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Phenotypic Description and Discrimination of Some Early-Bearing Cacao (Theobroma Cacao L.) Genotypes Using Pod and Bean Traits

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Abstract: *Crop improvement procedures are usually heralded by genetic variability studies among relevant species. Nine early fruiting cacao genotypes from Owena, South-West Nigeria were analysed using a sampling unit of five uniformly ripe pods (fruits) from each of three replications (5x3=15). Seventeen quantitative data from the fruits and beans were subjected to analysis. Significant (P≤0.05) variability was shown by these genotypes. High broad sense heritability (Hbs) was observed in time to fruit harvest (97.22), fruit weight (82.02) and beans weight after fermentation (80.19). The genotypic coefficient of variation: phenotypic coefficient of variation (GCV: PCV) ratio was high for most of the traits. The high GCV: PCV ratios ranged from 69.05 (number of beans per row) to 98.69 (time to fruit harvest). The first principal component axis explained 45.18% of the total variation, while the first three axes accounted for 79.12% of the total variation. Significant genetic variation exists among these cacao genotypes. Both the pod and bean traits were important descriptors for the classification of cacao genotypes.*
Keywords*: Pod index, GCV: PCV ratio, eigen value.*

I. Introduction

Adequate variability within a species can provide genetic buffer for their survival in the face of unfavourable conditions (Adewale et al., 2014). This goes in tandem with the fact that the maintenance of sustainable and productive yield is the utmost challenge in crop production. The production capacity of cocoa could be greatly enhanced by generating high quality hybrids for increased cultivation (Gotsch 1997). The use of improved planting materials with good yield and quality potentials is necessary for a sustainable cocoa production system. This should guarantee good yield per unit area, timeliness in fruiting and the profitability of the venture. This has been a long term target in Nigeria (Oyedokun et al., 2011). Global environmental and climatic fluctuations have been a major scourge in agricultural productivity, with the weaker species and varieties being on the negative end of reception.

Sufficient significant genetic diversity in the cocoa genetic resources has been observed by Aikpokpodion (2010) in field genebanks and farmers' fields. These available genetic resources could serve as a good insurance against any threat posed by unfavourable environments to cocoa cultivation and production. Though genomic profiling of genetic diversity is considered more reliable in the characterization of cocoa (Aikpokpodion et al., 2009), phenotypic traits with high heritability are still useful for cacao germplasm characterization (Lachenaud and Oliver, 2005 and Bekele et al,.(2006)

Cascading on the achievements of the Cocoa Research Institute of Nigeria (CRIN) which previously generated hybrids of cocoa from some selected parents in a breeding programme, the evaluation of the offspring produced by these hybrids for some pod and bean values became necessary to understand variation among them. In this study some pod and bean phenotypic descriptors were used for a multivariate characterization of the early bearing F1 generation produced by some of the hybrid population to understand the diversity that exists among these offspring. This study gives up-to-date information on the diversity status of the genotypes being investigated. It also throws more light on the inherent genetic potentials in these genotypes for subsequent selection and further improvement.

II. Materials And Methods

Nineteen (19) newly generated hybrids were established at two different cocoa agro-ecologies: Ibadan, Oyo State and Owena, Ondo State, Nigeria in July, 2012. Sixty (60) individual seedlings were established per genotype as ten (10) seedlings per plot in three (3) replications in a Randomized Complete Block Design (RCBD) at each of the two locations. Nine of these nineteen hybrids were found to have fruited early in Owena, with harvest occurring from 24 through 28 months of field establishment. These nine early bearing genotypes were selected and subjected to the current study. The list of the nine genotypes and their pedigree is shown in Table 1. Five uniformly matured and ripe cocoa pods were harvested per genotype in each replication, giving a total of fifteen pods (fruits) per genotype. The time to fruit harvest (being the time of fruit maturation) was recorded in weeks. Each fruit was weighed, and the fruit length and girth measured using a vernier calliper. The fruits were carefully broken and pod husk thickness was estimated as the difference between the outer (ridge to ridge) and the inner diameter of the fresh pod husk using the venier calliper. The number of rows, number of beans per row and number of beans per pod was counted and the weight of the beans was recorded per fruit, while the weight of one individual bean was recorded as the average of the weight of ten beans randomly selected per fruit. The beans from each fruit were extracted and fermented in trays. The beans were weighed after fermentation, and the weight recorded per fruit, and per individual bean as the average of ten fermented beans weighed. The fermented beans were sun-dried, and the pod value recorded as the weight of the total dried beans obtained per fruit. The weight of one dried bean was also recorded as the average of the weight of ten dried bean per fruit. Dried bean length and girth were recorded by as an average of the values of ten dried beans using the vernier calliper. Pod index was inferred from the weight of dried beans from each pod as the number of pods required to produce one kilogramme of dry cocoa beans. The means from the sampling unit per genotype were subjected to analysis of variance (ANOVA) to estimate the variability among the genotypes while the means were separated using Duncan Multiple Range Test. Broad sense heritability for each trait was calculated as the ratio of the genotypic variance to the phenotypic variance.

