Improvement the bunch and oil yields of oil palm (*Elaeis guineensis* Jacq.) by introducing material of Yocoboué origin into the selection scheme in Côte d'Ivoire

ABSTRACT

The introduction of Yocoboué-origin material into Group B of the reciprocal recurrent selection (RRS) scheme in Côte d'Ivoire aimed to enhance extraction rates of La Mé material and augment genetic diversity within the group. In this study, 1120 trees from 13 progenies and 3 controls, from the first and second selection cycles, were evaluated for bunch and oil yields in a balanced square lattice design(BSLD) with 4 x 4 and 5 replications. Results indicated that twelve progenies exhibited significantly higher bunch yields, ranging from 23 to 25 t/ha/year, compared to the three controls. Remarkably, industrial oil extraction rates reached up to 27%, resulting in an impressive oil yield capacity of 6.90 t/ha/year. Noteworthy progenitors, including LM13878P, LM13015T, and LM13832T, played a key role in achieving these performances and displayed favorable crossing values with Deli testers. These findings underscore the potential for creating high-performance hybrid seeds and advancing genetic improvement in oil palm. The diverse choices presented by these performances hold promise for the continued enhancement of oil palm cultivation.

Key words:Improvement, bunch and oil yield, oil palm, 3rd cycle of RRS*, Yocoboué*

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.)breeding began with the selection of the best individuals from natural palm groves in South-East Asia and Africa [1]. In 1950, a large-scale exchange of basic material from oil palm breeding programs was carried out between five (5) stations in order to carry out intra-origin and inter-origin combinations [2]. The results obtained guided the choice of oil palm genetic improvement towards a reciprocal recurrent selection (RRS) scheme [3]. This scheme, set up at the La Mé station (Côte d'Ivoire), exploits the heterosis resulting from the cross between two groups A and B with complementary characteristics [4][5] [6]. Group A, made up of the Deli (Asian) and Angola populations, is characterised by a small number of large bunches of the *dura* varietal type (with thick-shelled fruit). Group B, made up of the other African populations (Côte d'Ivoire, Congo, etc.), is characterised by a large number of small bunches of the *tenera* (thin-shelled) or *pisifera* (shelled) varietal type [7].

After a first selection cycle, during which 15 crosses were selected [8], a second cycle was set up using introductions and the best progenitors selected during the previous cycle [5]. Only 33 individuals, most of them related, were used in this second cycle [9]. The high selection pressure exerted on the recurrent populations during these two cycles reduced the genetic variability of the selected genitors[10]. With the aim to recreating genetic variability and establishing long-term progress, several genotypes from oil palm populations resulting from surveys or exchanges between research institutes have been introduced into the selection scheme [11].

Thus, in 1968 the genitors from Yocoboué origin was included in the oil palm breeding program following a survey carried out in Côte d'Ivoire[12]. The advantage of this origin lies in the quality of its fruits, which are better, with a higher percentage of pulp and relatively larger bunches than those of the La Mé origin. They were therefore introduced into the selection scheme, on the one hand to increase the oil extraction rate of the La Mé material and, above all, to broaden the variability of the Côte d'Ivoire origin (Adon B, 1995. Cocody University, Côte d'Ivoire, postgraduate thesis, unpublished results). Evaluation of this material showed that, in addition to the large bunches produced and a high percentage of pulp, two progenitors (YO 3 T and YO 9T) had low vertical growth[12]. They were therefore recombined in group B by crosses of the type (La Mé x La Mé) x (Yocoboué x La Mé) and (La Mé x La Mé) x (Yocoboué x Yocoboué).Work on vertical growth characteristicshas made it possible to determine the genetic gain produced by these recombinations when crossed with the Deli tester [16] [15]. However, the bunch and oil yield characteristics of hybrid progenies from these recombinations crossed with the Deli tester remain undetermined to our knowledge.

The aim of this study was to assess the bunch and oil yields of hybrid progenies improved by introduction of Yocoboué material and to estimate the contribution of these progenitors to the reciprocal recurrent selection scheme.

2. MATERIALS AND METHODS

2.1 STUDY SITE AND PLANT MATERIAL

The study was conducted on two different regions. The trial was set up on plot C8-4 of PALMCI's Integrated Agricultural Unit (UAI) at Ehania (5°19' N, 2°46' W and 12 m) in 2002. On this site, which contains the genetic block for experiments in the 3rd cycle of reciprocal recurrent selection (Kablan K. A. B. M, 2020. NanguiAbrogouaUniversity, Côte d'Ivoire, postgraduate thesis, Unpublished results), field observations of yield components were carried out. Analyses of oil production and its components were carried out at the La Mé research station (CNRA) (5°26' N; 3°50' W; 23 m). This site hosts the genetic selection service, which manages the various plant material introductions as well as genetic manipulations [16]. These sites are both located in the South-East of Côte d'Ivoire. The climate in this part of the country is equatorial, characterised by bimodal rainfall with two wet periods and two dry seasons. Annual rainfall varies between 1276 and 2007 mm, with average atmospheric humidity estimated at 85% each annual. Total annual insolation reaches 1,800 hours, with an average annual temperature of around 27°C. Soil texture is predominantly clay and sand. The soils are deep and the pH is between 4.5 and 7 (Kablan K. A. B. M, 2020. NanguiAbrogouaUniversity, Côte d'Ivoire, postgraduate thesis, Unpublished results).

