__Original Research Article__

Evaluation of cocoa full-sib progenies for yield and resistance to black pod disease in Cameroon

Abstract

23 cocoa full-sib progenies were assessed and compared to 3 control progenies. in a trial plot set up in a research station located in Cameroon. The cocoa trees were assessed during eight consecutive years of cocoa production. A large level of variation was observed among the progenies for mortality rate (ranging between 6 and 52%), annual potential yield (ranging between 151 and 1,808 kg/ha), annual actual yield (ranging between 114 and 1,159 kg/ha) and black pod disease incidence (ranging between 19 and 39,8%) caused by*Phytophthora megakarya***.** Nine of the assessed full-sib progenies were identified as promising and the authors suggest how to confirm their performances before their release to farmers.

Keywords: breeding, *Theobroma cacao* L., *Phytophthora megakarya*, disease incidence, potential yield, actual yield

Introduction

Cacao (Theobroma cacao L.) is a Malvacea (Alverson et al. 1999) originating in South America (Motamayor et al 2002), cultivated for its beans. used for the confection of chocolate. The first indices of use of cocoa beans were discovered in Ecuador, dating back to 3.300 years A.C. (Zarrillo.et al 2018).

The species was separated in three morpho-geographical groups: Criollo, Forastero and Trinitario, the last one being described as a hybrid group between Forastero and Criollo (Motamayor et al, 2003). The Forastero group is separated in Upper amazon Forastero and Lower amazon Forastero, this last sub-group including the amelonado variety, largely used for cocoa cultivation in Africa. This classification of Criollo and Forastero groups was revised and refined by Motamayor et al 2008, who proposed a structure consisting in ten genetic groups, from their molecular diversity results.

The first introduction of cacao to Cameroon dates back to 1876, probably from Trinidad, with an unknown impact on cacao cultivation, because of the low number (13) of plants introduced. Later, a second introduction of 322 plants, probably from Sao Tomé, took place in the south western region of the country. These plants consisted in varieties collected in various countries of Latin America and are supposed to have been used as sources of seeds for cocoa cultivation in this region (Bartley, 2005).

Today, Cameroon produces 290,000 tons of cocoa beans (exported after fermentation and drying processes), and is now the fourth highest producing country of the world), contributing to 6% of the worldwide production (ICCO, 2022).

In Cameroon, the first cocoa breeding effort dates back to the beginning of the 1950s, based on the identification of promising trees in the cocoa farms in the south of the country. The seeds collected on the promising cacao trees were sown in a research station of the IRCC (Institute of Research of Cacao and Coffee) in Nkoemvone, and allowed the selection of 489 high yielding trees. These trees were multiplied using rooted cuttings and included in the local cocoa gene bank. with a SNK name (Selection of Nkoemvone). Among these SNK clones, 35 were released to local cocoa farmers as plants issued from plagiotropic rooted cuttings from 1957. This program was abandoned in 1968 because of the poor performances of the clones released to farmers, probably because of the absence of taproot of the cloned trees (Paulin et Eskes, 1995).

In 1959, a new cocoa breeding program was initiated. based on the creation and selection of full-sib progenies. issued from 350 crosses between local SNK clones and imported clones. issued from selection performed in Trinidad and from collecting expedition in Peru (Paulin et Eskes. 1995). The parents of the 22 highest-yielding full-sib progenies were planted in bi-clonal seed-gardens between 1971 and 2002 in the southern, central and south western parts of the country (Efombagn. 2012).

A round of farmers' interviews performed in the late 1990s revealed that a major part of them were satisfied with the level of yield shown by the commercial varieties but, on the other hand. they tended to find them more susceptible to black pod disease, caused by *Phytophthora megakarya*, than the traditional amelonado variety, locally called "German cocoa" (Efombagn et al 2009). This finding showed the need for the future release of new cocoa varieties combining high yield and resistance to black pod disease.

In 2005, in the frame of an international project (Eskes 2011), a progeny trial plot was set up in the research station of Barombi-kang, in the south west region of Cameroon, a region with climatic conditions favoring the incidence of black pod disease. Thistrial plot was set upas part of a regional trial, aiming at comparing full-sib progenies from Cameroon, Ghana, Côte d'Ivoire and Nigeria and at selecting new cocoa progenies tolerant to black pod disease. This article presents the data obtained on survival, vigor, yield and yield components and incidence of *Phytophthora megakarya* on the 26 progenies under assessment, and proposes ways to valorize the most promising genotypes.

