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Relationships among Bean Yield Traits in Some Cacao (*Theobroma cacao* L.) Genotypes

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Abstract: Cacao (*Theobroma cacao* L.) produces the cocoa bean, a major foreign exchange earner for most West African countries and many smallholders' enterprise. Ample production of cacao is however limited by declining yield among other factors. This study aimed at determining the correlations of the phenotypic traits that were related to the yield of the cacao genotypes. Nine new cacao hybrids were produced from some high-yielding parents in the research farm of Cocoa Research Institute of Nigeria, Ibadan and evaluated from 2012 through 2014 in Owena (7°11′ N, 5°1′ E), Ondo state, Nigeria. Analysis of variance, character correlations and path coefficient analysis were used in the analysis of the relationships among the genotypes. Analysis of variance revealed significant ($p \leq 0.05$) variations for number of rows, weight of beans per fruit, fresh weight of one bean, weight of one bean after fermentation, pod value, dry bean length, weight of beans (per fruit) after fermentation and pod index. The study concluded that significant genotypic and phenotypic correlations existed among some of the pairs of the fruit and bean characters with one another and with pod index, suggesting that the contribution of these characters is either positive or negative to growth and yield in the cacao genotype, and that fruit and bean traits are determinants of bean yield in cacao.

Key words: Bean yield, cacao, correlation, genetic variability, phenotypic traits.

1. Introduction

The cacao tree (*Theobroma cacao* L.) produces cocoa bean, a major foreign exchange earner for most West African countries and many smallholder enterprises. Declining yield is, however, a limiting factor in cacao cropping in Nigeria. The F_3 Amazon hybrid, a derivative of the Upper Amazon Forastero material [1], which takes up to four years to flower, is the common variety in farmer plots across Nigeria. The need to obtain early fruiting genotypes with improved yield led to the discovery and release of eight new cacao varieties by the Cocoa Research Institute of Nigeria (CRIN) in 2011 [2].

Variability is the basis for genetic improvement. There is therefore a need for improved genotypes obtained through appropriate breeding procedures to widen the genetic base of cacao genotypes in farmer plots in Nigeria, which is perceived to be narrow due to farmers' practice of using seed from their own crop for new plantings [3]. This will enable to get the required genetic variability for this crop improvement, namely bean yield. Building on the achievement of CRIN in the release of the new hybrids, some F_1 offspring of these newly-released hybrids were found to have fruited early in the Owena sub-station of the institute, with first fruit harvest occurring already during 104-124 weeks of field planting of these F_1 offspring. Information has been published on the genetic variability of these F_1 offspring [4].

Seventy per cent (70%) of world cocoa beans are produced by small holders in West Africa whose yield has remained low [5]. Cocoa bean yield is influenced by the variety and age of plant [6]. Bean yield in cocoa is also negatively influenced by climatic changes and increased land use for food crops [5].

Correlation is a measure of the degree of relationship between variables [7]. Estimates of

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genotypic, phenotypic and environmental correlations among characters can provide the basis of planning of more efficient breeding programmes. A plant breeder should know whether the improvement of one character will result in simultaneous change in other characters through estimates of inter-character correlations [7]. Cocoa bean yield has remained low in Nigeria [3] and the yield is believed to be influenced by a number of characters. This study was therefore carried out to determine the correlations between phenotypic traits that were related to the yield of cocoa bean among some Nigerian cacao genotypes.

2. Materials and Methods

Nine newly produced early hybrids were planted in July, 2012, at the Owena (7°11′ N, 5°1′ E) sub-station of CRIN, in Ondo state, Nigeria and evaluated through January 2015. Thirty individual seedlings were established per genotype as 10 seedlings per plot in three replications in a randomized complete block design (RCBD). The list of the nine genotypes and their pedigree are shown in Table 1. Five uniformly matured and ripe cocoa pods were harvested per genotype in each replication, giving a total of 15 pods (fruits) per genotype. The fruits were carefully broken to get the beans. The number of rows, number of beans per row and number of beans per pod were counted. Also, 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 10 beans randomly selected per fruit. 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 10 fermented beans weighed. The fermented beans were sun-dried, and the pod value recorded as 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 10 dried bean per fruit. Dried bean length and width were recorded as average of values of 10 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 1 kg of dry cocoa beans. The studied genotypes were subjected to analysis of variance using SAS package (version 9.2) [8] to assess the variability significance among them, while their means were separated using Duncan's multiple range test. The phenotypic, genotypic and environmental correlation coefficients were estimated using the formula of Miller *et al*. [9]:

$$r(x,y)=\frac{Cov(xy)}{\sqrt{(\delta x)^2(\delta y)^2}} \quad (1)$$

where $r_{(x,\ y)}$ is either genotypic or phenotypic or environmental correlation between variables x and y; $Cov_{(xy)}$ is the covariance of variables x and y; $(\delta_x)^2$ is either the genotypic or phenotypic or environmental variance of variable x; $(\delta_y)^2$ is either the genotypic or phenotypic or environmental variance of variable y. The formula applies equally in the determination of each of genotypic, phenotypic and environmental correlation coefficients.

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

S/N	Genotype code	Pedigree	Weeks to harvest
1	A × J	$(T_{82/27} \times T_{12/11}) \times (T_{65/7} \times T_{57/22})$	122
2	A × K	$(T_{82/27} \times T_{12/11}) \times (T_{53/5} \times N_{38})$	117
3	B × J	$(P_7 \times T_{60/887}) \times (T_{65/7} \times T_{57/22})$	124
4	C × J	$(T_{86/2} \times T_{9/15}) \times (T_{65/7} \times T_{57/22})$	114
5	C × K	$(T_{86/2} \times T_{9/15}) \times (T_{53/5} \times N_{38})$	105
6	E × I	$(T_{86/2} \times T_{22/28}) \times (T_{65/7} \times T_{22/28})$	117
7	F × J	$(T_{65/7} \times T_{9/15}) \times (T_{65/7} \times T_{57/22})$	104
8	G × H	$(P_7 \times P_{A150}) \times (T_{101/15} \times N_{38})$	117
9	G × J	$(P_7 \times P_{A150}) \times (T_{65/7} \times T_{57/22})$	114

The significance of the correlation coefficients was tested using the non-directional probability in the software of Lowry [10].

The direct and indirect path coefficients were calculated to reveal the strength of the relationship among pod index and the yield-related characters by solving a series of simultaneous equations as suggested by Dewey and Lu [11].

3. Results and Discussion

The mean squares of the characters and the coefficients of variation for 12 characters among the nine cacao genotypes are presented in Table 2. Significant ($p \leq 0.05$) genotypic variation existed among the nine hybrids for 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. Highly significant ($p \leq 0.01$) genotypic variation also existed for weight of beans (per fruit) after fermentation. The highest coefficient of variation was observed for fruit width (19.94) and pod thickness (19.25). The significant genotypic variations and moderate coefficients of variations of some of the quantitative traits indicate genetic variability of the genotypes.

The separation of the means for the 12 characters describing the nine hybrids is presented in Table 3. Hybrid G × H had the largest bean weight per fruit (141.76), while hybrid C × J had the lowest (109.23); hybrid G × H had the heaviest single bean weight (3.91), weight of beans after fermentation (118.56), weight of one bean after fermentation (2.7), one dry bean weight (1.30), dry bean length (23.10) and dry bean width (12.39). Hybrid C × K had the least bean weight after fermentation (85.25) and weight of one bean after fermentation (1.98). Hybrid C × K also had some of the least weight of one bean (2.47), pod value (37.79), one dry bean weight (1.08), dry bean length (21.78) and dry bean width (12.17). Hybrid F × J had the highest pod index (28.59) while hybrid A × J had the least (20.72). Hybrids A × J and G × H had the highest pod values of 48.58 and 47.43, respectively. Selection can therefore be done among the genotypes for the purpose of further improvement.