The plant material consists of 13 oil palm hybrid progenies used in the recurrent selection scheme in Côte d'Ivoire. These progenies were obtained from crosses involving group B progenitors (tested progenitors) resulting from 4-way recombinations between two populations of Côte d'Ivoire origin (La Mé and Yocoboué), tested with group A progenitors of Deli origin (Table 1). These crosses involved two progenitors of the pisifera variety, six progenitors of the *tenera* varietyand eight progenitors of the *dura* variety. The performance of the progenies evaluated was compared using two extension controls from the first cycle and a parental cross from the second cycle. These were the reference crosses DA10 D x LM 2 T and DA 115 D x LM 2 T from the first selection cycle and the cross (LM 630 D x TNR 115) x (LM5T x LM 10 T) from the second cycle.

2.2 EXPERIMENTAL DESIGN

All palms of various progenies were planted in 4 x 4 balanced square lattice design with 5 replicates. Each replication is made up of 4 blocks within which there are 4 elementary plots. Each elementary plot comprised 14 trees, i.e. 70 palms per progeny. These palms were planted at a standard density of 143 trees per hectare. A total of 1,120 oil palms were planted over an area of 7.83 hectares.

2.3 PARAMETERS MEASURED

2.3.1 Bunch yield assessment

Bunches were harvested from mature palms over a period of six (6) consecutive years (2012-2017), at a frequency of two (2) to three (3) times per month. The bunch number (BN) was determined by counting the bunch number harvested in one anof production. The bunches harvested annually per tree were weighed individually at the feet of each tree (Fig 1). The sum of the weighing values was used to calculate the total bunch weight (TBW expressed in kg/tree/year). The average bunch weight (ABW) was determined by the following ratio:

ABW = TBW / BN

The bunch yield of a progeny, which corresponds to the tonnage per hectare per year of production, was determined using the following formula:

BY = TBW x D x 0.95

where

BY: bunch yield of the progeny;
TBW: total bunch weight of the progeny (expressed in kg/tree/year);
D: planting density or number of trees per hectare. D is equal to 143 oil palms per hectare in the trial concerned by this study;
0.95: coefficient applied given that not all the palms planted per hectare produce.

2.3.2 Evaluation of oil yield

Observations to determine oil yield were made only on tenera palms from all the progenies tested, as they are the only ones representative of the future variety [17].
Each bunch harvested at maturity is sent to the bunch analysis laboratory with the fruits detached. The bunch is dehusked by separating the spikelets from the rachis. Two samples of spikelets of equal weight are taken when the bunch weighs fourteen kilograms (14 kg) or more. Only one sample is taken for further analysis. The fruit is separated from the spikelets with a knife and weighed to estimate the percentage of fruit on the bunch (% F/B). A sample of thirty (30) fruits was taken, weighed and then pulped. The mesocarp (or pulp) of the 30 fruits was carefully separated from the shell with a knife. The nuts obtained were weighed in turn and the fresh pulp was ground until fine homogeneous particles were obtained. Fifty grams (50 g) of crushed pulp were taken directly to the near infrared spectrometer (MPA Bruker optics GBMH, Germany), which had previously been calibrated to determine the percentage of oil in the fresh pulp (% O/FP). The calculations used to determine the oil yield and its components were as follows:
%F/B = (FW / BW) x 100
%P/F = ((FSW-NW) / FSW) x 100
OB = (%F/B x %P/F x %O/FP) / 10000
OER = ((%F/B x %P/F x %O/FP) / 10000) x 0,855
OY = BY x OER
with :

- %F/B: percentage of fruit on the bunch,
- WF = fruit weight
- BW = bunch weight
- %P/F: percentage of pulp on fruit
- FSW = fruit sample weight ;
- NW = nut weight;
- OB: oil content on bunch ;
- OER: industrial oil extraction rate;

- 0.855: coefficient applied as not all the oil can be extracted;
- OY: oil yield of a progeny.