Material and Methods

Vegetal material

The 26 assessed progenies, indicated in table 1, were obtained as follows:

- 23 full-sib progenies were issued from hand-pollination performed:
  - in the IRAD research station of Nkolbisson, near Yaoundé, in the central part of the country, in the case of the local full-sib-progenies
  - in the research station of Divo of the CNRA (Centre National de Recherche Agronomique), in Côte d'Ivoire, in the research station of Tafo of the CRIG (Cocoa Research Institute of Ghana) and in the research station of Ibadan of the CRIN (Cocoa Research Institute of Nigeria) in the case of the full-sib progeniesintroduced from other countries.

- The seeds from other countries were brought to Nkolbisson, by researchers from the previously mentioned research institutes.
- All the seedlings were raised in the nursery of the Nkolbisson research station, before their shipment to Barombi-kang, where they were planted upon arrival.
- 3 half-sib progenies were used as controls and consisted in:

    progeny 26: mixture of four full-sib progenies, issued from pods harvested in four local bi-clonal seed-gardens. Thus, this control represents a subset of commercial varieties.

    progeny 9: mixture of seedlings issued from pods harvested on a commercial plot set using commercial varieties. This type of vegetal material is often used by farmers who have no access to commercial varieties and will be referred in the paper as farmers'hybrid.

    - progeny 10: mixture of seedlings issued from pods harvested on farmers' plot planted with the traditional variety (German cocoa). This type of vegetal material is often used by farmers who have no access to commercial varieties.

The control half-sib progenies were raised in greenhouse in Barombi-kang.

Design of the trial plot

For each of the 26 progenies, five rows of ten seedlings were established in the plot, resulting in 50 trees per progeny.

Agronomical management of the trial plot

A total number of 1,500 cocoa seedlings were established in absence of permanent shade in a 1.25 ha plot, at a planting space of 3 x 3 meters. corresponding to a 1,111 trees/ha planting density. The cocoa seedlings were intercropped with maize during the first two years after establishment of the cocoa seedlings.

The plot was regularly submitted to weeding (manual or chemical).

No fungicide was applied during the assessment period and insecticide was applied from 2013.

Assessment methodology

Every two weeks, healthy ripe pods as well as rotten pods (ripe and unripe) were harvested on each cocoa tree and counted, during eight consecutive years, during the period from 2008 to 2016. These harvested and counting rounds were used to estimate the yield of each cocoa tree and the incidence of pod rot, caused by *Phytophthora megakarya*. The traits assessed are described below:

Cumulated number of total pods: sum of all the pods (healthy, unripe rotten and ripe rotten) harvested during the period from 2008 to 2016 were summed up. This number was calculated for all the trees, including the ones which died before the end of the assessment period.

Cumulated number of healthy pods: sum of all the healthy pods harvested during the period from 2008 to 2016 were summed up. This number was calculated for all the trees, including the ones which died before the end of the assessment period.

Mean weight of cocoa per pod (g): In 2012 and 2015, the weight of cocoa was estimated on 871 of the 1,300 trees. For this purpose, the beans extracted from the pods harvested on each one of the trees were placed in separated fermentation nets and submitted to a six days fermentation in a box. The samples of fermented cocoa beans were then dried and then weighted separately.

Potential yield per tree (g): cumulated number of total pods multiplied by the weight of cocoa per pod estimated on the tree (or by the mean value of the progeny when the data for the individual tree were not available)

Actual yield per tree (g): cumulated number of total pods multiplied by the weight of cocoa per pod estimated on the tree (or by the mean value of the progeny when the data for the individual tree were not available).

Estimated potential annual yield (kg/ha): “potential yield per tree” x 1,111/(8x1,000). 1,111 is the usually recommended planting density, 8 is the number of years of the assessment and 1,000 the conversion rate from gram to kilo.

Estimated actual annual yield (kg/ha): "actual yield per tree" x 1,111/(8x1,000). 1,111 is the usually recommended planting density, 8 is the number of years of the assessment and 1,000 the conversion rate from g to kg.

