



Assessment of international cocoa accessions (*Theobroma cacao* L.) for pod filling and graining in Côte d'Ivoire

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1 ABSTRACT

This article deals with an assessment of 15 international cocoa accessions for pods filling. The objective of this study is to identify within the CNRA cocoa collection high-performance genotypes for agronomic traits of interest. Fifteen (15) cocoa accessions introduced from the Reading International Quarantine Center were characterized agromorphologically using 8 descriptive agronomic parameters of pods and beans following a complete randomized block experimental design with 2 repetitions. The results indicate that accessions EET95, UF273 and Playa Alta 2 presented the best pod fillings with a high number of beans (respectively 48.28; 40.90; 40.83 beans) and high weights of fresh beans per pod (152.59g; 244.23g; 154.54g). Concerning graining, the family averages varied from 2.47 g to 1.01 g per dry bean with an overall average of 1.47 g and a CV of 17.63%. Accessions APA5; RB49 and UF 273 were the best performers for this trait with respectively 2.47 g; 2.03 g and 1.83g per dry bean. This study indicated that accessions EET95, UF273 and Playa Alta 2 present the best pod filling and graining. These result constitute an indicator for breeder for introduction of good genotypes in cocoa collection and their dissemination to farmers by in seeds or budwoods gardens.

2 INTRODUCTION

The cocoa tree is a perennial plant of the genus *Theobroma*. Among the 22 species contained in this genus, only the species *Theobroma cacao* Linné is cultivated for the commercialization of its beans (Mossu, 1990). Côte d'Ivoire is the world's leading producer with a production of approximately 2.150 million tons of commercial cocoa for the 2018-2019 campaign, for a plantation area of approximately 2 million hectares. This production represents 44% of the world supply

and 15% of the Gross Domestic Product (GDP). The main production constraints in Côte d'Ivoire are the aging of the orchard (at least 20% of the orchard is over 30 years old) (Assiri et al., 2009; 2016; Koua et al., 2018), the high pest pressure due to mirids (Kouamé et al., 2014) and diseases such as brown pod rot and Cocoa Swollen Shoot (CSSV) (Kouakou et al., 2011). Also, in recent decades, cocoa production areas in Côte d'Ivoire have been marked by strong climatic variability (Kassin et



al., 2012) and the low level of use of improved plant material for the creation of plantations (Koua *et al.*, 2018). One of the solutions to address the many constraints of cocoa production in Côte d'Ivoire is the dissemination to producers of plant material adapted to the new production context. For this it is necessary to expand the genetic base of the CNRA collection by introduction into CNRA collection cocoa trees presenting good characteristics. The objective of this introduction of clones of various geographical and genetic origins is to select in CNRA germplasm the best cocoa trees for each production constraint. The CNRA clone

collection has around 1000 local and international clones whose some their agronomics characteristics are little known (Guiraud, 2019; Guiraud *et al.*, 2021). This clones include 15 accessions from International cocoa center of Reading for which yield related traits were not yet assessed. The objective of this study is therefore to identify in the collection high-performance accessions for traits of agronomic interest. Specifically, it will involve evaluating the morphological and technological traits of the pods and beans of 15 cocoa accessions potentially tolerant to exogenous diseases.

3 MATERIALS AND METHODES

3.1 Plant material: The plant material used in this study consisted of 15 international accessions introduced from the Reading Quarantine Centre in England for their tolerance to witches' broom and brown rot. After introduction, these accessions were

cloned and planted in a timber yard at the Divo Research Station. Twelve (12) plants per accession were been evaluated five (5) years after planting. The list of accessions is given in Table The list of accessions is given in Table 1:

Table 1. List of plant material from the Reading quarantine centre

Number	Accessions names
1	GU183/G
2	Playa Alta 2
3	ICS 75
4	RB 49
5	APA 5
6	ICS 60
7	ICS 6
8	EET 59
9	OC 77
10	SCA 9
11	CL10/5
12	CL19/10
13	LcTEEN163/A
14	EET95
15	UF 273

3.2 Methods

3.2.1 Experimental design: The experimental design consisted of one bloc in which the accessions were planted in line. Twelve (12) cocoa trees have been established

per accession since June 2018. Field density was 3 x 2.5 m for 0.17 ha

3.2.2 Morphological and technological data collection: In this study, data collection



mainly focused on the pods and beans of cocoa trees planted in the woodlot.

