Original Research Article

COMPARISON BETWEEN FARMERS' AND COMMERCIAL COCOA VARIETIES in CAMEROON

ABSTRACT

The present paper shows the results from eight on farm progeny cocoa trial plots set up in 2007 and 2008 on fallow and savannah, in four sites of Central Cameroon region. Mortality rate and yield were estimated on commercial cocoa varieties, consisting in progenies issued from pods harvested in bi-clonal seed gardens set up by researchers and managed by extension bodies, as well as on farmers' varieties, issued from seeds obtained by farmers from pods harvested in their own fields. Despite the high variability observed among the trial plots for the three traits under assessment, it was possible to observe significant differences between some of the assessed varieties. The significantly highest yielding progeny is one of the assessed commercial varieties, issued from the cross IMC 67 x SNK 64. The significantly lowest yielding progeny is the farmers' traditional amelonado variety (German cocoa). No significant difference was observed between "farmers' hybrids" and the two other assessed commercial varieties, consisting in the progeny issued from the cross between UPA 143 and SNK 64 and from a mixture of six commercial progenies. The consequences of these data on the selection and release of commercial varieties in Cameroon are discussed.

Keywords: cocoa, yield, farmers' varieties, commercial varieties

1. INTRODUCTION

Cacao tree (*Theobroma cacao* L.), a Malvacea (Alverson et al,1999), originating from South America (Motamayor et al 2002), is cultivated for its beans, used for the confection of chocolate. Cocoa bean use dates back to 3,300 years B.C. (Zarrillo et al 2018), in Ecuador. The species is composed of three morpho-geographical groups: Criollo, Forastero and Trinitario, the last one being considered as a hybrid group, between Forastero and Criollo (Motamayor et al, 2003). This classification of Criollo and Forastero groups was refined by Motamayor et al (2008), who showed the existence of ten genetic groups, based on a molecular diversity study. First cacao introduction to 1876 Cacao was introduced to Cameroon in 1876, probably from Trinidad, but the impact of this first introduction (only 13 plants) on cacao cultivation in the country remains unknown. Later, in 1885, 322 plants were introduced to the south western region of the country, most probably from Sao Tomé. The 322 plants represented varieties collected in various countries of Latin America. It is supposed that these new plants were then 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), representing 6% of the worldwide production, and placing this country at the position of fourth highest producing country of the world (ICCO, 2022). In Cameroon, cocoa breeding started at the beginning of the

1950s, and was first based on the identification of promising trees in the cocoa farms, in the south of the country, followed by the selection of the highest yielding individual trees issued from open pollination of these promising trees and assessed in the research station located in the same area as the visited farms. These high yielding trees were then vegetatively multiplied and included in the local cocoa gene bank, named with a SNK code (Selection of Nkoemvone), and 35 of these SNK clones were released to local cocoa farmers, under the form of plants issued from rooted cuttings, from 1957. However, the poor performances of the clones released to farmers, probably caused by the poor rooting system of the plants issued from rooted plagiotropic cuttings (Paulin and Eskes, 1995). In 1959, a new cocoa breeding program was initiated, consisting in the creation, assessment and selection of full-sib progenies, issued from 350 crosses between local SNK clones and imported Upper Amazon Forastero clones (Paulin and Eskes, 1995). The releasing of the 22 highest-yielding full-sib progenies was then ensured by the establishment of bi-clonal seed-gardens, planted with the parents of these progenies, between 1971 and 2002, in the southern, central and south western parts of the country (Asare et al 2010, Efombagn, 2012). These progenies have been shown to partially contribute to the genetic background of the cocoa farms in Cameroon (Efombagn et al, 2006). However, the release of the progenies issued from these bi-clonal seed-gardens has slowed down during the last twenty and it is estimated that it has failed to cover more than 20% of the demand (Asare et al 2010, Efombagn 2012). As a result, the cocoa farmers have continuously used their own cocoa plots or the ones of their neighbors as sources of seeds. In other cases, the use of these progenies has resulted from farmers' preference for the traditional variety (German cocoa), considered as less susceptible to black pod disease caused by *Phytophthora megakarya* than the varieties issued from the seed gardens (Efombagn et al, 2009). In order to evaluate the impact of resulting from the use of their own vegetal material by farmers, on farm experimental plots were set up in 2007 and in 2008, in which commercial progenies issued from seed gardens are compared to progenies issued from farmers' fields.

