same happened to other variables, except CA and CB which were lower in the two PMIs, during the four years of study. All variables dry mass obtained different values, in which variations were observed between them in relation to the total dry mass in the PMI186 of 486.78 g $plant^{-1}$ of MSTA (1th year), 1214.68 g $plant^{-1}$ of MSTA (2th year), 5080.71 g $plant^{-1}$ of MSTA (3th year), 12785.00 g $plant^{-1}$ of MSTA (4th year), which was higher than the total dry matter in the PMI215 of 610.18 g $plant^{-1}$ of MSTB (1th year), 1847.16 g $plant^{-1}$ of MSTB (2th year), 4799.36 g $plant^{-1}$ of MSTB (3th year), 12164.54 g $plant^{-1}$ of MSTB (4th year). The difference in values reinforces the justification that has differences in the absorption of nutrients provided by the genetic trait of progenies.

The PMI186 showed higher dry biomass compared to PMI215. The largest biomass plant was promoted by greater photosynthesis capacity and production photoassimilates, providing greater accumulation of biomass therefore, higher level of carbon was absorbed due to the ease in capturing light and assimilate production, which allows a higher flow of carbohydrates in the root system in which a part is stored in nutrition and accumulated in reserve structures (vesicles type) in formation with mycorrhiza and the other is accumulated in the plant storage tissues, in the form of reserve substance (Ozdemir et al., 2010).

The PMI186 progeny showed a higher stem mass compared to the PMI215. Probably because the system in which the PMIs were conducted during the four years of study was characterized by being an intercropping system with other fruit trees, together with occurring successive incorporations of plant materials at the time of falling leaves and branches originating from the

Table 6. Estimate of Pearson correlation coefficient of the Progenies*Plant parts*Years between dry matter production variables in PMI186 (A) leaves (FA), stems (CA), primary branches (RPA), secondary branches (RSA), total dry matter (MSTA) and dry matter in PMI215 (B) leaves (FB), stems (CB), the primary branches (RPB), secondary branches (SBR), total dry mass (MSTB) of cupuassu (*Theobroma grandiflorum*), according to the age.

	FA	CA	RPA	RSA	MSTA	FB	CB	RPB
FA	-	0.99**	0.99**	0.96*	0.99**	0.99**	0.98*	0.99**
CA	0.99**	-	0.99**	0.93ns	0.96*	0.99*	0.97*	0.99*
RPA	0.99**	0.99**	-	0.97*	0.99**	1.00**	0.99**	1.00**
RSA	0.96*	0.93*	0.97*	-	0.98*	0.97*	0.98*	0.97*
MSTA	0.99**	0.98*	0.99**	0.98*	-	0.99**	0.99**	0.99**
FB	0.99**	0.99*	1.00**	0.97*	0.99**	-	0.99**	1.00**
CB	0.98*	0.97*	0.99**	0.98*	0.99**	0.99**	-	0.99**
RPB	0.99**	0.99**	1.00**	0.97*	0.99**	1.00**	0.99**	-
RSB	0.97*	0.95*	0.98*	0.99**	0.99*	0.98*	0.99*	0.98*
MSTB	0.99*	0.98*	0.99**	0.98*	0.99**	0.99**	0.99**	0.99**

**: significant ($p \leq 0.01$); *: significant ($p \leq 0.05$); ^{ns}: not significant ($p > 0.05$) by the t test.

cultivation, which allowed the cycling of plant material, it is a beneficial process to the cultivation system for providing the plants a nutrient reserve and soil friability, and facilitating the exchange of elements, allowing the root system to present good development, thereby, improving the uptake of water and nutrients.

Pearson correlation

The Pearson correlation presented in Table 6 shows the effects of PMI186 (Codajás) and PMI215 (Manacapurú) presenting a statistical difference between the PMIs, probably, by plants showing distinctive vegetative structure on the dry matter production in its components (leaves, stems, primary and secondary branches), as well as the size of the sum of this material for intercropping conditions with other fruits, such as açaí and banana plants. In order to understand the interactions between the components with their respective PMIs analyzed, the Pearson correlation test was analyzed, a positive correlation (+) indicated very strong PMI186 with their respective components, as leaves (FA), stems (CA) primary branches (RP) and secondary branches (RS). The positive correlation occurred in all PMIs, except for the correlation between CA and RSA that was not significant, possibly, this occurred because the dry matter intake did not have much difference during the four years of the study. Unfortunately, there are no parameter studies which serve to explain these results, but in accordance with the field observations and laboratory production of dry matter there was no difference in stem and secondary branch.

The Pearson correlation is considered in the analysis as a very strong correlation (+) and almost perfect, when their values are above 0.92, which occurred in this study. The degree of perfection is very characteristic when plant parts relate to each other, thus, when the value reaches 1.00, which means that their explanatory power is at 100%. In Table 6, the explanatory power is not 100% for all parameters, but their fit is almost perfect, meaning that the analysis is correct and that these interactions exist because the plants originate from the same mother, but there is no knowledge of who the father is. The father of knowledge would enable a good understanding of certain parameters, such as FB*CA which correlate very well, probably, due to the ability of a plant, compared to another, to produce more dry matter in plant tissues, without affecting production. Similar results were founded by Locatelli et al. (2001) in the consortium of Brazil nuts and cupuassu.

Conclusion

The progeny PMI186 (Codajás) obtained the highest production of dry matter compared to PMI215 (Manacapurú). The largest production of total dry matter occurred in 2007, in which the PMI186 progeny (Codajás) had the highest production of dry matter, with 4332.92 g plant^{-1} in the primary branch (in the year of 2007), while PMI215 progeny provided a production of 4086.26 g plant^{-1} of dry matter in the primary branch.

Conflict of interests

The authors have not declared any conflict of interests.

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