The phenotypic, genotypic and environmental correlation coefficients among the fruit and bean characters of the nine cacao hybrids are presented in Table 4. For selection of genotypes to be successful, the phenotypic expression of their traits must serve as a guide. Moreover, phenotypic correlation is a composite of the genotypic and environmental correlations. The significant phenotypic correlation coefficients are therefore stated thus. Number of rows was negatively significantly ($p \leq 0.01$) correlated with beans per row (-0.47), beans weight per row (-0.39), weight of one bean (-0.42), one dry bean weight (-0.58) and dry bean width (-0.57). Number of beans per row was positively significantly ($p \leq 0.01$) correlated with beans per fruit (0.77), beans weight per fruit (0.39), pod value (0.56) and one dry bean weight (0.41) but negatively correlated with dry bean length (-0.39) and pod index (-0.71). Number of beans per fruit was positively significantly ($p \leq 0.05$) correlated with pod value (0.43) but negatively correlated with weight of one bean (-0.39), dry bean length (-0.48), dry bean width (-0.49) and pod index (-0.56). Beans weight per fruit was positively significantly ($p \leq 0.05$) correlated with weight of one bean (0.86), beans weight after fermentation (0.83), one bean weight after fermentation (0.83), pod value (0.87), one dry bean weight (0.86) but negatively correlated with pod index (-0.78). Weight of one bean was positively correlated with beans weight after fermentation (0.73), one bean weight after fermentation (0.74), pod value (0.56), one dry bean weight (0.76), dry bean length (0.66) and dry bean width (0.38) but negatively correlated with pod index (-0.41). Beans weight after fermentation was positively significantly ($p \leq 0.01$) correlated with one bean weight after fermentation (0.96), pod value (0.87) and one dry bean weight (0.53) but negatively correlated with pod index (-0.71). One bean weight after fermentation was positively significantly ($p \leq 0.01$)

Table 2 ANOVA (mean squares) of characters of nine cacao hybrids used in the study.

Source of variation	df	Rows	Bns/Row	Bns/Frt	Bns Wgt/Frt (g)	Wgt of 1 Bn (g)	Bns Wgt Ferm (g)	1 Bn Wgt Ferm (g)	Pd Val (g)	1 DB Wgt (g)	DBL (mm)	DBW (mm)	P. I.
Block	2	0.01	0.19	25.07	10.58	0.16	41.45	0.05	1.90	0.00	0.02	0.09	3.60
Hybrid	8	0.10*	0.60	16.73	256.69*	0.44*	336.81**	0.23*	40.44*	0.02	0.94*	0.13	20.21*
Error	16	0.03	0.31	14.83	77.21	0.17	66.74	0.09	15.55	0.01	0.30	0.08	8.01
C.V. (%)		3.77	6.30	9.33	7.05	13.06	7.97	12.34	9.19	9.33	2.43	2.33	11.50

*, ** Significance at $p \leq 0.05$ and 0.01, respectively.

ANOVA = analysis of variance; Bns/Row = number of beans per row; Bns/Frt = beans per fruit; Bns Wgt/Frt = weight of beans per fruit; Wgt of 1 Bn = weight of a single bean per fruit; Bns Wgt Ferm = weight of beans per fruit after fermentation; 1 Bn Wgt Ferm = weight of one bean after fermentation; Pd Val = pod value, i.e., total weight of dry beans per pod; 1 DB Wgt = weight of one dry bean; DBL = dry bean length; DBW = dry bean width; P. I. = pod index.

Table 3 Mean performance of nine cacao hybrids used in the study.