Table 1: Genetic origins of progeny evaluated in the study

Progenies	**Crossing**	**Type of recombinations**	**Number of oilpalms**
DA4662	DA10D x LM2T	DE x LM (T1*)	70
LM22662	DA115D x LM2T	DE x LM (T2*)	70
LM22412	LM5476D x LM5448T	(LM x LM) x (DE x ANG) (T3*)	70
LM23912	LM12894D x LM13878P	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x LM)]	70
LM23764	LM12897D x LM13878P	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x LM)]	70
LM23756	LM12902D x LM13877P	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x LM)]	70
LM23737	LM13032D x LM13877P	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x LM)]	70
LM22363	LM13009D x LM13011T	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x YO)]	70
LM22306	LM13011T x LM12894D	[(LM x LM) x (YO x YO)] x [(DE x DE) x (DE x DE)]	70
LM23750	LM13031D x LM13011T	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x YO)]	70
LM22349	LM13009D x LM13015T	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x YO)]	70
LM22596	LM13015T x LM13016D	[(LM x LM) x (YO x YO)] x [(DE x DE) x (DE x DE)]	70
LM23163	LM13010T x LM13031D	[(LM x LM) x (YO x YO)] x [(DE x DE) x (DE x DE)]	70
LM22179	LM13831T x LM13009D	[(LM x LM) x (YO x YO)] x [(DE x DE) x (DE x DE)]	70
LM22259	LM13832T x LM13016D	[(LM x LM) x (YO x YO)] x [(DE x DE) x (DE x DE)]	70
LM24201	LM12905D x LM13832T	[(DE x DE) x (DE x DE)] x [(LM x LM) x (YO x YO)]	70

DE : Deli ; ANG : Angola ; LM : La Mé ; YO : Yocoboué ; (T1) : Control 1 DA 10 D x LM 2 T ; (T2*) : Control 2 : LM 2 T x D A115 D ; (T3*) : Control 3 (LM5T x LM 10 T) x (LM 630 D x TNR 115)*

Fig 1: Technique for weighing bunches per tree

2.3.3 Statistical analysis of the data

The data relating to the components of bunch and palm oil yield collected on the controls and progenies were analysed using SAS version 9.4 and XLSTAT version 2019 software. An overall assessment of the variables measured was carried out using descriptive statistics parameters such as the mean, standard deviation, minimum and maximum. Next, an analysis of variance (ANOVA) with one factor (crosses) and two classification criteria (repetitions and blocks), incorporating the comparison of means according to Newman and Keuls at 5% risk, was applied to all the parameters measured to identify the best crosses compared with the controls [18].To structure the progeniesanalysed, a Hierarchical Ascending Classification (HAC) was used. It is based on Euclidean distances using as an aggregation option the Unweighted Pair-Group Method using Arithmetic average (UPGMA) [19]. Wilk's Lambda tests and Fisher's tests were used to assess the structuring provided by the HAC. These tests were used to evaluate the Mahalanobis distances between the classes highlighted by the HAC, using the discriminant analysis method. A progenitor involving Yocoboué origin has good crossover value for a given trait when the average performance of its crossovers is greater than or equal to that of the controls [11]. The ranking of the crossover values of the genitors involved in or less than two crosses was carried out after the Newman and Keuls test.

3. RESULTS
3.1 BUNCH AND OIL YIELD OF PROGENIES

Bunch and oil yields and their components are shown in Table 2. The bunchnumber (BN) of palms evaluated ranged from 7 to 10 bunches, with an average of 9 bunches and an average bunches weight

(ABW) equal to 21.1 ± 4.18 kg/tree/year. For a total bunch weight (TBW) ranging from 156.78 to 198.8 kg (176 kg/palm/year on average), these palms have an annual bunch yield of 23.91 t/ha. The percentages of fruit to bunch (% F/B), pulp to fruit (% P/F), and oil to fresh pulp (% O/FP) varied from 48.72 to 68.77% (% F/B), from 67.67 to 80.86% (% P/F), and from 47.84 to 71.98% (% O/FP) with average proportions of 61.08%, 79.8% and 58.45% respectively. These average proportions give an oil rate of 28.4% and an industrial extraction rate of 24.29%. Annual palm oil yields in this trial ranged from 4.13 to 8.69 t/ha.

3.2VARIABILITY OF PROGENIES FOR DIET AND OIL YIELD AND THEIR COMPONENTS

The analysis of variance (at the 5% significance level) applied to bunch yield and its components revealed the existence of statistically significant differences between the progenies studied (Table 3). In fact, the one-factor ANOVA ($F=6.67$; $P < .001$) showed that it is possible to establish significant differences between the progenies for the bunchnumber. The Newman and Keuls test indexed five (5) homogeneous groups. The first group, with a statistically significantly higher average number of bunch s (around 10 bunch s per tree) than control 2 (LM 22662), is made up of progenies LM 23764 and LM 22259 as well as controls 1 (DA 4662) and 3 (LM 22412**).**

The results of the ANOVA ($F = 6.68$; $P < .001$) applied to the average bunch weight showed a significant difference between the progenies. The first group made up solely of progeny LM 23163 (25.46 kg) followed by the second group represented by progeny LM 23737 (23.43 kg). The third group made up of progeny LM 23750 and LM 24201 (22.45 to 22.48 kg). All these groups had a statistically higher average bunch weight than the three (3) controls with an average weight of between 18.64 and 20.59 kg.