Mean weight of one fermented and dried bean (g): From each sample of fermented and dried cocoa beans, a sub-sample of 100 beans was weighted, in order to estimate the mean weight of one bean (wb). This trait is important. because some chocolate manufacturers are reluctant to process beans with a mean weight lower than one gram.

Mean number of beans per pod: For each tree, the number of beans per pod was estimated by the ratio between the weight of cocoa per pod and the mean weight of one bean.

Incidence of black pod disease, caused by *Phytophthora megakarya* is calculated by the ratio between rotten pods (ripe and unripe) and the total number of harvested pods.

Adult vigor: trunk's girth of the adult cocoa trees measured at a 30 cm height in 2012.

%survival: cumulated number of dead trees at the end of the 2008-16 period, divided by the number of initially planted trees

Statistical analyses

XLSTAT software was used for performing ANOVA and ranking of progenies using Tukey test for all the variables. Each row of 10 trees was used as a replication.

Result and Discussion

The results from ANOVA show a highly significant effect of the progeny for all the traits under evaluation, as shown in table 2, in which meanvalues and variation coefficient are presented for each trait.

The actual yield value(604 kg/ha) is rather low and similar to the one reported in traditional farmers plots in the central part of Cameroon by Jagoret et al 2017, but lower than the one observed on some of on farm progeny trial plots by Feumba de Tchoua et al 2021, in an area of Central Cameroon region with climatic conditions resulting in a low incidence of *Phytophthora megakarya*. The low mean level of yield in the plot can be explained by the rather high % of mortality (27%) and of rotten pods (31,4%). A similar % of mortality was observed on some of the on-farm trial plots assessed by Feumba de Tchoua et al 2021 in the central region of Cameroon.

The high % of mortality observed in our case can be explained by the setting up of the plot in full sun conditions, in absence of insecticide treatments until 2013

The results observed for the components of potential yield (cumulated total number of pods, weight of dried cocoa per pod) are indicated in Table 3. These data allow to estimate the level of yield that could be expected in absence of the black pod disease.

The lowest yielding progeny (progeny10) is the "german cocoa" control, a traditional variety cultivated in Cameroon since the introduction of cocoa in this country. Its very low level of yield in this plot can be explained by its poor level of adaptation to full-sun conditions, evidenced by its low level of survival (58%) in our plot and already reported by Sounigo et al 2017 in on farm trials.

The second lowest yielding progeny (progeny 26) is another control, consisting in a mixture of commercial hybrids released to the farmers since the late 1970s. The yield value of progeny 9, the third control (farmers'hybrids, progenies issued from pods harvested in a plot planted with commercial varieties) is much higher, although lower than the mean yield value of the plot

The low level of yield observed on progenies 9 and 26 are partially explained by their low level of survival (54 and 48%).The very low level of potential yield observed on the mixture of commercial progenies, similar to the one observed on the traditional variety, is surprising and coincides neither with the general satisfactory level of yield reported in cocoa farmers' interviews (Efombagn et al 2009) nor with the two-fold higher level of yield observed by Sounigo et al (2017) for this type of material in comparison with the traditional variety, in on farm progeny trials. The higher yield value of the farmers' hybrids than for the mixture of commercial varieties does not coincide with the comparable level observed by Sounigo et al (2017) for these two types of progenies.

The progenies 11, 14, 15,13, 18, 12, 2 and 1 present a level of potential yield significantly higher than the control progeny 9, ranging between 1,101 (progeny 1) and 1,808 (progeny 11) kg/ha.

The two progenies 11 and 14 are the highest yielding, despite a relatively low level of survival (70 and 68%) which can be considered as the result from a poor level of adaptation to full sun conditions. Progeny 20 produced a high number of pods (271), but these contain a low weight of cocoa (25 grams of dried cocoa per pod). Progeny 22 produced a rather large number of pods (202), but suffered a high mortality rate (44%).

The variation in stem girth values of the 8 highest yielding progenies suggests a certain level of variation for their optimal planting density.

The ranking of the progenies based on actual yield, indicated in table 4, shows some differences with the one based on potential yield, because of differences of black pod incidence between progenies.

