Yield potential of oil palm (*Elaeis guineensis* Jacq.) clones: preliminary results observed in the Aek Loba Timur genetic block in Indonesia

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ABSTRACT

This paper follows on from the one presented by Nouy *et al.* (2006) in Bali. Forty two different clones were planted in 3 comparative trials set up in the Aek Loba Timur genetic block located at the Aek Loba estate (Socfindo, North Sumatra). The clones were propagated from ortets selected from 17 Deli x La Mé crosses of the second Reciprocal Recurrent Selection (RRS) cycle, tested in 7 different trials of Socfindo's Aek Kwasan experimental block. The paper compares the phenotypic data for cross/ortet/clone triplets and, based on ortet/clone pairs, the coefficients of correlation and the values obtained for broad sense heritability.
When compared to the original crosses, clones present negative differences, albeit tiny, for the extraction rate and 2 of its components (M/F% and O/M%), for total bunch weight and for oil production over the entire observation period. Only the F/B% of the clones and the average bunch weight are slightly better than those of the initial crosses. If we consider the entire Aek Loba genetic block, there are 5 clones among the best 40 treatments tested at Aek Loba for oil yield, i.e. 12% of the clones from 10% of the treatments. Correlations, linear regressions and comparative values between clones/ortets/crosses reveal that, for 10 out of the 12 traits measured, the correlations are significant and that the clone values are not only lower than those of the original ortets for all the traits except the average bunch weight in the immature period, but also lower than the mean value of their initial cross, except once again for the average bunch weight. Results are discussed in relation with genetic progress, somaclonal variation and consequences for breeding. Finally if a cloning approach is to be used the best way is probably to develop clones from random individuals within reproductions of the best families identified in progeny trials.

INTRODUCTION

The success of certain oil palm (*Elaeis guineensis* Jacq.) *in vitro* vegetative propagation methods in the 1970s (Smith and Jones, 1970; Rabéchault *et al*., 1970) led to hopes of a substantial improvement in yields for commercial planting material by exploiting the variability subsisting within selected crosses and by enabling the propagation of parents combining particularly desirable traits.

It was thus that field trials were set up with clonal material as early as 1977 by the Unilever company (Corley, 1981) and in 1983 by organizations associated with CIRAD (Durand-Gasselin *et al*., 1990). The expected gains in oil yield at the time generally varied between 12 and 30%, depending in particular on the prediction methods used, on the reference planting material and on the hypotheses put forward as to the heredity of the traits (Hardon *et al.*, 1982; Noiret *et al.*, 1985; Soh, 1986; Meunier *et al.*, 1988). The first results reported were encouraging (Corley *et al*., 1977; Choo *et al*., 1981; Corley *et al*., 1982; Duval *et al*., 1988; Durand-Gasselin *et al.*, 1990; Le Guen *et al*., 1991).

In Indonesia, scientific collaboration was established in the 1970s between PT Socfin Indonesia in Medan (Socfindo, one of the oldest private companies involved in agribusiness) and CIRAD (the Tree Crops Department of the *Centre de Coopération Internationale en Recherche agronomique pour le Développement*) to assist in developing the seed production operation of that company. To that end, genetic improvement programmes were drawn up that were fully integrated into the Recurrent Reciprocal Selection network supported by CIRAD. Those programmes included an *in vitro* vegetative propagation component intended to produce clones from the best individuals identified among planting materials grown from seed. Some of those clones were planted from 1985 at sites belonging to Socfindo (Durand-Gasselin *et al.*, 1990) and, between 1995 and 2000 (Jacquemard *et al*., 2001), around forty of them were planted in the genetic block set up at Aek Loba (North Sumatra). The first assessment results became available in 1998.

This paper follows on from the one presented by Nouy *et al.* (2006), since the material studied by them has been re-used and extended to other clones. However, this is not the final stage, since of the 3 trials involved, 2 are still under observation. This paper will compare the phenotypic data for cross/ortet/clone triplets and, based on ortet/clone pairs, the coefficients of correlation and the values obtained for broad sense heritability will be calculated. Observed values will then be compared to expected values and the conclusions to be drawn for choosing palms to be cloned will be examined.