Means were obtained for each genotype across the three replications for the seventeen parameters, resulting in a 9 x 17 basic multivariate data matrix. The data was standardised (mean = 0; standard deviation = 1) to eliminate the effects of the different scales of measurements among the parameters. The resulting product was subjected to Principal Component (PC) Analysis as well as a Single Linkage Cluster Analysis (SLCA) in the Statistical Analysis System, SAS-V9.2 (SAS Institute Inc., 2007). The PC Analysis produced an eigen vector for each PC axis, while a dendrogram was produced for the SLCA. The character loading was used to determine the genotype component scores.

III. Results

The mean scores of the variance components and the coefficients of variation for seventeen (17) characters among the nine cacao genotypes are presented in table 2. Significant ($P \leq 0.05$) genotypic variation existed among the nine hybrids for fruit length, number of rows, weight of beans per fruit, fresh weight of one bean, weight of one bean after fermentation, pod value, dry bean length and pod index. Significant ($P \leq 0.01$) genotypic variation also existed for time to fruit harvest, fruit weight and weight of beans (per fruit) after fermentation. The blocking effect showed significant ($P \leq 0.05$) variation only for time to fruit harvest (6.67). The highest coefficient of variation was observed for fruit girth (19.94) and pod thickness (19.25).

The separation of the means for the seventeen characters discriminating among the nine genotypes is presented in table 3. Genotypes AxJ had the highest mean (119.53a) for time to fruit harvest, while genotypes CxK had the least (106.40e). For fruit length, hybrid AxK had the highest mean (192.29a) while hybrid FxJ had the least (160.64c). Genotype GxH had the highest mean for beans weight per fruit (141.76a), while genotype CxK had the least (109.23c). Genotype GxH had the highest mean for weight of one bean (3.91a), weight of beans after fermentation (118.56a), weight of one bean after fermentation (2.8a), one dry bean weight (1.30a), dry bean length (23.10a) and dry bean girth (12.39a). Genotype CxK had the least means for beans weight after fermentation (85.25e) and weight of one bean after fermentation (1.98c). Genotype CxK also had some of the least means for weight of one bean (2.47bc), pod value (37.79b), one dry bean weight (1.08b), dry bean length (21.78b) and dry bean girth (12.17ab). Genotypes FxJ had the highest pod index (28.59a) while genotypes AxJ had the least (20.72c). Genotypes AxJ and GxH stand out as having the highest means for pod value (48.58a and 47.43a respectively).

Some estimates of genetic variability of seventeen (17) agronomic, fruit and bean traits of the nine cacao genotypes are presented in table 4. Characters that exhibited high broad sense heritability included time to fruit harvest (97.22), fruit weight (82.03) and beans weight after fermentation (80.19). Characters also with reasonable broad sense heritability ranged between 60.38 (pod index) and 69.92 (beans weight per fruit). The poorest values for heritability was observed among fruit girth (1.04), pod thickness (2.70), number of beans per fruit (11.36), one dry bean weight (31.25) and dry bean girth (40.15). In all the seventeen characters, the genotypic coefficients of variation (GCV) were lower than the phenotypic coefficients of variation (PCV). The least of both estimates (GCV and PCV) was observed in dry bean girth. The highest for PCV was observed in fruit girth (115.14), while pod thickness had the highest GCV (18.25). The GCV: PCV ratio was high for most of the traits. Traits with high GCV: PCV ration ranged from 69.05 (number of beans per row) to 98.69 (time to fruit harvest) while traits with low GCV:PCV ratio ranged from 10.19 (fruit girth) to 63.21 (dry bean girth).