Genotype	Rows	Bns/Row	Bns/Frt	Bns Wgt/Frt (g)	Wgt of 1 Bn (g)	Bns Wgt Ferm (g)	1 Bn Wgt Ferm (g)	Pd Val (g)	1 DB Wgt (g)	DBL (mm)	DBW (mm)	P. I.
A × J	5.00^{a}	9.20^{a}	44.53^{a}	130.47^{ab}	3.07^{bc}	115.35^{ab}	2.76^{ab}	48.58^{a}	1.14^{ab}	21.68^{b}	12.02^{ab}	20.72^{c}
A × K	4.80^{a}	9.33^{a}	44.80^{a}	129.40^{ab}	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}
B × J	4.80^{a}	9.00^{ab}	42.00^{a}	123.64^{bc}	3.14^{abc}	92.52^{de}	2.27^{bc}	41.10^{ab}	1.14^{ab}	22.58^{ab}	12.06^{ab}	24.87^{abc}
C × J	4.93^{a}	8.33^{ab}	37.67^{a}	122.58^{bc}	3.32^{ab}	100.97^{bcd}	2.24^{bc}	41.73^{ab}	1.11^{ab}	22.71^{ab}	12.16^{a}	25.18^{abc}
C × K	4.67^{ab}	9.13^{ab}	41.93^{a}	109.23^{c}	2.47^{bc}	85.25^{e}	1.98^{c}	37.79^{b}	1.08^{b}	21.78^{b}	12.17^{ab}	27.37^{ab}
E × I	4.67^{ab}	8.73^{ab}	39.93^{a}	127.49^{ab}	3.36^{ab}	109.14^{abc}	2.54^{abc}	43.56^{ab}	1.14^{ab}	22.72^{ab}	12.40^{a}	24.42^{abc}
F × J	4.93^{a}	8.07^{b}	39.13^{a}	120.52^{bc}	3.22^{abc}	97.35^{cde}	2.37^{abc}	39.02^{b}	1.15^{ab}	23.34^{a}	11.92^{ab}	28.59^{a}
G × H	4.40^{b}	9.27^{a}	40.20^{a}	141.76^{a}	3.91^{a}	118.56^{a}	2.87^{a}	47.43^{a}	1.30^{a}	23.10^{a}	12.29^{a}	22.09^{bc}
G × J	4.87^{a}	8.60^{ab}	41.07^{a}	116.47^{bc}	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 letter along the column are not significantly different using Duncan's multiple range test (DMRT) at 0.05 level of probability.

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; Wgt of 1 Bn = weight of a single bean per fruit; Bns Wgt Ferm = weight of beans per fruit after fermentation; 1 Bn Wgt Ferm = weight of one bean after fermentation; Pd Val = pod value; 1 DB Wgt = weight of one dry bean; DBL = dry bean length; DBW = dry bean width; P. I. = pod index.

Table 4 Phenotypic, genotypic and environmental correlation coefficients among 12 fruit and beans characters of nine cacao hybrids used in the study.

Character		Bns/Row	Bns/Frt	Bns Wgt/Frt	Wgt of 1 Bn	Bns Wgt Ferm	1 Bn Wgt Ferm	Pd Val	1 DB Wgt	DBL	DBW	P. I.
	r_p	-0.47**	0.11	-0.39*	-0.42*	-0.21	-0.25	-0.16	-0.58**	-0.23	-0.57**	0.15
Rows	r_g	-0.63**	-0.29	-0.31	-0.23	-0.06	-0.04	-0.03	-0.63**	-0.44*	-0.72**	0.11
	r_e	-0.27	0.36	-0.57**	-0.77**	-0.65**	-0.65**	-0.39*	-0.63**	0.19	-0.45**	0.24
	r_p		0.77**	0.39*	-0.04	0.20	0.21	0.56**	0.41*	-0.39*	0.03	-0.71**
Bns/Row	r_g		1.33**	0.17	-0.05	0.00	0.13	0.41*	0.40*	-0.71**	-0.24	-0.56**
	r_e		0.67**	0.74**	-0.03	0.63**	0.32	0.75**	0.43*	0.02	0.24	-0.90**
	r_p			0.12	-0.39*	0.03	0.05	0.43*	0.08	-0.48**	-0.49**	-0.56**
Bns/Frt	r_g			-0.02	0.08	0.05	0.94	0.97**	1.84**	-2.45**	-2.29**	-0.96**
	r_e			0.24	-0.70**	0.03	-0.34	0.30	-0.34	0.38*	0.00	-0.52**
	r_p				0.86**	0.83**	0.83**	0.87**	0.86**	0.39	0.21	-0.78**
Bns Wgt/Frt	r_g				1.04**	0.81**	0.89**	0.87**	1.18**	0.66**	-0.15	-0.75**
	r_e				0.52**	0.94**	0.74**	0.88**	0.68**	-0.20	0.68**	-0.86**
	r_p					0.73**	0.74**	0.56**	0.76**	0.66**	0.38*	-0.41*
Wgt of 1 Bn	r_g					0.79**	0.67**	0.65**	0.77**	1.30**	0.31	-0.56**
	r_e					0.66**	0.86**	0.40*	0.81**	-0.51**	0.47**	-0.18
	r_p						0.96**	0.87**	0.53**	0.14	0.26	-0.71**
Bns Wgt Ferm	r_g						1.02**	0.91**	0.52**	0.29	0.04	-0.72**
	r_e						0.87**	0.84**	0.74**	-0.30	0.70**	-0.76**
	r_p							0.82**	0.58**	0.15	0.28	-0.64**
1 Bn Wgt Ferm	r_g							0.86**	0.31	0.56**	-0.01	-0.71**
	r_e							0.74**	0.86**	-0.59**	0.58**	-0.53**
	r_p								0.60**	-0.03	0.05	-0.96**
Pd Val	r_g								0.62**	0.24	-0.50**	-0.97**
	r_e								0.64**	-0.52**	0.63	-0.94**
	r_p									0.54**	0.17	-0.54**
1 DB Wgt	r_g									1.67**	-0.03	-0.57**
	r_e									-0.47**	0.28	-0.55**
	r_p										-0.06	0.16
DBL	r_g										0.19	0.09
	r_e										-0.35	0.29
	r_p											-0.03
DBW	r_g											0.44*
	r_e											-0.50**