MATERIAL AND METHODS

1. Planting material

The planting material studied consists of 42 clones propagated from ortets selected from 17 Deli x La Mé crosses of the second Reciprocal Recurrent Selection (RRS) cycle, tested in 7 different trials of Socfindo's Aek Kwasan experimental block. The clones were produced by the ORSTOM/CIRAD procedure used by Socfindo in the *in vitro* vegetative propagation laboratory at Bangun Bandar. Table 1 indicates their numbers and genetic origin. Of the 42 clones, 23 figured in the material studied by Nouy *et al.* (2006). Culturing was carried out between 1988 and 1994.

Trial and planting date	Cross	Origin	Number of ortets
AK-GP 03	LM 5373 = LM 2345 D x LM 1571 P	DA 115 D self x LM 2 T self	1
(10/1975)	LM 5399 = LM 3360 D x LM 1574 P	LM 404 D self x LM 2 T self	1
	LM 5412 = LM 2935 D x LM 1594 P	LM 404 D x DA 10 D x LM 2 T self	1
AK-GP 06	LM 6418 = LM 3466 D x LM 2246 P	LM 404 D x DA 10 D x LM 2 T self	4
(11/1976)	LM 6629 = LM 2935 D x LM 3943 T	LM 404 D x DA 10 D x LM 2 T self	3
AK-GP 08	LM 5557 = LM 3038 D x LM 1571 P	DA 5 D x DA 3 D x LM 2 T self	1
(11/1976)	LM 5941 = LM 3037 D x LM 2256 P	DA 5 D x DA 3 D x LM 2 T self	1
	LM 6061 = LM 3604 D x LM 2255 P	DA 5 D x DA 3 D x LM 2 T self	5
AK-GP 11	LM 5809 = LM 2750 D x LM 1595 P	DA 10 D x DA 3 D x LM 2 T self	5
(05/1978)	LM 6784 = LM 3258 D x LM 3943 T	LM 404 D self x LM 2 T self	5
AK-GP 11/18	LM 5783 = LM 2749 D x LM 2275 P	DA 10 D x DA 3 D x LM 2 T self	2
AK-GP 11/18	LM 5922 = LM 2781 D x LM 2256 P	DA 10 D x DA 3 D x LM 2 T self	5
AK-GP 12	LM 5885 = LM 2509 D x LM 2255 P	DA 115 D self x LM 2 T self	2
(05/1978)	LM 6261 = LM 2536 D x LM 2448 T	DA 115 D self x LM 2 T self	1
AK-GP 18	LM 5559 = LM 2767 D x LM 1594 P	DA 10 D x DA 3 D x LM 2 T self	1
(04/1979)			
AK-GP 19	LM 6143 = LM 1949 D x LM 2951 P	DA 5 D self x LM 5 T self	2
(11/1978)	LM 7380 = LM 3954 T x LM 2361 D	DA 5 D self x LM 5 T self	2
			42

Table 1. Trials and original crosses of ortets at Aek Kwasan propagated by cloning.

The method used to select the crosses and ortets from which the clones were derived was described by Baudouin *et al.* (1994) and taken up again by Nouy *et al.* (2006).

2. Experimental design

The 42 clones involved in the study are planted in 3 comparative trials set up at the Aek Loba estate (Socfindo, North Sumatra), which benefits from a highly suitable environment (deep loamy sand soils, low water deficit and high insolation). The first trial (AL-GP 05) was set up in 1995, the other 2 (AL-GP 19 and AL-GP 22) in 1998; all three belong to the Aek Loba Timur (AL) genetic block designed by Socfindo, CIRAD and the CRA-PP station, at Pobé in Benin.

It should be noted that the material from which all the clones are derived was assessed under similar conditions, since it was planted on the same Socfindo estate, in the Aek Kwasan (AK) genetic block set up between 1975 and 1979.