A lower incidence of *Phytophthora*is observed on the traditional control variety progeny (progeny 10) than on control progenies issued from commercial varieties (progenies 9 and 26), coinciding with the information reported by interviewed cocoa farmers (Efombagn et al 2009).

The progenies with a level of actual yield, based on healthy pods, significantly higher than the highest yielding control progeny (progeny 9) are progenies 11, 14, 12, 2 and 21, with a level of yield ranging between 777 and 1,159 kg/ha.The progenies 1,13, 15 y 18, despite their high potential yield level, are not included in this list, because of their relatively high level of black pod diseaseincidence, ranging between 34.5 and 39.1%.On the contrary, the progeny 21 is part of this list, thank to its low level of black pod disease incidence (19%). Progeny 11 combines high levels of both potential and actual yield despite its high level of black pod disease incidence (35.6%), while progenies 14,12 and 2 combine high levels of potential and actual yield levels with relatively low levels of black pod disease incidence, ranging between 23.6 and 27.7%.

The weight of cocoa per pod is a combination of two traits: the mean weight of one bean and the number of beans per pod, and table 5 shows the data for these attributes. The mean values of dried cocoa per pod range between 25 and 44, the first value being much lower than currently observed values which are usually around 40 g per pod. In addition to its contribution to yield, this trait is also an indicator of the amount of work dedicated to pod harvest and breakage for the obtaining of one kilo of commercial cocoa, and farmers obviously prefer cocoa trees producing pods with higher cocoa weight. The highest progenies (in bold in the table) show mean weight of cocoa per pod values between 31 (progeny 12) and 44 (progeny 11) grams.

The mean weight of one bean of dried cocoa observed for the highest-yielding progenies ranges between 1,1 (progeny 12) and 1,37 (progeny 11) grams, corresponding to suitable values for the trade of this product without any risk of rejection from the buyers.

The mean numbers of beans per pod are rather low, ranging between 24.4 and 34.5 and are the main reason for the low mean cocoa weight per pod.

The nine highest yielding progenies identified for potential and/or actual yield in the trial plot should be assessed in confirmation trials before their release to cocoa farmers.Table 6 indicates the conditions in which the trial plots should be set up and the adequate conditions for the release of the confirmed progenies to farmers.

Only five of the selected progenies can be confirmed in trial plots in Cameroon, because of the absence of the parents of the progenies 12,13,18 and 21 in the country, as mentioned in table 1.

If one considers that the high level of mortality observed on most of the progenies is mainly due to the establishment of the plot under full-sun conditions, then the progenies 2,11,12,14 and 18 (mortality ranging between 18 and 32%) should be assessed under shaded conditions, for their future release to farmers cultivating their cocoa in shades agroforestry systems, while the progenies 1,13 and 21 can be assessed under low shade management, because of their lower mortality rate (ranging between 6 and 12%).

The progenies 2, 12, 14 and 21, with a % of rotten pods ranging between 19 and 27.7%, can be assessed in sites with high black pod incidence for their future release to farmers in areas with high prevalence of this disease, while the progenies 1,11,13,15 and 18, with a % of rotten pods ranging between 34.5 and 39.1%, should be assessed and released in areas with low incidence of this disease.

The rather high vigor observed for progenies 11,13 and 14 (stem girth ranging between 44.2 and 50.5 cm) indicate that it would be appropriated to assess them under average and low planting density conditions while the relatively low vigor of progenies 1,12 and 21 (stem girth ranging between 35 and 38 cm) indicate that it would be apropriated to assess them under average and high planting density conditions.

The assessment of the progenies introduced from other countries in our trial allows their evaluation under high black pod incidence conditions. It must be noted that some of our full-sib progenies created in Cameroon have also been introduced to Ghana, Ivory Coast and Ghana, where they can be assessed for their resistance to cocoa swollen shoot virus.

If the promising progenies can only be confirmed in the countries where the parents are present, on the other hand, the favorable alleles brought by the introduced progenies can be introduced to the local breeding program through to the selection of individual trees from these progenies and their use as parents in a next cycle of crosses.