NB: df = 25; *, ** Significance at 0.05 and 0.01, respectively; r_p = phenotypic correlation coefficients; r_g = genotypic correlation coefficients; r_e = environmental correlation coefficients.

Bns/Row = number of beans per row; Bns/Frt = number of beans per fruit; Bns Wgt/Frt = weight of beans per fruit; Wgt of 1 Bn = weight of a single bean per fruit; Bns Wgt Ferm = weight of beans per fruit after fermentation; 1 Bn Wgt Ferm = weight of one bean after fermentation; Pd Val = pod value, i.e., weight of total dry beans from a pod; 1 DB Wgt = weight of one dry bean; DBL = dry bean length; DBW = dry bean width; P. I. = pod index.

Table 5 Direct and indirect path coefficients between pod index and nine beans characters of the nine cacao hybrids used in the study.

		Indirect effects through other plant characters									
	Direct effect	Bns/Row	Bns/Frt	Bns Wgt/Frt	Wgt of 1 Bn	Bns Wgt Ferm	1 Bn Wgt Ferm	Pd Val	1 DB Wgt	DBW	Corr with pod index
Bns/Row	-0.4542		-0.2589	0.2054	0.0996	0	0.0668	-0.378	0.2189	-0.0596	-0.56
Bns/Frt	-0.1946	-0.6041		-0.0242	-0.1594	-0.0047	0.4831	-0.8943	1.007	-0.5688	-0.96
Bns Wgt/Frt	1.2080	-0.0772	0.0039		-2.0717	-0.0768	0.4575	-0.8021	0.6458	-0.0373	-0.75
Wgt of 1 Bn	-1.992	0.0227	-0.0156	1.2563		-0.0749	0.3444	-0.5993	0.4214	0.0770	-0.56
Bns Wgt Ferm	-0.0948	0	-0.0097	0.9785	-1.5737		0.5243	-0.8390	0.2846	0.0099	-0.72
1 Bn Wgt Ferm	0.5140	-0.059	-0.1829	1.0751	-1.3347	-0.0967		-0.7929	0.1697	-0.0025	-0.71
Pd Val	-0.922	-0.1862	-0.1888	1.0510	-1.2948	-0.0863	0.4420		0.3393	-0.1242	-0.97
1 DB Wgt	0.5473	-0.1817	-0.3581	1.4254	-1.5339	-0.0493	0.1593	-0.5716		-0.0075	-0.57
DBW	0.2484	0.1090	0.4457	-0.1812	-0.6175	-0.0038	-0.0051	0.4610	-0.0164		0.44

Bns/Row = number of beans per row; Bns/Frt = number of beans per fruit; Bns Wgt/Frt = weight of beans per fruit; Wgt of 1 Bn = weight of a single bean per fruit; Bns Wgt Ferm = weight of beans per fruit after fermentation; 1 Bn Wgt Ferm = weight of one bean after fermentation; Pd Val = pod value, i.e., weight of total dry beans from a pod; 1 DB Wgt = weight of one dry bean; DBW = dry bean width; Corr with pod index = correlation with pod index.
Residual effect = 0.2139.

correlated with pod value (0.82) and one dry bean weight (0.58) but negatively correlated with pod index (-0.64). Pod value was positive significantly ($p \leq 0.05$) correlated with one dry bean weight (0.60) but negatively correlated with pod index (-0.96). One dry bean weight was positively significantly ($p \leq 0.05$) correlated with dry bean length (0.54) but negatively correlated with pod index (-0.54).