The 3 clonal trials at Aek Loba are as follows (Table 2):

Trial	Treatment number	Number of clones	Design	Planting date
AL-GP 05	25	23	5x5 lattice	11/1995
AL-GP 19	12	11	Fisher blocks, 6 rep	06/1998
AL-GP 22	17	13	Fisher blocks, 6 rep	11/1998

Table 2: Clone comparative trials

Each clone is represented by 6 elementary plots of 16 palms (AL-GP 05) or 9 palms (AL-GP 19 and AL-GP 22) each.

One of the clones in trial AL-GP 19 has been excluded from the analysis, for lack of bunch quality data. Another clone, SOC 2602 (AL-GP 19), is not in 2 replicates out of 6; it is partially abnormal with erected leaves and numerous white stripes. In addition, that trial shares 4 clones in common with AL-GP 05. The identity of the clones and their distribution per trial is given in annex 1.

3. Traits measured

The usual observations of yield, diseases and vegetative or reproductive parameters have been carried out in the three clonal trials. They were presented in detail by Jacquemard *et al*. (2001) and primarily concern (Nouy *et al*., 2006):

- individual recording on each harvesting round of the number of bunches and bunch weight between the ages of 3 and 9 years (AL-GP05) or 3 and 7 years (AL-GP 19 and AL-GP 22),
- determination of the extraction rate on a sample of bunches taken from bearing palms in each treatment at 5 and 6 years, the end result being multiplied by 0.855 to approach the industrial extraction rate,
- calculation of oil yield based on 95% of bearing palms per hectare, i.e. 135 palms for a density of 143.

All palms with mantled fruits are excluded irrespective of the severity of the abnormality.

Of course, the same traits were observed earlier in the trials at Aek Kwasan from which the clones came, with some special measurements enabling as close as possible an evaluation of the genetic value of the palms being studied (cf. § 4.2).

Ultimately, for the 2 sets of data, we have:

- bunch analyses: extraction rate and its 3 components (F/B%, M/F%, O/M%),

- FFB and oil production on immature palms: 3-5 or 4–6 years at Aek Kwasan (4–5 years for AK-GP 18); 3-5 years at Aek Loba,
- FFB and oil production on mature palms: 6–9 or 7–10 years at Aek Kwasan, 6–7 years at Aek Loba for the 3 clonal trials (6–9 years for AL-GP 05 only).

Other observations, the results of which are not reported here, are also carried out, primarily concerning vertical growth, fatty acid composition of the oil and mineral nutrition.

4. Calculation methods

4.1 Mean values of the original crosses

The choice of progenies from which ortets are selected is the first stage in creating clones. As all the trials at Aek Kwasan are planted in a statistical design, it has been possible to estimate the value of the crosses in each trial. In order to compare the materials of different trials, the values were then expressed in relation to the reference cross LM 2 T x DA 10 D, a first cycle cross used as a control in the network of trials monitored by CIRAD. Calculation was carried out directly when the control was present in the trial; in the other cases, it was calculated via crosses common to the different trials.

4.2 Mean values of ortets

The second stage in selecting ortets is to identify the best individuals within the crosses chosen from the first stage. In order to get as close as possible to the genetic value of the material, and thereby limit the share of the environment effect when calculating individual data, several measures were taken: replication of bunch quality observations (multiplication of analyses on ortet candidates), smoothing of bunch production data (Baudouin *et al*., 1987) so as to subtract the effects of the soil fertility factor from the environmental variance, taking into account competition between palms in trials comparing materials with heterogeneous development.

Once obtained and corrected where necessary by the smoothing factor, the observed data were compared to the original crosses and to the control cross.