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Progeny Id	geographic origin	Female parent: Name	Female parent: Geographic origin	Female parent: Morpho-geographic group	Male parent: Name	Male parent: Geographic origin	Male parent: Morpho-geographic group
1	Cameroon	T 60/887	Trinidad	UAF	SNK 413	Cameroon	TR
2	Cameroon	UPA 134	Cameroon	UAF	SNK 64	Cameroon	TR
3	Cameroon	PA 107	Peru	UAF	SNK 614	Cameroon	*UAF x TR*
4	Cameroon	PA 107	Peru	UAF	ICS 40	Trinidad	TR
5	Cameroon	*SNK 625*	*Cameroon*	*UAF x TR*	*SNK 620*	*Cameroon*	*TR x UAF*
6	Cameroon	SNK 614	*Cameroon*	*UAF x TR*	SCA 24	Peru	UAF
7	Cameroon	SNK 614	*Cameroon*	*UAF x TR*	PA 7	Peru	UAF
8	Cameroon	SNK 614	*Cameroon*	*UAF x TR*	SNK 608	Cameroon	TR
9	*Cameroon*	*farmers' trees*	*Cameroon*	*UAF x TR UAF x AMEL*	*open pollination*		
10	*Cameroon*	*farmers' trees*	*Cameroon*	*AMEL*	*open pollination*		
11	Cameroon	SNK 625	Cameroon	*UAF x TR*	NA 33	Peru	UAF
12	Côte d'Ivoire	*IFC 303*	Côte d'Ivoire		*PA 121*	Peru	UAF
13	Côte d'Ivoire	*PA 4*	Peru	UAF	P 7	Peru	UAF
14	Côte d'Ivoire	T 60/887	Trinidad	UAF	ICS 89	Côte d'Ivoire	TR
15	Côte d'Ivoire	SNK 12	Cameroon	TR	PA 150	Peru	UAF
16	Côte d'Ivoire	*PA 13*	Peru	UAF	*P 19*	Peru	UAF
17	Ghana	*T 60/78*	Trinidad	UAF	*T 85/87*	Trinidad	UAF

18	Ghana	T 63/967	Trinidad	UAF	*T 17/524*	Trinidad	UAF
19	Ghana	MAN 15/2	Brazil	AMEL	*T 85/799*	Trinidad	UAF
20	Ghana	GU 144/C	French Guiana	GU	NA 33	Peru	UAF
21	Ghana	*AI/154*	Ghana	UAF	*T 60/78*	Trinidad	UAF
22	Ghana	GU 144/C	French Guiana	GU	EQX 3338	Ecuador	
23	Nigeria	*T 85/799*	Trinidad	UAF	*PA 120*	Peru	UAF
24	Nigeria	*P 7 x PA 150*	Nigeria	UAF	IMC 47	Peru	UAF
25	Cameroon	*SNK 620*	*Cameroon*	*TR x UAF*	*PA 150*	*Peru*	*UAF*
26	*Cameroon*	*mixture*	*Peru and Cameroon*	*UAF, TR, AMEL*	*mixture*	*Peru and Cameroon*	*UAF, TR, AMEL*

Table 1. Description of the 26 progenies assessed in the trial plot. UAF = upper amazon Forastero, TR = Trinitario, AMEL = Amelonado, GU = Guyanese. The parents indicated in italics are not present in Cameroon.

Variable	F	Significance	Mean value	CV (%)
Total number of harvested pods 2008-16	7.5	**	179	47
Number of healthy harvested pods 2008-16	6.7	**	124	51
% of rotten pods 2008-16	3.4	**	31,4	29
Potential yield (cocoa from total pods) 2008-16 (g/tree)	8.8	**	6,34 *(880 kg/ha)*	47
Actual yield (cocoa from healthy pods) 2008-16 (g/tree)	7.1	**	4,35*(604 kg/ha)*	50
Trunk girth 2012 (cm)	15.5	**	38.8	17

% survival	4,1	**	73	28
Weight of cocoa per pod (g)	13.3	**	36.2	14
Weight of one dried bean (g)	3.4	**	1.18	11
Estimated number of beans per pod	9.5	**	30.7	9

Table 2: data from the ANOVA performed on several traits (the values in italics are yield expressed in kilos of cocoa per hectare)