The eigen values of the Principal Component axes are presented in Table 5. The first, second and third principal components accounted for 45.18, 21.06 and 12.89% respectively of the total variation among the nine cacao genotypes. These three, in essence, together accounted for 79.12% of the total variation among the seventeen characters that described the 9 cacao genotypes in the diversity studies. In addition, these first three principal components had eigen values of 7.68, 3.57 and 2.19 respectively. The relative discriminatory power of the principal axes as indicated by the eigen values was highest (7.68) for the first principal axis and least (1.09) for the fifth principal axis. Both the fourth and fifth axes accounted for 16.75% of the total variation observed among the cacao genotypes, indicating that as much as 95.87% of the total variation was captured by the first five principal axes

The scores of the major characters describing the first five principal axes are also presented in the same table. The first principal component was loaded largely by Time to fruit harvest (0.26), Fruit weight (0.28), Fruit Length (0.23), fruit girth (0.28), weight of beans per fruit (0.34), weight of one bean (0.28), weight of fermented beans (0.29), weight of one fermented bean (0.27), pod value (0.35), weight of 1 dry bean (0.25), dry bean length (0.20) and pod index (-0.32). Characters loaded in a high magnitude on the second axis, but not present on the first include fruit length (-0.34), number of beans per row (-0.46) and number of beans per fruit (-0.46). Two character not described by the first two axes but loaded in a high magnitude on the third principal component are Pod thickness (0.50) and dry bean girth (-0.20). Thus all the seventeen characters that describe the nine cacao genotypes were loaded on the first three principal axes. Axes IV and V were loaded by characters already present on the first three axes.

A plot of the graph of the genotypes on axes 1 & 2; 1 & 3; and 2 & 3 is presented in Figures 1, 2 and 3 respectively. These figures depict the nine genotypes as clearly separated from one another on the graphs, indicating the distinctness of each genotype in its expression of the traits that their classification was based upon. Figure 4 shows the dendrogram drawn from the Single Linkage Cluster Analysis (SLCA) to illustrate the relationship between the nine cacao genotypes on the basis of overall similarity. At the zero percent level of similarity, all the genotypes were distinct from one another. The first cluster was formed between genotypes AxJ & ExI at the 4.71% level of similarity, while the last cluster was formed between the cluster of CxK & FxJ and the other clusters earlier formed at the 207% level of similarity.

IV. Discussion

As all the characters under consideration are related with yield among the nine cacao genotypes, the coefficients of variability (CV) is generally low as expected among most of the traits, except fruit girth and pod thickness. The low values of the CV among the genotypes indicate that the experiment was conducted precisely. Since CV gives an idea of the repeatability of an experiment, this experiment can be said to be capable of producing similar results (means) as presently obtained if repeated several times.

Since reliable breeding selection programme can be based on high GCV: PCV ratio, high broad sense heritability and high genetic advance (Adewale & Kehinde, 2014), the selection of these genotypes based on the high values of some of these characters highlighted can be reliable. This applies to the selection of the genotypes relying on all traits which exhibited high GCV: PCV ratios, since such traits are much under the influence of genetic factors rather than the environmental factors (Kaushik et al., 2007). Characters with high broad sense heritability estimates (time to fruit harvest, fruit weight and weight of beans after fermentation) are believed to have high genetic potentials, as the effect of the environment on them is low and additive gene effect could be playing a dominant role on their expression (Kandasamy et al., 1989).

The proportion of total variation among the plant characters accounted for by the first principal axis (45.18%) attests to the strength of the analysis. The percentage of the total variation accounted for by the first five principal axes indicates that the remaining axes (which accounted 4.13%) can be discarded in describing the variation among the cacao genotypes. The relative discriminatory power of the principal axes clearly indicates the strength of the first axis (with eigen value of 7.68) in discriminating among the nine cacao genotypes. This suggests that the traits loaded on it played a significant role in describing the variation among the genotypes, since PCA measures axes along which variation between genotypes is maximised (Ariyo, 1993).

It can be inferred that significant variations exist among the nine cacao genotypes that the study was based on. The role of the environment in the expression of the seventeen traits was lower than the genetic counterpart. Selection of the genotypes based on these traits may be reliable. The distinctness exhibited by the genotypes from one another, according to the PCA graphs, further validates the variations observed among them. Each genotype can thus be treated as an individual entity. The grouping of the genotypes by the SLCA indicated that each genotype had at least one neighbour with more that 207% level of similarity.

Genotype GxH (Pedigree: (P_7 x P_{A150}) x ($T_{101/15}$ x N_{38})) is clearly outstanding among these nine early bearing cacao genotypes. This genotype exhibited means that are significantly different from that of the others with respect to majority of the traits that describe the variations among the genotypes. This genotype can therefore be considered when selecting individuals for yield and for further hybridization that is focused on yield and other yield-related traits.