- **Pod-related traits:** Four pod-related parameters were measured on a sample of 15 pods per accession. These are

- **The weight of a ripe pod harvested per tree (PCab):** this parameter was determined using a precision balance by individually weighing the pods of each accession, then dividing this total weight by the number of pods used.

- **The volume of pods harvested per tree (VolCab):** according to the formula of Walters and Hunter (1928), the average volume of a pod (VolCab) of each clone is evaluated according to the following formula

$$VolCab = \frac{L. (\pi. D)^2}{22}$$

where VolCab = volume of the pod; Lcab = length of the pod; Dcab = diameter of the pod;

- **Cortex thickness (EC) of the pod:** this parameter was measured using a caliper after opening the pod.

- **Empty pod weight including the rachis (PCVR):** this parameter was determined after opening the pod and ejecting all fresh beans from the pod (Figure 10).

3.2.3 Bean-related traits: Four bean-related parameters were measured on a sample of 15 pods per accession. These are

- **Number of normal fresh beans (NFFN) per pod:** the number of normal beans was determined on a sample of 15 pods per accession. Each pod was opened and the normal beans were counted.

4 RESULTS

4.1 Evaluation of pod-related traits of 15 cocoa accessions: The comparison of 15 cocoa accessions for four agromorphological traits related to cocoa pods (the weight of a pod (PCab), the weight of an empty pod including the rachis (PCVR), the volume of the pod (VolCab) and the cortex thickness (EC) of a pod) is presented in **Table 2**. The analysis of variance carried out on each of the traits

- **The Number of Flat Fresh Beans (NFFP) of a pod:** after opening each of the pods of each accession, the number of flat beans was determined. These are empty beans, devoid of embryo.

- **The Weight of Normal Fresh Beans (PFFN) of a pod:** the weight of fresh beans of a pod was determined by weighing for each pod the normal fresh beans using a precision electric balance.

3.2.4 Weight of a dry bean, Graining, (P1FS): Graining (P1FS) was assessed by determining the weight of a dry bean (commercial cocoa) (P1FS). Preparation of the commercial cocoa beans was necessary before determining this parameter. The operation consisted of using a sample of fresh beans from healthy and ripe pods of each accession and placing them in carefully labeled openwork fabrics before fermenting them in specially designed containers. Fermentation lasted six days. During the six days, the beans were turned every 2 days and on the 7th day, the fermentation process was stopped, and the fermented beans of each sample representing each family were placed in the sun on racks for drying. This last step lasted approximately seven to eight days depending on the degree of sunshine. After drying, the commercial cocoa beans were transported to the laboratory where a sample of 100 commercial cocoa beans per accession was weighed individually using a precision electric balance.

showed a highly significant accession effect ($P = 0.0001$) on the weight of an empty pod including the rachis, the volume of a pod and the cortex thickness of a pod. The classification of the 15 accessions for the empty pod weight including the rachis trait indicated that the mean values varied from 618.09 g to 295.91 g with a plot mean of 471.6 g and a coefficient of variation (CV) of 29.59%. Accessions UF 273



and ICS 75 had the largest pods with 805.62 and 762.0 cm³ respectively. As for cortex thickness, accession CL10/5 (3.47 cm) had the

highest value. The best empty pod weight values including the rachis were obtained with EET95 (774 g) and ICS75 (735.3 g).

Table 2. Comparison of 15 cocoa accessions for morphological characters related to pods