2. RESEARCH METHOD

*Planting material:*A total number of 1,838 cocoa trees was assessed, representing 5 progenies or progeny mixtures, as described in Table 1.

Table 1: origin of the progenies assessed in the experimental plot

Progeny Id	Type of material	Type of progeny	Genetic origin
2	commercial	full-sib progeny	IMC 67 x SNK 64

12	commercial	full-sib progeny	UPA 143 x SNK 64
14	farmers'	mixture of half-sib progenies	amelonado trees ("german cocoa" traditional variety)
15	farmers'	mixture of half-sib progenies	Open pollination of commercial varieties (farmers' hybrids)
19	commercial	mixture of full-sib progenies	UPA 143 x SNK 64, IMC 67 x SNK 64,T 79/501 x SNK 109, SNK 109 x IMC 67, SNK 109 x T79/501, SCA 12 x SNK 16

Experimental design: The study was performed on 8 trial plots set up in 2007 and 2008, by farmers, under the supervision of researchers., in four villages, located in three counties of the central region of Cameroon, as shown in table 2.

Table 2: environnemental conditions of the trial plots

Village	Bakoa	Ngat	Edou	Lekie Assy
Administrative district	Mbam et Inoubou	Mefou et Afamba	Mefou et Afamba	Lekie
Landscape	Forest/savannah	Forest	forest	forest
Annual rainfall (mm)	1,300	1,470	1,470	1,280
Rainfall (days)	84	90	90	84
Type of soil	SAND/silt	CLAY/sand	CLAY/sand	SAND/clay
PH	6.71	5.18	5.18	5.75
organic matter/clay ratio	0.16	0.1	0.1	0.07

The cocoa trees were planted after cleaning of the land and destruction of the trees which were already present before the setting up of the plots. The cocoa trees were planted simultaneously with fruit trees (avocado-citrus-safu (*Dacryodes edulis))* or oil palm, according to spatial designs resulting in respective cocoa tree densities of 960 and700 cocoa trees per hectare (Bourgoing et Todem 2010a, Bourgoing et Todem 2010b). Table 3 shows the number of trees of each progeny planted in each trial plot.

Table 3 : number of assessed trees per progeny in each trial plot

			Progeny identifier				
Plot identifier	**Site**	**Associated crop**	**2**	**12**	**14**	**15**	**19**
A	Bakoa	oil palm		43			28
B	Bakoa	oil palm	63	54	54	54	60
C	Bakoa	fruit	86	84	44	43	87
D	Lékié Assy	fruit		48	40	32	29
E	Edou	fruit	86	87	87		87
F	Edou	fruit	90	91	91		90
G	Ngat	fruit	44	44		43	44
H	Ngat	fruit	35	35		35	

Assessed traits and statistical analyzes:

Annual yield estimation: The methodology adopted here is derived from the ones developed by other authors for on farm yield assessment (Tahi et al., 2009, Jagoret et al., 2017), and allows yield assessment without harvesting, independently from the farmers' harvest calendar. The yield was estimated on each individual tree, using the following formula: Yi = Ni × Cj , where Yi = annual yield (g of cocoa) of the tree i, Ni = number of pods produced yearly by the tree i, belonging to the progeny j, estimated by the cumulated number of mature but unripe pods, counted during six annual rounds, at a two months interval, during the period from beginning of 2011 until the end of 2017 (seven years of production), then divided by seven. It was decided to count only unripe pods, to avoid the risk of counting the same pods twice (the counted unripe pods ripen during the two-month period after their counting). Cj = weight of cocoa per pod (g) of the progeny j. A sample of at least 50 ripe pods was harvested on at least 20 trees of each progeny. The beans from each pod sample were fermented and dried, separately. The fermented and dried cocoa obtained from each sample of pods was weighted. The weight obtained was then divided by the number of sampled pods.