4.3 Mean values of clones

To assess the performance of the clones at Aek Loba Timur and compare them to each other although they were not planted in the same trials, we have taken advantage of the existence of treatments that establish connections between the trials. The statistical model corresponding to that approach is as follows:

$Y_{ijk} = m + a_i + r_{ij} + c_k + E_{ijk}$

where:

Y_{ijk} is the observed value for cross k, in replicate j of trial i,
m is the mean of the variable over all the trials,

a_i is the effect of trial i,
r_{ij} is the effect of replicate j of trial i,
c_k is the effect of cross k,
E_{ijk} is the residual error

Application of that procedure makes it possible to calculate the means for each treatment, adjusted for the trial effects via the LSMEANS module of the SAS software, which makes it possible to estimate the means of treatments, accompanied by a standard deviation, which would have been observed if they had been planted in all the trials, i.e.:

$$m + \hat{c}_k$$

This calculation model excludes any treatment/trial interaction. That is not strictly true, but the ranges of values obtained are very small compared to the differences between treatments, which renders them negligible.

The reference cross LM 2 T x DA 10 D is also planted in the design.

4.4 Ortet/clone comparison

The measurements carried out at Aek Kwasan and Aek Loba provide 42 ortet/clone pairs that can be studied in parallel through correlations and regressions bringing into play clone values estimated from the above model, along with ortet values corrected via the control cross LM 2 T x DA 10 D to take into account the differences between the trials in the Aek Kwasan block. It is also possible to estimate ortet and clone values in comparison to that same reference and to use those estimations to compare ortets to their clones. The ortet/clone regression lines can also be used to deduce an estimation of trait heritability.

RESULTS

Generally speaking, the results obtained on the planting material in our study are roughly the same as those reported by Nouy *et al.* (2006) for clones forming a subset of our material.

1. Mean values of crosses

Table 3 (rows a and b) gives the mean values of the main yield components for the control LM 2 T x DA 10 D and for the clones from which the clones tested at Aek Loba were derived. These last values are also expressed in relation to the control in Table 4 (row a).

All the original crosses display an oil production mean that is 17% and 14% better than that of the control for the immature and mature periods respectively: 4.8 tonnes of oil per hectare (as opposed to 4.1 for the control) over the immature period, 7.6 (as opposed to 6.7) over the mature period. That improvement is primarily due to an improvement in the extraction rate, for which the 3 components progress, particularly the fruit/bunch percentage and the mesocarp/fruit percentage. The nature of the gain associated overall with the 16 genetic trials in the Aek Kwasan block can clearly be seen here (Nouy *et al*., 1989).

2. Mean values of ortets

The mean values of the ortets are shown in Table 3 (row b), and Table 4 (row b) indicates the mean differences between the ortets and their original crosses. These are unprocessed phenotypic values without smoothing. In terms of oil production, they place the ortets at 11% better than the crosses: 5.4 tonnes of oil for the immature period, 8.7 tonnes for the mature period.

When the ortets are compared to the control (row c of Table 4) the differences exceed 29% in both situations. It is therefore logical to think that their true value places them between the mean values of the crosses (+14% compared to the control) and the mean phenotypic values (+29%). In theory, it is also the value that can be expected from the clonal material that will be derived from them.

3. Mean values of clones

The mean performances of the material observed in the clonal trials are shown in Table 3 (row d). As trials AL-GP 19 and AL-GP 22 were only planted in 1998, the reference for production in the mature period is 6-7 years.

When compared to the control (Table 4 - row d), the data show over 10% superiority for oil production in the immature period and around 7% for production in the mature period.

In order to compare clones to the original crosses, the value of the latter need to be estimated in the Aek Loba context, which can be done by basing oneself on their relative values compared to the control.

We then find negative differences (Table 4 – row e), albeit tiny, for the extraction rate and 2 of its components (M/F% and O/M%), for total bunch weight and for oil production over the entire observation period. Only the F/B% of the clones and the average bunch weight are slightly better than those of the initial crosses. When considering oil production between 6 and 7 years (Annex 2), it can be seen that only 7 out of the 42 clones exceed the production of their cross, with just one clone (SOC 3208 – AL-GP 22) exceeding it by more than 15%. That superiority is entirely relative because, if we consider the entire Aek Loba genetic block, which comprises 406 treatments (out of a total of 513) for which production at 6 and 7 years is available in 2006, the first clone, which comes in 9th position, is SOC 3607 (GP 22). Clone SOC 3208 is found in 29th position; it clearly outstrips its original progeny, but the latter is characterized by mediocre production when compared to the values that the other original crosses would have achieved if they had been planted at Aek Loba. There are 5 clones among the best 40 treatments tested at Aek Loba, i.e. 12% of the clones from 10% of the treatments, the latter providing progress of 1.1 tonnes compared to the block mean (8.80 t as opposed to 7.67 tonnes).