Progeny Id	cumulated potential yield 2008-16 (g/tree)	N.K (5%)	estimated annual potential yield (kg/ha)	cumulated total number of pods 2008-16	N.K (5%)	mean weight of dried cocoa per pod (g)	N.K (5%)	% survival 2008-2016	N.K (5%)	mean trunk girth 2012	N.K (5%)
11	13,019	a	1,808	307	a	44	a	70	abcd	46.4	ab
14	8,952	ab	1,243	255	abc	37	abcdefg	68	abcd	44.2	abcd
15	8,822	ab	1,225	239	abc	38	abcdef	90	ab	42.2	bcde
13	8,463	bc	1,175	226	abcd	38	abcdef	94	a	50.5	a
18	8,432	bc	1,171	209	abcde	40	abcd	82	abcd	39.9	bcde
12	8,426	bc	1,170	278	ab	31	gh	82	abcd	37.4	cde
2	8,260	bc	1,147	239	abc	35	cdefg	80	abcd	40.8	bcde

1	7,926	bcd	1,101	214	abcde	38	abcdef	90	ab	38,0	cde
7	7,240	bcde	1,006	203	abcde	36	cdefg	78	abcd	41.7	bcde
20	7,202	bcde	1,000	271	ab	25	h	78	abcd	39.3	bcde
22	7,002	bcde	972	202	abcde	35	cdefg	56	abcd	37	de
21	6,863	bcde	953	159	bcdefg	43	a	88	abc	35	ef
3	6,694	bcdef	930	187	abcdef	36	cdefg	72	abcd	45.2	abc
24	6,405	bcdef	889	197	abcdef	34	defg	92	ab	44.6	abcd
17	6,050	bcdef	840	155	bcdefg	40	abcde	66	abcd	36.8	de
19	5,820	bcdef	808	165	bcdef	35	cdefg	80	abcd	37.9	cde
16	5,808	bcdef	807	174	abcdef	33	fg	86	abcd	39.1	bcde
4	5,772	bcdef	802	173	bcdef	34	efg	54	bcd	44.5	abcd
25	4,668	bcdefg	648	127	cdefg	37	bcdefg	54	bcd	37.8	cde
6	4,601	bcdefg	639	175	abcdef	26	h	78	abcd	28.3	fg
23	4,210	cdefg	585	122	cdefg	35	cdefg	94	a	35.2	ef
5	3,979	cdefg	553	96	defg	43	ab	62	abcd	35.9	ef
8	3,429	defg	476	85	efg	41	abc	50	cd	38.1	cde
9	3,381	efg	470	101	defg	35	cdefg	54	bcd	34.5	ef
26	2,210	fg	307	64	fg	35	cdefg	48	d	35.7	ef
10	1,087	g	151	32	g	39	abcdef	58	abcd	21.7	g

Table 3: mean value and ranking of the progenies for traits associated to potential yield, estimated from the total number of pods (healthy ripe + unripe rotten + ripe rotten) harvested on all the planted cocoa trees and for vigor, measured by trunk girth.

Progeny Id	Cumulated actual yield 2008-16 (g/tree)	N.K (5%)	Estimated annual actual yield (kg/ha)	Cumulated number of healthy pods 2008-16	N.K (5%)	% of rotten pods 2008-16	N.K (5%)	Mean weight of dried cocoa per pod (g)	N.K (5%)
11	8343	a	1,159	198	ab	35.6	ab	44	a
14	6746	ab	937	190	ab	24.4	ab	37	abcdefg
12	6398	abc	889	213	a	23.6	ab	31	gh
2	5931	abcd	824	172	abc	27.7	ab	35	cdefg
21	5593	abcde	777	130	abcde	19,0	b	43	a
20	5538	abcdef	769	209	a	23.2	ab	25	h
13	5507	abcdef	765	146	abcd	35.7	ab	38	abcdef
18	5497	abcdef	763	136	abcde	34.5	ab	40	abcd
15	5484	abcdef	762	148	abcd	39.1	a	38	abcdef
1	5029	abcdef	698	137	abcde	36.9	a	38	abcdef
3	5005	abcdef	695	140	abcde	27.8	ab	36	cdefg