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Table 1: List of nine cacao genotypes used in the study

S/N	Genotypes	Pedigree
1	AxJ	$(T_{82/27}$ x $T_{12/11})$ x $(T_{65/7}$ x $T_{57/22})$
2	AxK	$(T_{82/27}$ x $T_{12/11})$ x $(T_{53/5}$ x $_{N38})$
3	BxJ	$(P_7$ x $T_{60/887})$ x $(T_{65/7}$ x $T_{57/22})$
4	CxJ	$(T_{86/2}$ x $T_{9/15})$ x $(T_{65/7}$ x $T_{57/22})$
5	CxK	$(T_{86/2}$ x $T_{9/15})$ x $(T_{53/5}$ x $_{N38})$
6	ExI	$(T_{86/2}$ x $T_{22/28})$ x $(T_{65/7}$ x $T_{22/28})$
7	FxJ	$(T_{65/7}$ x $T_{9/15})$ x $(T_{65/7}$ x $T_{57/22})$
8	GxH	$(P_7$ x $P_{A150})$ x $(T_{101/15}$ x $N_{38})$
9	GxJ	$(P_7$ x $P_{A150})$ x $(T_{65/7}$ x $T_{57/22})$

Table 2: ANOVA summary of discriminatory characters of 9 cacao hybrids which fruited at Owena

Source of variation	Df	TFH (Wks)	Frt Wgt (g)	Frt Lth (mm)	Frt Gth (mm)	P T (mm)	Rows	Bns/Row	Bns/Frt	Bns Wgt /Frt (g)
Block	2	6.67*	3403.95	187.19	358001.66	2094.05	0.01	0.19	25.07	10.58
Hybrid	8	81.97**	14083.71**	300.59*	157651.95	2083.94	0.10*	0.60	16.73	256.69*
Error	16	2.28	2530.23	113.60	156014.50	2027.60	0.03	0.31	14.83	77.21
C.V. (%)		1.32	10.48	6.07	19.94	19.25	3.77	6.30	9.33	7.05
Source of variation	Df	Wt of 1 Bn (g)	Bns Wgt Ferm (g)	1 Bn Wgt Ferm (g)	Pd Val (g)	1 D B Wgt (g)	D B L (mm)	D B G (mm)	P. I.	
Block	2	0.16	41.45	0.05	1.90	0.00	0.02	0.09	3.60	
Hybrid	8	0.44*	336.81**	0.23*	40.44*	0.02	0.94*	0.13	20.21*	
Error	16	0.17	66.74	0.09	15.55	0.01	0.30	0.08	8.01	
C.V. (%)		13.06	7.97	12.34	9.19	9.33	2.43	2.33	11.50	

*, **, ***= Significance at $P \leq 0.05$, 0.01 and 0.001 respectively

ANOVA= Analysis of variance; TFH= Time to Fruit Harvest; Frt Wgt= Fruit Weight; Frt Lth= Fruit Length; Frt Gth= Fruit Girth; PT= Pod Thickness; Bns/Row= Number of beans per row; Bns/ Frt= Beans per Fruit; Bns Wgt/Frt= Weight of beans per fruit; tg of 1 Bn= Weight of a single bean per fruit; Bns Wgt Ferm = Weight of beans per fruit after fermentation; 1Bn Wgt Ferm = Weight of one bean after fermentation; Pd Val = Pod Value; 1 DB Weight = Weight of one dry bean; DBL = Dry Bean Length; DBG = Dry Bean Girth; P. I. = Pod Index