For both total bunch weight and bunch yield, ANOVA results ($F=2.87$; $P < .001$) showed statistically significant differences between progenies. Five (5) homogeneous groups were formed. Of these, the first group, comprising four progenies (LM 23912, LM 22349, LM 22596 and LM 24201), recorded the highest total bunch weights (181 to 182 kg/tree) and bunch yields (24.60 to 24.82 t/ha) in the trial. Like this group, there was an intermediate group (LM 23737, LM 23750, LM 23163, LM 22179 and LM 22259) with total bunch weights (177.12 to 179.60 kg) and yields (24.06 to 24.39 t/ha). These two groups were higher than those of the three (3) controls, with total bunch weights ranging from 165.1 to 174.24 kg, or a bunch yield of 22.43 to 23.67 t/ha.

Table 2. Mean value, standard deviation, minimum and maximum yields of bunch and oil and their components.

Variables	**Bunch yields and their components**			
	Mean	**standard deviation**	**Minimum**	**Maximum**
BN	9.19	0.97	6.36	10.93
TBW (kg/tree/ year)	176	8.82	156.78	198.8
ABW (kg/tree/ year)	21.1	4.18	16.39	40.16
BY (t/ha/ year)	23.91	1.2	21.3	27.01
Variables	**Oil yields and their components.**			
	Mean	**standard deviation**	**Minimum**	**Maximum**
%F/B	61.08	4.19	48.72	68.77

%P/Fe	79.80	4.23	67.67	80.86
%O/FP	58.45	4.6	47.84	71.98
THR (%)	28.40	3.49	21.11	41
TE (%)	24.29	3	18.05	35.05
OY (tonne/ha/ year)	5.81	0.77	4.13	8.69

BN: number of bunches; TBW: total weight of bunches; ABW: average weight of bunches; BY: bunch yield; %F/B: percentage of fruit; %P/F: percentage of pulp; %O/FP: percentage of oil on fresh pulp; OB: oil rate on bunches.OER: industrial extraction rate; OY: oil yield.

Table 3. Analysis of variance relative to the components of yield in the diet of the progenies studied

Progenies	BN	TBW(kg/tree/ year)	ABW(kg/tree/ year)	BY(t/ha/year)
DA4662	9.88 ± 0.78^{a}	165.1 ± 5.61^{c}	18.64 ± 4.53^{d}	22.43 ± 0.76^{c}
LM 22662	9.15 ± 0.57^{ab}	169.01 ± 6.61^{bc}	19.84 ± 3.35^{cd}	22.96 ± 0.9^{bc}
LM 22412	9.88 ± 1.38^{a}	174.24 ± 4.49^{abc}	20.59 ± 7.21^{bcd}	23.67 ± 0.61^{abc}
LM 23912	8.63 ± 0.69^{c}	182.24 ± 9.65^{a}	20.62 ± 2.39^{bcd}	24.82 ± 1.31^{a}
LM 23764	9.61 ± 0.64^{a}	172.36 ± 8.61^{abc}	18.84 ± 1.91^{d}	23.41 ± 1.17^{abc}
LM 23756	8.45 ± 0.97^{c}	170.63 ± 8.84^{abc}	21.09 ± 2.7^{bcd}	23.18 ± 1.2^{abc}
LM 23737	8.68 ± 1.1^{c}	177.12 ± 10.85^{ab}	23.43 ± 8.97^{b}	24.06 ± 1.47^{ab}
LM 22363	9.27 ± 0.41^{ab}	173.07 ± 10.4^{abc}	20.81 ± 2.46^{bcd}	23.51 ± 1.41^{abc}
LM 22306	8.52 ± 0.77^{c}	174.63 ± 4.74^{abc}	21.98 ± 3.2^{bcd}	23.72 ± 0.64^{abc}
LM 23750	9.04 ± 0.86^{bc}	179.60 ± 12^{ab}	22.45 ± 4.79^{bc}	24.39 ± 1.63^{ab}
LM 22349	8.5 ± 0.85^{c}	181.47 ± 10.33^{a}	20.49 ± 1.9^{cd}	24.65 ± 1.4^{a}
LM 22596	8.74 ± 0.78^{c}	181.10 ± 6.58^{a}	20.53 ± 3.12^{bcd}	24.60 ± 0.89^{a}
LM 23163	7.82 ± 0.98^{d}	177.53 ± 9.6^{ab}	25.46 ± 5.42^{a}	24.11 ± 1.3^{ab}
LM 22179	9.19 ± 0.63^{ab}	178.03 ± 4.93^{ab}	20.67 ± 3.24^{bcd}	24.18 ± 0.67^{ab}
LM 22259	10.03 ± 0.96^{a}	177.45 ± 3.88^{ab}	19.01 ± 2.95^{d}	24.10 ± 0.53^{ab}
LM 24201	8.69 ± 0.38^{c}	182.7 ± 4.83^{a}	22.48 ± 0.93^{bc}	24.75 ± 0.66^{a}
Valeur F	6.67	2.87	6.68	2.87
P	<.001	<.001	<.001	<.001