24	4817	bcdefg	669	148	abcd	24.6	ab	34	defg
22	4584	bcdefg	637	133	abcde	34.8	ab	35	cdefg
7	4492	bcdefg	624	126	abcdef	39,0	a	36	cdefg
16	4141	bcdefgh	575	125	abcdef	29.3	ab	33	fg
19	4134	bcdefgh	574	116	abcdef	29.1	ab	35	cdefg
17	4114	bcdefgh	571	106	bcdef	32.2	ab	40	abcde
4	3480	bcdefgh	483	104	bcdef	39.3	a	34	efg
6	3340	bcdefgh	464	127	abcdef	27.3	ab	26	h
23	3006	cdefgh	418	86	cdef	30.5	ab	35	cdefg
25	2941	cdefgh	408	81	cdef	37.1	a	37	bcdefg
5	2470	defgh	343	59	def	38.4	a	43	ab
8	2311	efgh	321	58	def	32.8	ab	41	abc
9	2045	fgh	284	62	def	39.8	a	35	cdefg
26	1447	gh	201	43	ef	32.3	ab	35	cdefg
10	819	h	114	24	f	22.6	ab	39	abcdef

Table 4:mean value and ranking of the progenies for incidence of *Phytophthora* and other traits associated to actual yield, estimated from the number of healthy pods.

Id	mean weight of dried cocoa per pod (g)	N.K (5%)	mean weight of 1 dried bean (g)	N.K (5%)	mean number of beans per pod	N.K (5%)
11	**44**	**a**	**1.37**	**ab**	**31.9**	**abcde**
21	**43**	**a**	**1.32**	**abc**	**32.9**	**ab**
5	43	ab	1.43	a	30	bcdef
8	41	abc	1.28	bcde	32.3	abcd
18	**40**	**abcd**	**1.23**	**cdefg**	**32.6**	**abc**
17	40	abcde	1.15	fghij	34.4	a
10	39	abcdef	1.16	fghij	33.3	ab
13	**38**	**abcdef**	**1.20**	**defghi**	**31.7**	**abcde**
15	**38**	**abcdef**	**1.2**	**defghi**	**31**	**abcde**

1	**38**	**abcdef**	**1.22**	**cdefgh**	**31.3**	**abcde**
14	**37**	**abcdefg**	**1.3**	**bcd**	**28.6**	**cdef**
25	37	bcdefg	1.17	efghij	31.1	abcde
3	36	cdefg	1.13	ghijk	31.7	abcde
7	36	cdefg	1.24	cdefg	28.5	defg
2	**35**	**cdefg**	**1.20**	**cdefghi**	**29.4**	**bcdef**
22	35	cdefg	1.11	hijkl	31.4	abcde
19	35	cdefg	1.06	jkl	33.4	ab
23	35	cdefg	1.14	ghijk	30.5	abcdef
9	35	cdefg	1.23	cdefg	28.6	cdef
26	35	cdefg	1.26	bcdef	27.9	efg
24	34	defg	1.02	kl	33	ab
4	34	efg	1.27	bcdef	26.6	fg
16	33	fg	1	l	33	ab
12	**31**	**gh**	**1.09**	**ijkl**	**28.3**	**defg**
6	26	h	0.83	m	31.5	abcde
20	25	h	1.01	kl	24.4	g

Table 5: cocoa bean and pod attributes (the values in bold are the ones observed for the highest yielding progenies).

N°	cross	country for confirmation trials	adapted to low shade management	adapted to high incidence of black pod disease	expected optimal planting density
1	T 60/887 x SNK 413	Cameroon	Yes	no	average/high
2	UPA 134 x SNK 64	Cameroon	No	yes	average
11	SNK 625 x NA 33	Cameroon	No	no	average/low
12	IFC 303 x PA 121	Côte d'Ivoire	No	yes	average/high
13	PA 4 x P 7	Côte d'Ivoire	Yes	no	average/low
14	T 60/887 x ICS 89	Cameroon and Côte d'Ivoire	No	yes	average/low
15	SNK 12 x PA 150	Cameroon and Côte d'Ivoire	Yes	no	average
18	T 63/967 x T 17/524	Ghana	No	no	average

21	AI/154 x T 60/78	Ghana	Yes	yes	average/high

Table 6: promising progenies, that can be considered for future release to farmers after their assessment in confirmation trials.