Two types of yield were considered: *the actual yield*, which considers the values obtained on all planted trees, including the ones which died before the end of the assessment period. This yield estimation considers trees' mortality and truly reflects the agronomical performances of the progenies in farms' conditions. *The potential yield*, which only considers the trees that survived the whole assessment period. This methodology estimates the potential of the progenies under favorable conditions

Statistical analysis: Two factor ANOVA were performed on individual trees' yield values, using the following model: yijk = µ + gi + pj + sij + eijk where yijk is the yield of tree k of progeny i in plot j, µ is the general mean, gi is the effect of progeny i, pj is the effect of plot j, sij is the interaction between gi and pj, and eijk is the residual effect. In each plot, the number of assessed progenies ranges between 2 and 5. Each progeny is represented in a number of plots ranging between 5 and 8, by a number of trees ranging between 28 and 91 (Table 3). The design is an incomplete and unbalanced randomized design. The adjusted mean values were estimated for progenies and trial plots (LSMEANS proc GLM) and ranked using the Newman–Keuls method at a 5% threshold.

3. RESULTS AND DISCUSSION

Results from ANOVA

The results from the ANOVA (Table 4) show highly significant effects for plot, progeny and interaction in both cases of actual and potential yield, the most significant effect being the plot, followed by the progeny, the interaction effect being much lower than these two effects.

Table 4: Results from two factor ANOVA performed on yield data

		Actual yield		**Potential yield**	
Factor	**Degrees of Freedom**	**F value**	**Pr > F**	**F value**	**Pr > F**
Plot	7	45.36	<.0001	46.24	<.0001
Progeny	4	27.29	<.0001	26.18	<.0001
Plot x progeny	19	4.49	<.0001	2.39	<.0001

Results from the ranking of the plots.

The results from the Newman-Keuls ranking at 5% of the plots are indicated in table 5 and show large differences for both actual and potential yield. Plot A is the one with the highest level of mean actual yield (759 g/tree) and plot G the one with the lowest level (208 g/tree). Plot C is the one with the highest level of potential yield (1209 g/tree) and plot G is the one with the lowest level (427 g/tree). Plot A is the plot with the lowest mortality rate (7%) while plot G is the plot with the highest one (62%). The usually rather unfavorable planting conditions in which the plots were set up (fallow and savannah) explain the high mortality rate and the low yield level.

Table 5: Ranking of the trial plots for their level of yield according to Newman Keuls at 5%

Plot Identifyer	% mortality	Actual yield (g/tree)	N.K 5%	Potential yield (g/tree)	N.K 5%
A	7	1,097	a	1,163	a
C	44	726	b	1,210	a
D	17	613	c	642	b
F	38	435	d	651	b
E	47	384	d	658	b
B	56	368	d	623	b
H	37	298	de	452	c
G	62	232	e	445	c