In the same column, mean values indexed by the same letter are statistically equal at the 5% threshold (Newman Keuls test); BN: number of bunches; TBW: total weight of bunches; ABW: average weight of bunches; BY: bunch yield

Table 4 summarises the results of the analysis ofvariance applied to oil yield and its components. The ANOVA (F = 9.28; *P* < *.001*) carried out on the percentage of fruit on the bunch of the progenies showed a significant difference. The first group had the highest percentage of fruit on the bunch (62.75 to 64.02%). It is made up of progenies LM 23912. LM 23764. LM 22306. LM 23750, as well as controls 2 and 3 (LM 22662 and LM 22412).

With regard to the percentage of pulp on the fruit. four different homogeneous groups (F = 10.78; *P* < *.001*) were identified. The first group with the highest percentage of pulp on fruit (85.03%) comprised progeny LM 22596. Also, the intermediate group is made up of progenies LM 23912. LM 23764. LM 23756. LM 23737. LM 22363. LM 22306. LM 23750. LM 22349. LM 23163. LM 22179. LM 22259 and LM24201, which recorded proportions of pulp on fruit between 79.34 and 82.83% statically higher than those of the three (3) controls between 73.45 and 75.53%.

The ANOVA (F = 2.85; *P* < *.001*) applied to the percentage of oil on fresh pulp showed a significant difference between the progenies. The first group, made up solely of progeny LM 23750 (62.42%). followed by the second group represented by progenies LM 22363. LM 22306. LM 22179 and LM 24201 obtained statistically higher percentages of oil on fresh pulp (59.25 to 60.73%) than the 3 controls. whose percentages ranged from 56.99 to 58.04%.

The results of the ANOVA (F = 2.31; *P= .004*) showed that there were significant statistical differences between the progenies for the rates of oil on diet and industrial extraction. Four homogeneous groups were identified, the first of which, made up of progenies LM 22306 and LM 23750, was characterised by statistically higher yields (31.26 to 32.67% oil on bunch. i.e. an industrial oil extraction rate of 26.72 to 27.93%) compared with the controls (24.94 to 27.27% oil on bunch. i.e. an industrial oil extraction rate of 21.34 to 23.31%).

As for oil yield, the ANOVA showed that there were significant differences between the progenies. Three homogeneous groups can be distinguished according to the Newmanand Keuls test. Only the first group, made up of progenies LM 23912. LM 22363. LM 22306. LM 22349. LM 23750 and LM 24201, gave an oil yield (6.38 to 6.90 t/ha) that was statistically higher than that of all the controls (4.78 to 5.56 t/ha).
However, controls 1 (DA4662) and 2 (LM 22662) recorded the lowest oil yields at 4.78 and 5.03 t/ha.

3.3PROGENIES CLASSIFICATIONACCORDING TO BUNCH AND OIL YIELD AND THEIR COMPONENTS

Hierarchical ascending classification revealed three classes (Fig 2). The first class (C1) is made up of progenies LM22259. LM22179. LM22349. LM23912. LM22596. LM23737. LM23756 and LM23163, while the second (C2) includes progenies LM22306. LM22363. LM23750 and LM24201. Four other progenies (LM23764. LM22412. LM22662 and DA4662) made up the third class (C3). The Wilks' Lambda test revealed a significant difference between the classes (*P* < *.001*). In addition, the Fischer test showed a significant difference between class 3 and the other two, which were identical at the 5% level (Table 5). Class 3 (C3) differs from the other classes in that the values of its components for oil and bunch production are lower than those of the other classes for all variables except the bunch number

Table 4. Analysis of variance relating to oil yield components of the progenies studied

Progenies	%F/B	%P/Fe	%O/FP	OB	OER	OY
DA4662	58.81 ± 3.88^{b}	74.78 ± 4.57^{c}	58.04 ± 4.15^{b}	24.96 ± 1.11^{c}	21.34 ± 0.95^{c}	4.78 ± 0.25^{b}