			F/B %	M/F %	O/M %	**OER**	BNi	**FFBi** kg/palm	ABWi kg	**Oili** t/ha	BNm	**FFBm**	ABWm	**Oilm**
AK trials(1)	a	Control	62.0	79.2	53.3	**22.4**	23.1	**135.2**	5.9	**4.1**	17.0	**219.1**	10.1	**7.6**
	b	Crosses (17)	65.9	84.9	55.0	**26.3**	24.6	**135.3**	5.5	**4.8**	17.0	**214.8**	12.8	**7.6**
	c	Ortets (42)	69.6	84.3	55.6	**27.9**	25.0	**143.3**	5.7	**5.4**	18.0	**231.8**	13.0	**8.7**
AL trials (2) (AL-GP 05, GP 19 & 22)	d	Control	60.4	78.2	54.3	**22.0**	29.2	**162.5**	5.7	**4.8**	23.1	**230.0**	10.12	**7.1**
	e	Clones (42)	65.2	83.0	55.4	**25.8**	27.2	**153.0**	5.7	**5.3**	21.8	**220.0**	10.1	**7.6**

Table 3 : Mean observed values of the planting material at Aek Kwasan and Aek Loba
(42 clones derived from 17 crosses studied in 7 different trials)
i: immature palms; m: mature palms

(1) immature period 3-5 years or 4-6 years; mature period 6-9 or 7-10 years
(2) immature period 3-5 years; mature period 6-7 years

				F/B %	M/F %	O/M %	**OER**	BNi	**FFBi**	ABWi	**Oili**	BNm	**FFBm**	ABWm	**Oilm**
AK trials (1)	a	Crosses	as a % of control	6.3	7.2	3.1	**17.5**	6.9	**0.1**	-6.6	**17.6**	-0.3	**-2.0**	-0.6	**14.1**
	b	Ortets	as a % of crosses	5.6	-0.6	1.0	**5.9**	1.7	**6.3**	2.8	**11.0**	5.7	**7.9**	1.4	**13.2**
	c	Ortets	as a % of control	12.2	6.5	4.2	**24.4**	9.5	**6.4**	-2.5	**29.7**	5.4	**5.7**	0.6	**29.6**
AL trials (2) (AL-GP 05. GP 19 & 22)	d	Clones	as a % of control	8.0	6.2	1.9	**16.8**	-7.0	**-5.9**	0.4	**10.5**	-5.5	**-4.4**	0.2	**7.3**
	e	Clones	as a % of crosses	1.5	-0.9	-1.2	**-0.5**	-13.3	**-8.3**	5.1	**-7.8**	-6.0	**-4.5**	0.9	**-8.6**

Table 4: Relative differences for ortets and clones in ALGP 05, AL-GP 19 and AL-GP 22
(42 clones derived from 17 crosses studied in 7 different trials)
i: immature palms; m: mature palms

(1) estimation of the control directly or via common crosses; immature period 3-5 years or 4-6 years; mature period 6-9 or 7-10 years
(2) estimation of the control via LSMEANS; immature period 3-5 years; mature period 6-7 years

4. Comparative values for ortets and clones

4.1 Based on correlations and regressions

Table 5 groups together the coefficients of correlation calculated from all the parameters, along with their broad sense heritability estimated from the slope of the ortet/clone regression lines:

	Ortet/clone correlation	h^2
FB	0.472**	0.506
MF	0.792**	0.788
OM	0.724**	0.572
OER	0.476**	0.432
BNi	0.482**	0.364
FFBi	0.484**	0.396
ABWi	0.592**	0.587
Oili	0.309*	0.244
BNm	NS	0.076
FFBm	0.322*	0.239
ABWm	0.424**	0.358
Oilm	NS	0.152

Table 5: Correlation between the ortets at Aek Kwasan and the clones at Aek Loba
Broad sense heritability of the traits (i: immature; m: mature)

For 10 out of the 12 traits measured, the correlations are significant and it can be hoped that they will be substantially improved by selecting the best individuals.