Table 3: Separation of means of 9 hybrids which fruited at Owena

Genotype	TFH (Wks)	Frt Wgt (g)	Frt Lth (mm)	Frt Girth (mm)	P T (mm)	Rows	Bns/Row	Bns/Frt	Bns Wgt /Frt (g)
AxJ	119.53 a	526.68 b	172.06 abc	86.03 a	13.63 a	5.00 a	9.20 a	44.53 a	130.47 ab
AxK	117.00 ab	450.09 b	192.29 a	82.17 a	15.51 a	4.80 a	9.33 a	44.80 a	129.40 ab
BxJ	118.87 ab	441.93 b	187.43 ab	82.92 a	15.04 a	4.80 a	9.00 ab	42.00 a	123.64 bc
CxJ	112.20 d	431.21 b	173.78 abc	81.95 a	15.03 a	4.93 a	8.33 ab	37.67 a	122.58 bc
CxK	106.40 e	430.60 b	167.15 bc	602.43 a	15.03 a	4.67 ab	9.13 ab	41.93 a	109.23 c
ExI	115.87 c	517.59 b	172.39 abc	85.44 a	14.59 a	4.67 ab	8.73 ab	39.93 a	127.49 ab
FxJ	104.87 e	442.57 b	160.40 c	600.20 a	14.64 a	4.93 a	8.07 b	39.13 a	120.52 bc
GxH	116.33 bc	635.54 a	182.08 ab	88.92 a	16.86 a	4.40 b	9.27 a	40.20 a	141.76 a
GxJ	115.40 c	445.27 b	172.03 abc	81.88 a	92.99 a	4.87 a	8.60 ab	41.07 a	116.47 bc
Genotype	Wgt of 1 Bn (g)	Bns Wgt Ferm (g)	1 Bn Wgt Ferm (g)	Pd Val (g)	1 D B Wgt (g)	D B L (mm)	D B G (mm)	P. I.	
AxJ	3.07 bc	115.35 ab	2.76 ab	48.58 a	1.14 ab	21.68 b	12.02 ab	20.72 c	
AxK	3.07 bc	100.38 b-e	2.26 bc	45.47 ab	1.20 ab	22.93 a	11.74 b	22.08 bc	
BxJ	3.14 abc	92.52 de	2.27 bc	41.10 ab	1.14 ab	22.58 ab	12.06 ab	24.87 abc	
CxJ	3.32 ab	100.97 bcd	2.24 bc	41.73 ab	1.11 ab	22.71 ab	12.16 ab	25.18 abc	
CxK	2.47 bc	85.25 e	1.98 c	37.79 b	1.08 b	21.78 b	12.17 ab	27.37 ab	
ExI	3.36 ab	109.14 abc	2.54 abc	43.56 ab	1.14 ab	22.72 ab	12.40 a	24.42 abc	
FxJ	3.22 abc	97.35 cde	2.37 abc	39.02 b	1.15 ab	23.34 a	11.92 ab	28.59 a	
GxH	3.91 a	118.56 a	2.87 a	47.43 a	1.30 a	23.10 a	12.29 a	22.09 bc	
GxJ	2.93 bc	103.17 bcd	2.40 abc	41.40 ab	1.04 b	22.38 ab	11.88 ab	26.09 abc	

Means with the same letters along the column are not significantly different using DMRT at 0.05 and 0.01 levels of probability.

TFH= Time to Fruit Harvest; Frt Wgt= Fruit Weight; Frt Lth= Fruit Length; Frt Gth= Fruit Girth; PT= Pod Thickness; Rows = Number of rows per pod Bns/Row= Number of beans per row; Bns/ Frt= Beans per Fruit; Bns Wgt/Frt= Weight of beans per fruit; Wtg of 1 Bn= Weight of a single bean per fruit; Bns Wgt Ferm = Weight of beans per fruit after fermentation; 1Bn Wgt Ferm = Weight of one bean after fermentation; Pd Val = Pod Value; 1 DB Weight = Weight of one dry bean; DBL = Dry Bean Length; DBG = Dry Bean Girth; P. I. = Pod Index

Table 4: Estimates of genetic variability of 17 agronomic, fruit and bean traits of 9 cacao hybrids from Owena

Character	Mean	Genotype mean square	Error	PCV	GCV	GCV:PCV (%)	Hbs
TFH (Wks)	114.05	81.97	2.28	4.58	4.52	98.69	97.22
Frt Wgt (g)	480.16	14083.71	2530.23	14.27	12.92	90.54	82.03
Frt Lth (mm)	175.51	300.59	113.60	5.70	4.50	78.95	62.21
Frt Gth (mm)	199.10	157651.95	156014.50	115.14	11.73	10.19	1.04
P T (mm)	23.70	2083.94	2027.60	111.19	18.28	16.44	2.70
Rows	4.79	0.10	0.03	3.87	3.19	82.43	67.96
Bns/Row	8.85	0.60	0.31	5.04	3.48	69.05	47.82
Bns/Frt	41.25	16.73	14.83	5.72	1.93	33.74	11.36
Bns Wgt /Fruit (g)	124.62	256.69	77.21	7.42	6.21	83.69	69.92
Wgt of 1 Bn (g)	3.17	0.44	0.17	12.14	9.51	78.34	61.40
Bns Wgt Ferm (g)	102.52	336.81	66.74	10.34	9.25	89.46	80.19
1 Bn Wgt Ferm (g)	2.41	0.23	0.09	11.46	8.96	78.18	61.14
Pd Val (g)	42.90	40.44	15.55	8.56	6.71	78.39	61.55
1 D B Weight (g)	1.15	0.02	0.01	6.38	3.57	55.96	31.25
D B L (mm)	22.58	0.94	0.30	2.47	2.04	82.59	67.81
D B G (mm)	12.07	0.13	0.08	1.74	1.10	63.21	40.15
P. I.	24.60	20.21	8.01	10.55	8.20	77.73	60.38