LM 22662	62.79 ± 3.32^{a}	73.45 ± 1.65^{c}	56.99 ± 5.35^{bc}	26.17 ± 1.64^{bc}	22.37 ± 1.40^{bc}	5.03 ± 0.47^{b}
LM 22412	62.89 ± 6.49^{a}	75.53 ± 5.92^{bc}	57.02 ± 3.48^{bc}	27.27 ± 3.87^{ab}	23.31 ± 3.31^{ab}	5.56 ± 0.83^{ab}
LM 23912	63.60 ± 1.67^{a}	79.34 ± 3.71^{ab}	57.41 ± 5.6^{bc}	28.87 ± 3.47^{ab}	24.68 ± 2.96^{ab}	6.09 ± 0.58^{a}
LM 23764	62.75 ± 3.47^{a}	80.19 ± 3.43^{ab}	54.98 ± 1.43^{c}	27.67 ± 1.55^{ab}	23.65 ± 1.32^{ab}	5.54 ± 0.48^{ab}
LM 23756	61.64 ± 1.01^{ab}	79.40 ± 2.78^{ab}	57.22 ± 2.95^{bc}	27.96 ± 1.28^{ab}	23.90 ± 1.1^{ab}	5.59 ± 0.45^{ab}
LM 23737	61.33 ± 1.49^{ab}	81.04 ± 2.26^{ab}	56.11 ± 2.48^{bc}	27.90 ± 0.89^{ab}	23.85 ± 0.76^{ab}	5.69 ± 0.47^{ab}
LM 22363	60.35 ± 2.29^{ab}	82.55 ± 2.35^{ab}	60.73 ± 4.45^{ab}	30.30 ± 3.44^{ab}	25.90 ± 2.94^{ab}	6.05 ± 0.4^{a}
LM 22306	63.92 ± 2.59^{a}	81.66 ± 2.53^{ab}	59.72 ± 5.7^{ab}	31.26 ± 3.55^{a}	26.72 ± 3.04^{a}	6.38 ± 0.61^{a}
LM 23750	64.02 ± 4.13^{a}	82.83 ± 1.77^{ab}	62.42 ± 6.74^{a}	32.67 ± 5.86^{a}	27.93 ± 5.01^{a}	6.90 ± 1.28^{a}
LM 22349	61.82 ± 3.98^{ab}	79.85 ± 3.39^{ab}	57.76 ± 3.84^{bc}	28.46 ± 1.66^{ab}	24.33 ± 1.42^{ab}	6.03 ± 0.67^{a}
LM 22596	56.65 ± 4.56^{c}	85.03 ± 8.69^{a}	58.56 ± 4.12^{b}	27.95 ± 3.53^{ab}	23.90 ± 3.02^{ab}	5.79 ± 0.6^{ab}
LM 23163	58.1 ± 5.13^{b}	81.79 ± 1.96^{ab}	58.01 ± 3.94^{b}	28.70 ± 4.03^{ab}	24.53 ± 3.44^{ab}	5.93 ± 0.9^{ab}
LM 22179	61.06 ± 2.14^{ab}	79.57 ± 1.15^{ab}	59.25 ± 3.67^{ab}	28.68 ± 2.66^{ab}	24.52 ± 2.28^{ab}	5.99 ± 0.57^{ab}
LM 22259	59.48 ± 4.84^{b}	79.45 ± 2.66^{ab}	58.66 ± 2.72^{b}	27.81 ± 1.38^{ab}	23.78 ± 1.18^{ab}	5.78 ± 0.31^{ab}
LM 24201	61.03 ± 6.04^{ab}	82.05 ± 4.15^{ab}	60.25 ± 7.83^{ab}	29.99 ± 6.11^{ab}	25.64 ± 5.22^{ab}	6.43 ± 1.27^{a}
Valeur F	9.28	10.78	2.85	2.31	2.31	3.93
P	<.001	<.001	<.001	<.001	<.001	<.001

In the same column.mean values indexed by the same letter are statistically equal at the 5% threshold (Newman Keuls test); %F/B : percentage of fruit on bunch; %P/F: percentage of pulp on fruit; %O/FP: percentage of oil on fresh pulp; OB: oil contains on bunch.OER: industrial oil extraction rate; OY: oil yield