Selection of the genotypes based on the relationships of the few pairs of character that exhibited significant phenotypic correlations, but not with corresponding significant genotypic correlation will not be reliable, since the genetic components are obviously not playing significant role in the variability expressed by such character. This applies to the pairs of association between number of rows and each of beans weight per fruit and weight of one bean; bean per row and beans weight per fruit; beans per fruit with weight of one bean; weight of one bean with dry bean weight; and one bean weight after fermentation with one dry bean weight.

Selection of the genotypes based only on inter-character associations which are genotypically correlated but not phenotypically correlated may not be of practical value in breeding programme since selection is mostly based on the phenotypes of the characters in consideration and such a selection will be unrepeatable and unreliable [12]. This applies to the many pairs of characters that exhibited this kind of relationship in the study, such as number of rows and dry bean length; beans weight per fruit and dry bean length; one bean weight after fermentation and dry bean length; and pod value and dry bean width.

The significant genotypic and phenotypic correlations of some of the pairs of the fruit bean characters with one another and with pod index suggested that these characters contributed either positively or negatively to growth and yield in the cacao genotypes. Such inter-character associations can therefore be used as criteria for selection of the genotypes that particularly exhibit good yield. This relationship applies to number of rows and number of beans per row; number of beans per row and dry bean length; number of beans per fruit and each of pod value and dry bean width; as well as weight of one bean and pod index.

The significant environmental correlations among many of the pairs of characters indicated the influence of the environment on which the genotypes were grown in the expression of these traits.

From the direct and indirect path coefficients estimating the relationship between pod index and the beans characters (Table 5), number of beans per row, number of beans per fruit, weight of one bean, weight of beans after fermentation, and pod value all had a negative direct effects on pod index. This implies an inverse relationship between each of these traits and pod index, which is very desirable since pod index refers to the number of cocoa pods required to produce 1.0 kg of dry cocoa beans [1], the lower the value (of pod index), the more desirable the genotype. This means that as each of these traits increased in magnitude and reduces the magnitude of pod index, fewer pods are required to give 1 kg of dry cocoa beans, thereby saving the cost of labour and other factors of production. The important negative indirect effects of these plant traits on pod index include their effects through number of beans per fruit, pod value and dry bean width (for number of beans per row); number of beans per row, beans weight per fruit, weight of one bean, weight of beans after fermentation, pod value and dry bean width (for number of beans per fruit); number of beans per fruit, weight of beans after fermentation, and pod value (for weight of one bean); number of beans per fruit, weight of one bean, and pod value (for weight of beans after fermentation); and number of beans per row, number of beans per fruit, weight of one bean, weight of beans after fermentation and dry bean width (for pod value). Hence, number of beans per row, number of beans per fruit, weight of one bean, weight of beans after fermentation, and pod value can be considered along with any or all of each of the other traits that enhance their negative expression in the selection of these cacao genotypes for desirable pod index. The moderate value of the residual factor recorded in the relationship between pod index and the fruit and bean characters indicated a reduction in rounding-off errors.

4. Conclusions

Significant genotypic variations exist among the cacao genotypes used in this study as shown by the phenotypic fruit and bean traits that describe them. Therefore, beyond the influence of climate, the fruit and bean traits used in this study are important determinants of yield in cacao. Selection among these genotypes for bean yield improvement can therefore be done with the aid of these traits, considering the negative impact of climate changes of cocoa bean yield.

Recommendations

The character association of each of the pairs of number of rows and number of beans per row, number of beans per row and dry bean length, number of beans per fruit and each of pod value and dry bean width, as well as weight of one bean and pod index are recommended as for consideration in the selection of cacao genotypes for improved bean yield. A similar study is also recommended in more multiple cacao agro-ecologies, considering the influence of climate changes on cocoa bean yield.

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