GCV= Genotypic coefficient of variation; PCV= Phenotypic coefficient of variation; Hbs= Broad sense heritabilityTFH= Time to Fruit Harvest; Frt Wgt= Fruit Weight; Frt Lth= Fruit Length; Frt Gth= Fruit Girth; PT= Pod Thickness; Rows + Number of rows per pod; Bns/Row= Number of beans per row; Bns/ Frt= Beans per Fruit; Bns Wgt/Frt= Weight of beans per fruit; Wtg of 1 Bn= Weight of a single bean per fruit; Bns Wgt Ferm = Weight of beans per fruit after fermentation; 1Bn Wgt Ferm = Weight of one bean after fermentation; Pd Val = Pod Value; 1 DB Weight = Weight of one dry bean; DBL = Dry Bean Length; DBG = Dry Bean Girth; P. I. = Pod Index

Table 5: Eigenvalues, percentages of total variation accounted for and scores of major characters of the first five principal component axes used in ordination of 9 cacao genotypes

Character	AXIS I	AXIS II	AXIS III	AXIS IV	AXIS V
Time to Fruit Harvest	0.26	-0.15	0.33	-0.15	-0.19
Fruit Weight	0.28	0.12	-0.16	-0.29	0.23
Fruit Length	0.23	-0.34	0.11	0.13	-0.27
Fruit Girth	0.28	0.06	-0.36	0.14	0.20
Pod Thickness	0.06	-0.01	0.50	-0.06	0.58
No of Rows	-0.09	0.18	0.41	0.33	-0.38
Beans/Row	0.13	-0.46	-0.16	-0.13	0.09
Beans/Fruit	0.10	-0.46	-0.04	0.15	0.23
Wt of Beans/Fruit	0.34	0.07	-0.13	0.13	-0.01
Wt of 1 Bean	0.28	0.31	-0.12	0.07	-0.16
Beans Weight (Fermented)	0.29	0.24	0.13	-0.11	-0.22
1 Bean Weight (Fermented)	0.27	0.27	0.10	-0.10	0.25
Pod Value	0.35	-0.06	0.06	0.02	0.04
1 Dry Bean Weight	0.25	-0.02	-0.41	0.27	0.05
Dry Bean Length	0.20	0.28	-0.12	0.44	0.06
Dry Bean Girth	0.00	0.17	-0.20	-0.63	-0.31
Pod Index	-0.32	0.20	-0.05	0.04	0.13
Eigen values	7.68	3.57	2.19	1.76	1.09
Proportion of Total Variation	45.18	21.06	12.87	10.33	6.42
Cumulative Percentage	45.18	66.24	79.12	89.46	95.87