Results from the ranking of the progenies

The results from table 6 show that the lowest levels of both actual and potential yield (266 and 480 g/tree) are observed for the traditional amelonado variety (German cocoa) (variety 14). This low level of yield and the high mortality rate (52%) observed for this variety indicates that it is not adapted to the conditions in which the plots were set up (very limited shade level).On the other hand, the commercial progeny 2 issued from IMC 67 x SNK 64 shows both the highest levels of actual and potential yield (625 and 1,000 g/tree, respectively), significantly higher than the ones observed for all the other assessed varieties. The variety 15 (farmers' hybrids), consisting in the mixture of half-sib progenies issued from pods harvested by farmers on their plots set up commercial varieties, shows levels of actual and potential yields (517 and 721 g/tree) similar to the ones of the variety 19 (443 and 755 g/tree), consisting in a mixture of six commercial full-sib progenies, as well as to the ones of commercial progeny 12, issued from the cross UPA 143 x SNK 64 (525 and 735 g/tree).The use of seeds collected in plots set up with commercial varieties (farmers' hybrids) results, in most cases, in progenies that show the same level of yield as the ones of commercial varieties issued from seeds collected in seed gardens. The lack of yield depression observed on the farmers' progenies issued from open pollination of commercial "hybrid trees" can be explained by the usually high level of heterozygosity of the parents of the commercial hybrid trees, which results in commercial progenies far from being F1 progenies. However, one of the commercial varieties (IMC 67 x SNK 64) out yields all the other commercial and farmers' varieties in our trial. A significant difference in both actual and potential levels of yield was observed by Feumba de Tchoua et al (2021), between the commercial progenies from IMC 67 x SNK 64 (845 and 1,015 g/tree) and UPA 143 x SNK 64 (647 and 791 g/tree) in other on farm progeny trial plots set up under the same conditions in Bakoa and another site in the same department. Furthermore, from the same on farm trial, these authors identified three commercial progenies with a similar or higher level of yield than IMC 67 x SNK 64.The mean weight values of dried cocoa per pod are in the usual range, between 39 and 53 g of dry cocoa per pod and none of the assessed varieties presents a mean weight of one bean lower than one gram,considered as the lowest acceptable value by some cocoa manufacturers.

Table 6 Ranking of the varieties for their level of yield according to Newman Keuls at 5%

Progeny Id	Progeny	mortality rate (%)	actual yield (g/tree)	N.K 5%	potential yield (g/tree)	N.K 5%	weight of dried cocoa per	mean weight of one dried

							pod (g)	bean (g)
2	IMC 67 x SNK 64	45	625	a	1,000	a	53,1	1,3
12	UPA 143 x SNK 64	36	525	b	735	b	44,3	1,3
15	Farmers' hybrids	37	517	b	721	b	46,1	1,2
19	Mixture of commercial progenies	45	443	b	755	b	38,7	1,03
14	Traditional amelonado variety (german cocoa)	52	266	c	480	c	40,7	1,01

4. CONCLUSION

Cameroon has recently been engaged in a zero-deforestation cocoa production initiative while it also aims at significantly increase its cocoa production. Beside the rehabilitation of old unproductive cocoa plots, the planting of new cocoa plots in non-forest areas is also an option. In this case, the cocoa trees do not benefit the shade of already existing trees~~. In order to conciliate these two objectives, several ways are envisaged such as the rehabilitation of unproductive cocoa farms and the planting of cocoa plots in non-forest areas. Both strategies require high yielding vegetal material and our study provides important information on the adaptation of the currently used vegetal to cocoa cultivation in non-forest areas, under sub optimal cultivation conditions.~~Our results show that the use of the traditional variety (German cocoa) is not a good option in the case of the setting up of cocoa plots under low or no shade conditions, corresponding to the conditions observed when planting is done on fallow or savannah, at least during the first years of establishment.The use of seeds from already existing plots cultivated using commercial progenies is a better option, as good as the use of a mixture of commercial progenies.Nevertheless, the best option consists in the use of the commercial progenies identified as the highest yielding ones, such as the one issued from the cross IMC 67 x SNK 64 and three other ones identified by the authors of the present paper in other progeny trials set up in the same conditions.

~~Our data also show a large difference of yield among the commercial progenies. For this reason, one short term strategy to increase farmers' cocoa yield could consist in releasing only the highest yielding progenies among the commercial ones. This could be achieved by the replacement of the parents of the low yielding progenies with the parents of the high yielding ones, in the seed gardens. In addition to the 4 commercial progenies already identified by these authors, it is expected to identify others from the current assessment of eight other commercial progenies issued from seed gardens in on farm progeny trials set up in 2013. At a larger term, other new full sib progenies issued from new crosses, involving other parents, are currently under assessment in progeny trial plots set up on farm and in research station, in order to select other potential commercial progenies and set up the seed gardens for their future release to cocoa farmers.~~

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