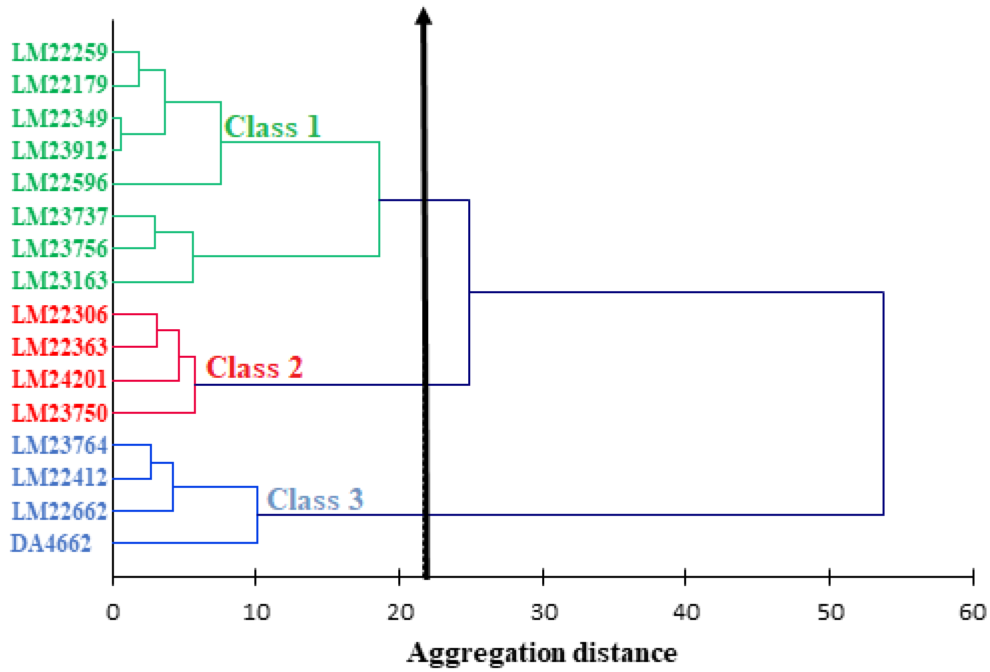

Fig 2: Hierarchical ascending classification of hybrid progenies based on bunch and palm oil yield components.

Table 5. Mahalanobis distance. Wilks' Lambda test and Fischer test between the classes formed by Hierarchical Ascending Classification

	Class 1	Class 2	Class 3
Class 1		D= 0.768	D= 3.391
Class 2	F= 0.904; p=0.534		D= 5.336
Class 3	F= 3.992; p< 0.001	F= 4.712; p< 0.001	
Wilks' Lambda test= 0.509			
P-value **<** *.001*			

D= Mahalanobis distance; F= Fischer test statistic; p= Fischer test probability; p-value= Wilks Lambda probability.

3.4.CROSS-BREEDING VALUE OF PROGENITORS

Table 6 summarises the cross-breeding value of genitors involving recombinations with the Yocoboué origin. The LM 13878 P. LM13015T and LM 13832 T progenitors have the highest yields when crossed with the testers. at over 24 t/ha. As for the industrial oil extraction rate.Only the LM 13011 T progenitor ran ks in pole position with the highest cross-breeding value (26.60%). LM 13878 P. LM 13011 T and LM 13832 T had the highest oil yields in crosses with the testers.Ranging from 5.88 to 6.33 t/ha.

Table 6. Cross-breeding values of *Pisifera*and *Tenera*progenitor in relation to industrial oil extraction rate. bunch and oil yield**.**

Genitorsinvolving Yocoboué	TestGenitors	Crossingmean	BYmean of the Genitors	OERmean of the Genitors	OYmean of the Genitors
DA4662 (T1*)		(22.43)(21.34)(4.78)	22.43^{c}	21.34^{c}	4.78^{b}
LM22662 (T2*)		(22.96)(22.37)(5.03)	22.96^{bc}	22.37^{bc}	5.03^{b}
LM22412 (T3*)		(23.67)(23.31)(5.56)	23.67^{ab}	23.32^{ab}	5.56^{ab}
LM13878P	LM12894D	(24.82)(24.68)(6.09)	24.12^{a}	24.27^{ab}	5.88^{a}
	LM12897D	(23.41)(23.62)(5.54)			
LM13877P	LM12902D	(23.18)(23.91)(5.59)	23.59^{ab}	23.89^{ab}	5.63^{ab}
	LM13032D	(24.06)(23.86)(5.69)			
LM13011T	LM13009D	(23.51)(25.90)(6.05)	23.87^{ab}	26.60^{a}	6.33^{a}
	LM12894D	(23.72)(26.72)(6.38)			
	LM13031D	(24.39)(27.93)(6.90)			
LM13015T	LM13009D	(24.65)(24.33)(6.03)	24.63^{a}	24.17^{ab}	5.94^{b}
	LM13016D	(24.60)(23.90)(5.79)			
LM13832T	LM13016D	(24.10)(23.78)(5.78)	24.41^{a}	24.56^{ab}	6.05^{a}
	LM12905D	(24.75)(25.64)(6.43)			

Note: The first parenthesis indicates the mean value of BY; the second parenthesis indicates the mean value of OERand the third parenthesis indicates the mean value of OY; In the same column, average values indexed by the same letter are statistically equal at the 5% threshold (Newman Keuls test); (T1) : Control 1 DA 10 D x LM 2 T ; (T2*) : Control 2 : LM 2 T x D A115 D ; (T3*) : Control 3 (LM5T x LM 10 T) x (LM 630 D x TNR 115); BY: bunch yield; OER: industrial oil extraction rate; OY: oil yield.*

4.DISCUSSION

The improvement of bunch and oil yields of oil palms through the introduction of material of Yocoboué origin involved 13 oil palm progenies. Overall, good yields were obtained thanks to the level of improvement in the material used. The material used underwent various intragroup recombinations, with the aim of selecting only the best hybrid combinations for the next cycle [5] [20]. These intra-group recombination phases have now brought the material in each group to 4-way crosses giving hybrid progeny at 3rd selection cycle level.