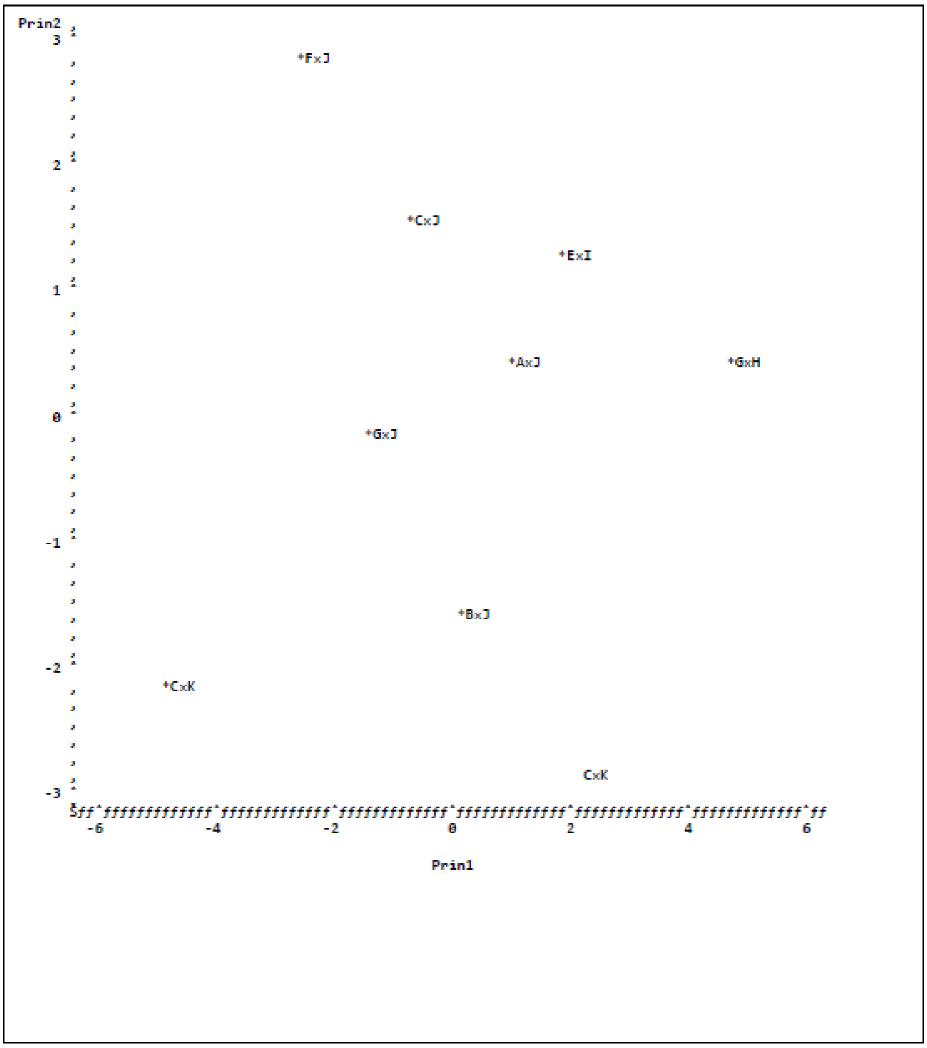

Fig. 1. Configuration of nine cacao genotypes under axes 1 and 2

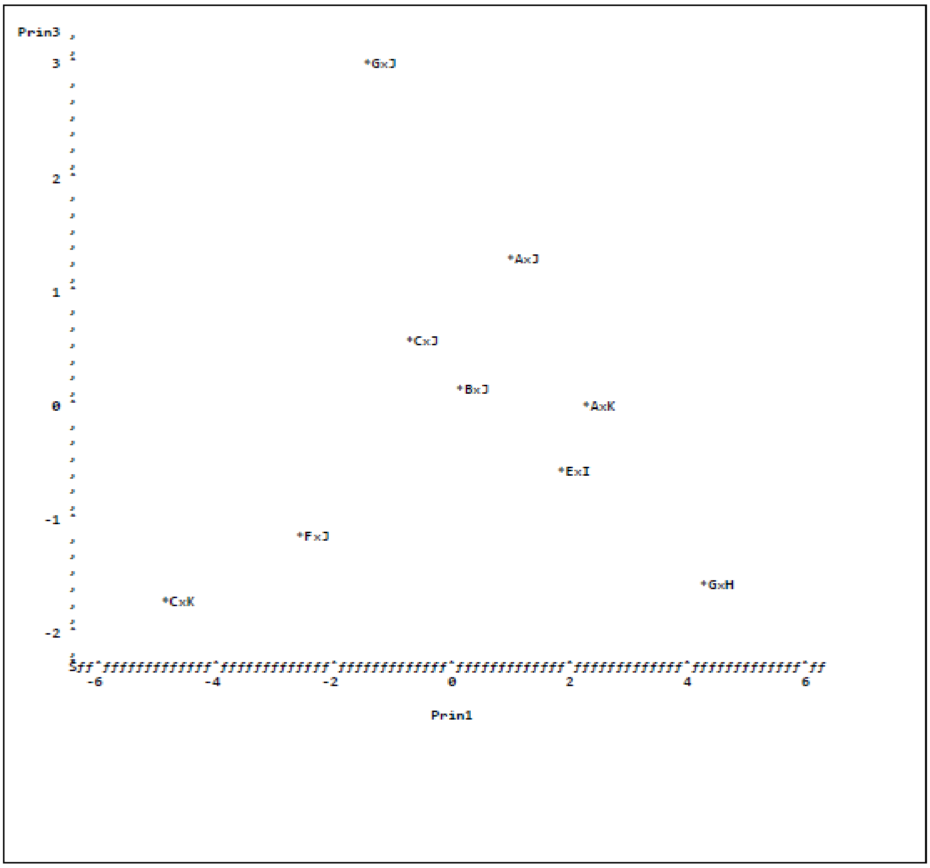

Fig. 2. Configuration of nine cacao genotypes under axes 1 and 3