Accessions	PCab (g)	PCVR (g)	VolCab (cm ³)	EC (cm)
GU183/G	900,5 ^a	418,00 ^{abc}	616,62 ^{abcd}	1,51 ^b
UF 273	822,4 ^a	571,05 ^{ab}	805,03 ^a	1,70 ^b
EET95	774,0 ^a	618,09 ^a	669,10 ^{abcd}	1,76 ^b
ICS 75	735,3 ^a	596,79 ^a	762,9 ^{ab}	1,80 ^b
OC 77	714,7 ^a	380,63 ^{bc}	494,94 ^{cde}	1,57 ^b
RB 49	703,9 ^a	537,69 ^{ab}	644,19 ^{abcd}	1,70 ^b
APA 5	686,9 ^a	520,87 ^{ab}	742,25 ^{abc}	1,69 ^b
CL 10/5	666,2 ^a	537,68 ^{ab}	661,34 ^{abcd}	3,47 ^a
Playa Alta 2	648,0 ^a	487,00 ^{abc}	663,20 ^{abcd}	1,77 ^b
EET 59	611,6 ^a	486,50 ^{abc}	690,44 ^{abc}	1,58 ^b
ICS 6	592,9 ^a	462,94 ^{abc}	582,73 ^{abcde}	1,52 ^b
ICS 60	554,5 ^a	443,53 ^{abc}	587,44 ^{abcde}	1,68 ^b
CL 19/10	540,6 ^a	415,36 ^{abc}	516,39 ^{bcde}	1,45 ^b
SCA 9	404,6 ^a	295,91 ^c	416,97 ^{ed}	1,55 ^b
LcTEEN163/A	375,9 ^a	300,04 ^c	377,82 ^e	1,53 ^b
Moyenne	663,46	471,6	620,66	1,72
CV	26,82	29,59	28,76	13,61
F	1,54	6,3	5,8	2,55
P	0,1004	< 0,0001	< 0,0001	0,0024

Means followed by different letters are statistically different according to the Newman & Keuls test at the 5% threshold.

4.2 Evaluation of fresh bean traits of cocoa accessions pods:

Table 3 presents the comparison of 15 accessions for three fresh bean traits: the number of normal fresh beans (NFFN) per pod, the number of flat fresh beans (NFFP) and the weight of normal fresh beans (PFFN) per pod. Analysis of variance revealed a highly significant accession effect ($P < 0.001$) on each of these three traits. Regarding the number of normal fresh beans

per pod, the results obtained varied from 46.28 beans to 24.8 beans with an overall mean of 36.57 beans and a CV of 21.83%. Accessions (EET95), UF 273 and PLAYA_ALTA2 presented respectively the best pod fillings with 46.28, 40.9 and 40.83 fresh beans per pod. They also obtained the best average weights of fresh beans per pod with respectively 152.59g; 244.23g and 154.54g.

Table 3. Comparison of 15 cocoa accessions for fresh bean-related traits

Accessions	NFFN	NFFP	PFFN (g)
EET95	46,28 ^a	1,71 ^{ab}	152,59 ^{bc}
UF 273	40,90 ^{ab}	1,00 ^{ab}	244,23 ^a
Playa Alta 2	40,83 ^{ab}	1,00 ^{ab}	154,54 ^{bc}
SCA 9	39,27 ^{ab}	0,33 ^{ab}	106,40 ^{bcd}
ICS 75	38,07 ^{ab}	1,45 ^{ab}	134,09 ^{bc}
CL 19/10	37,80 ^{ab}	1,20 ^{ab}	121,53 ^{bcd}
ICS 6	37,25 ^{ab}	1,87 ^{ab}	126,01 ^{bcd}
EET 59	37,10 ^{ab}	2,40 ^{ab}	118,52 ^{bcd}



ICS 60	36,65 ^{ab}	1,200 ^{ab}	105,71 ^{bcd}
APA 5	35,91 ^{ab}	0,45 ^{ab}	161,00 ^b
CL 10/5	35,22 ^{ab}	0,89 ^{ab}	123,61 ^{bcd}
RB 49	33,78 ^{ab}	0,11 ^b	163,02 ^b
GU183/G	33,74 ^{ab}	0,58 ^{ab}	116,25 ^{bcd}
OC 77	31,33 ^{ab}	3,39 ^a	101,09 ^{cd}
LcTEEN163/A	24,80 ^c	1,40 ^{ab}	71,47 ^d
Moyenne	36,57	1,31	129,79
CV	21,83	48,42	31,31
F	2,90	2,85	9,4
P	0,0006	0,0007	< 0,0001

Means followed by different letters are statistically different according to the Newman & Keuls test at the 5% threshold.