The study of the variability of the characteristics of bunch and oilyields in made it possible to differentiate the progenies. Progenies with a high bunch number have a low average bunches weight. The existence of such a relationship between these two components has been mentioned since the first cycle of palm breeding by Meunier *et al* (1970)[13]and recently by Isa and colleagues (2009)[21]. However.The relatively low number of bunch of all progenies (≤ 10) could be attributable to a contribution from the original Deli test parent, which consists of palms with a small number of large bunch[11]. As for the high average weight of the bunch n. this would be due partly to the contribution of the parent of Deli origin and partly to the parent of Yocoboué origin, which produces relatively larger bunch compared with the La Mé origin[12]. Total bunch weight would therefore be strongly influenced by average bunch weight. These results are contrary to those of Lubis *et al* (1991)[22], who showed that the bunch number is the most important factor in the total production of bunches and palm oil.

Although the ANOVA revealed a significant difference between the progenies, on the whole good bunches and oil production characteristics were obtained. With the exception of progenies DA4662, LM 22596, LM 23163 and LM 22259 the percentage of fruit on the bunches obtained (%F/B ≥ 60) was considered satisfactory. Corley and Tinker (2003) [23]indicate that a good percentage of fruit on the bunch is between 60% and 65%. According to Harun (2000) [24], this performance is due to a high level of pollination. In addition to the three controls, most of the progenies evaluated recorded percentages of pulp on fruit greater than or equal to the average characteristics of an improved tenera palm. In addition, high industrial extraction rates were obtained from these progenies, with a maximum of 27.93%, far exceeding the industrial extraction rate of tenera hybrids from the second breeding cycle that were popularized, which was between 22 and 23% [25]. This high industrial extraction rate is attributable to a major contribution from Yocoboué grandparents, which are very rich in pulp. The heritability of certain traits in oil palm has highlighted the high heritability of the percentage of pulp on fruit [5][13].These progenitors will therefore have passed this trait on to their offspring.

The progenies LM 23912, LM 22349, LM 22596 and LM 24201 with the highest bunch yields (BY ≥ 24.60 t/ha) also recorded the highest oil yields (OY ≥ 6 t/ha). These results are in line with those obtained by Isa et al (2009)[21], who showed causal relationships between these two traits. For these authors, total bunch weight and therefore bunch yield is the trait most strongly correlated with oil production (r = 0.93).

The multiple comparison of means using the Newmanand Keuls test with a 5% risk clearly defined several homogeneous groups. These groups overlapped, showing that the progenies had similar performances for the parameters studied. Bakoumé et al (2010) [26],work showed that the groups of progenies formed by Duncan's Multiple Range Test (DMRT) as a function of the parameter under consideration overlapped each other. According to these authors, this result can be explained by the fact that the progenies are close,although the ANOVA revealed significant inter-progenies variability. The variability generally found in cross-pollinated plants,and in oil palm in particular, translated into differences in performance between progenies in terms of both bunch yield and its components and oil yield (Adon B, 2022. Cocody University, Côte d'Ivoire, PhD thesis, Unpublished results). These observed differences would have made it possible to select the superior progenies emerging from the set [27]for characteristics linked to oil palm productivity.

Classification of the progenies thus led to the structuring of two distinct classes. On the one hand, there are the trees with low yields in terms of bunch and oil, made up of the controls and the LM 23764 progeny,and on the other, the other progeny, which have high yields in terms of bunch and oil. These progenitors of Yocoboué origin therefore carry favourable genes that they have passed on to their offspring. Analysis of the cross-breeding value of these progenitors shows that the interest of this origin in the selection scheme can be focused on bunch and oil yield as well as on extraction rate. In fact, three progenitors were selected for their cross-breeding values for these traits. The good performance observed in these progenitors could be attributed to the multiple intra-group recombinations that they have undergone to reach the level of 3rd cycle material today. Their use in the selection scheme could make it possible to improve the bunch and oil yields of recurrent group B populations.

5. CONCLUSION

The aim of this study was to assess the bunch and oil yield of oil palm hybrids improved by the introduction of Yocoboué material into the reciprocal recurrent selection scheme. Bunch and oil yield characteristics were measured on thirteen (13) progenies and compared with those of three controls (two controls from the first cycle and one parental cross from the second cycle). The study showed that there was variability between the progenies enabling them to be divided into two classes. The best class is made up of twelve (12) hybrid progenies with the highest yields. Three of the progenitors involved in expressing these performances also have good crossing values. These results offer good prospects to breeders for making highly productive improved material available to players in the oil palm sector.

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