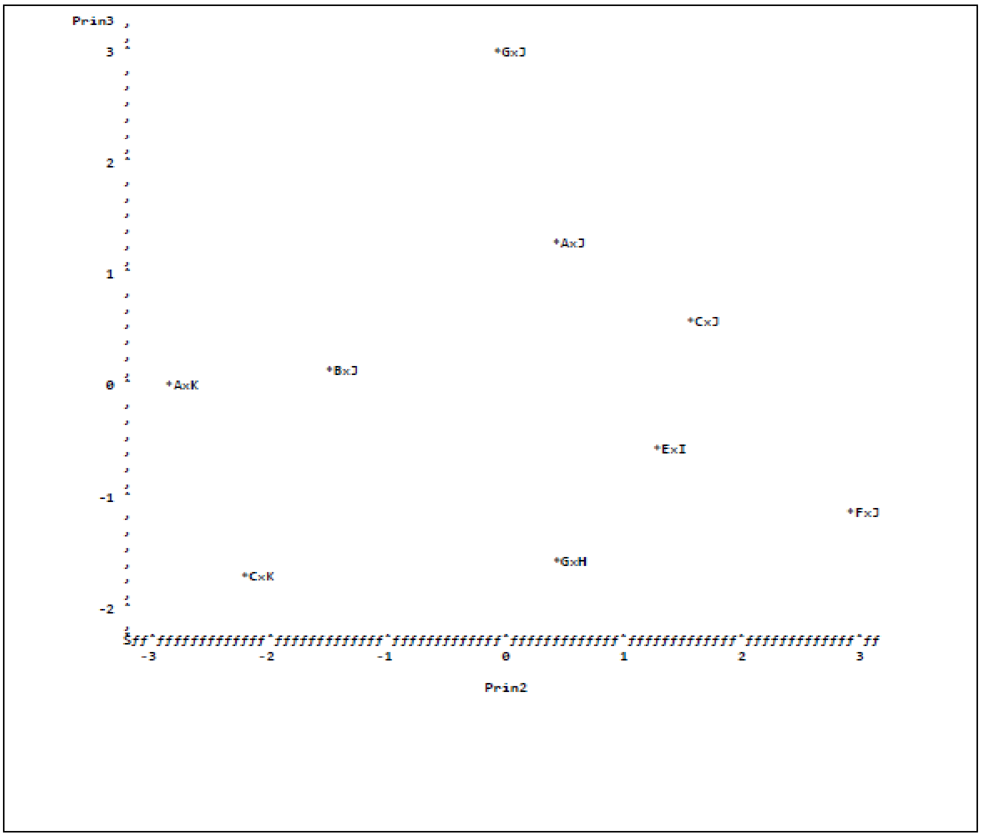

Fig. 3. Configuration of nine cacao genotypes under axes 2 and 3

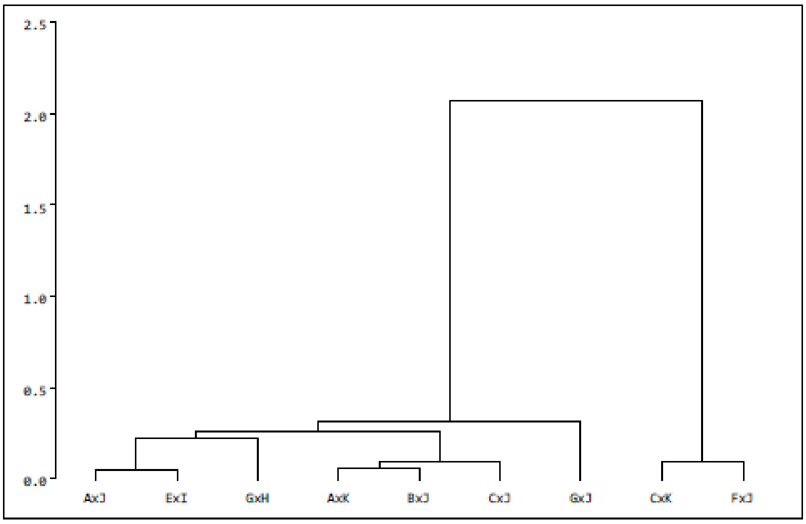

Fig. 4. Dendrogram resulting from the Single Linkage Cluster Analysis of nine cacao genotypes.