4.3 Comparison of 15 cocoa accessions for the weight of a dry bean:

The evaluation of the graining (P1FS) of the accessions materialized by the weight of a merchantable cocoa bean is presented in **Table 4**. The analysis of the table indicates a very highly significant accession effect ($P = 0.0001$) for this

parameter. The means varied from 2.47 g to 1.01 g with an overall mean of 1.47 g and a CV of 17.63%. The accessions APA 5 and RB 49 presented the heaviest dry beans with respectively 2.47 g and 2.03 g per dry bean. The lightest merchantable bean was presented by LCTEEN 163/A with the value of 1.01 g.

Table 4. Comparison of 15 cocoa accessions for graining assessed by the weight of a dry bean

Accessions	P1FS (g)
APA 5	2,47 ^a
RB 49	2,03 ^b
UF 273	1,83 ^c
ICS 6	1,45 ^d
GU183/G	1,43 ^d
CL 10/5	1,42 ^d
ICS 75	1,40 ^d
CL 19/10	1,39 ^d
Playa Alta 2	1,37 ^d
EET 59	1,35 ^d
OC 77	1,27 ^e
SCA 9	1,24 ^e
EET95	1,18 ^e
ICS 60	1,14 ^e
LcTEEN163/A	1,01 ^h
Moyenne	1,47
CV	17,63
F	212,70
P	< 0,0001

Means followed by different letters are statistically different according to the Newman & Keuls test at the 5% threshold.

5 DISCUSSION

This study aimed to select high-performance cocoa trees for pod filling and seeding. The

results showed a highly significant effect of accessions ($P = 0.0001$) on the weight of an



empty pod including the rachis, the volume of a pod, the thickness of the cortex of a pod, the number of normal fresh beans (NFFN) per pod, the number of flat fresh beans (NFFP), the weight of normal fresh beans (PFFN) per pod and the weight of a commercial cocoa bean. The results indicate that accessions UF 273 and ICS 75 had the largest pods with 805.62 and 762.0 cm³, respectively. Accessions EET 95, UF 273 and PLAYA_ALTA 2 presented the best values of number of normal beans with respectively 46.28, 40.9 and 40.83 fresh beans per pod. They also exhibited the best average weights of fresh beans per pod with respectively 152.59g; 244.23g and 154.54g. These accessions can be considered as presenting a good filling of the pods (Lachenaud *et al.*, 2006). Indeed, the good filling of the pods would be according to Braudeau (1969), Lanaud (1987) attributable to a sufficient quantity of compatible pollen allowing a good pollination of the flowers. The number of beans per pod thus constitutes an indicator of the good productivity of cocoa

trees (Lachenaud *et al.*, 2006). Regarding cortex thickness, it was rather accession CL10/5 (3.47 cm) that presented the highest value. The great thickness of the pod cortex of this clone is an asset for the resistance of their pods to *Phytophthora palmivora* (Lachenaud, 2007), the main agent of brown rot of pods in Côte d'Ivoire. Indeed, a great thickness of the cortex would delay the progression of *P. palmivora* zoospores in the tissues of the pod pericarp, which is an advantage for preserving cocoa beans from infections in the field caused by brown rot disease (Tahi, 2003). About the graining evaluated in our study by the average weight of a dry cocoa bean (P1FS), the accessions APA 5 (2.47 g), RB 49 (2.03 g) and UF 273 (1.83 g) showed the best average values. The lightest merchantable bean was presented by LCTEEN 163/A with 1.01 g. Thus, all these averages are above the industrial standard which is 1 g for 1 dry cocoa bean (Braudeau 1969). Therefore, the 15 accessions studied could be considered as good graining (Lachenaud *et al.*, 2006).

6 CONCLUSION

This study consisted of analyzing 15 accessions from the Reading quarantine center for pod filling and graining. It emerges from this study that accessions UF 273, EET 95 and Playa Alta 2 were characterized by good pod filling (40.90; 46.28; 40.83 beans), a higher weight of fresh beans per pod (244.23 g; 152.59g; 154.54g).

Accessions APA 5 (2.47 g), RB 49 (2.03 g) and UF 273 (1.83 g) exhibited the best graining with high values of weight of a merchantable cocoa bean. These results constitute an indicator for the breeder in the choice of parents to be introduced into the varietal improvement program.

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