For the bunch analyses, we find again in particular the good degree of correlation for the mesocarp/fruit percentage and the oil/bunch percentage already reported by Nouy *et al.* (2006). The ortet/clone regressions associated with those 2 parameters (Annex 3) are in phase with that observation and reveal the existence of good broad sense heritability, especially for the mesocarp/fruit percentage ($h^2 = 0.79$).

The correlations for the total bunch weight and its components, along with oil production, are all significant in the immature period and are accompanied by heritability values ranging from 0.24 (oil production) to 0.59 (average bunch weight). In the mature period, the correlations disappear for bunch number and oil production, but remain significant for total bunch weight and especially for the average bunch weight. Here again, the ortet/clone regression (Annex 3) shows there exists a linear relation between ortets and clones that makes it possible to predict the value of the latter.

4.2 Based on their relative values compared to the control and the crosses

A parallel examination of the rows in Table 4 shows that the clone values are not only lower than those of the original ortets for all the traits except the average bunch weight in the immature period, but also lower than the mean value of their initial cross, except once again for the average bunch weight, which remains even higher (though very slightly) in the mature period. However, it is seen for that period that clone production (in terms of bunch weight and oil production) does not catch up with that of the crosses, unlike the observations made by Nouy *et al.* (2006).

DISCUSSION

1. Heritabilities

For the 3 components of bunch quality heritabilities which were calculated are close to those obtained by Nouy *et al*. (2006). They reach a good level even for the fruit/bunch percentage ($h^2 = 0.51$) which is a parameter highly dependent upon environmental factors. This doubtless reveals the efficiency of pollination under Aek Kwasan and Aek Loba conditions.

Broad sense heritability is particularly high for mesocarp/fruit percentage. The same is often true for the narrow sense heritability, indicating that much of the variation is additively inherited (Corley and Tinker, 2003).

Heritability of the oil/bunch trait is rather high and close to the estimate made by Baudouin and Durand-Gasselin (1991) who consider that the heritability of the extraction rate involves a substantial genetic component (between 0,4 and 0,5). However it is below the value of the fruit/bunch percentage contrary to what can be seen in several studies (Corley and Tinker, 2003).

As far as bunch and oil yields are concerned the values of the 6 – 7 year period are below those of the 3 – 5 year period, which was already emphasized by Nouy *et al*. (2006) who mentioned that over the immature and mature periods the two sets of clone and ortet data can be out of phase. The increased productivity of the clones during the first period can be due to an earlier start of production (Le Guen *et al*., 1991) and to the progress made in precocity (Cochard *et al.*, 2000). There is afterwards a decrease of the oil yield heritability and we find, like Cochard *et al*. (2000), a value of 0.15 which corresponds more to the one given by Soh (1986) and Meunier *et al*. (1988). It is worth noting also that the mature period covers the 6 to 9 (or the 7 to 10) years for the ortets while it includes the 6 and 7 years for the clones which is not very representative of a stable production.

Finally, under our conditions the average bunch weight seems more heritable than the bunch number, what is not the case generally in most studies but would tally with the fact that bunch weight is clearly more stable from season to season.

2. Genetic progress

It is not seen any superiority of the clones compared to materials grown from seed even if the ortet-clone correlations are rather high for several parameters which means that the best clones are produced from the best ortets. Oil yield is below that of the crosses from which the clones were derived. The ortet phenotypic values were higher though. These results are nonetheless compatible with the low estimated within-family heritability and especially with the low selection pressure exerted within the crosses (Nouy *et al*., 2006). At Aek Kwasan it was between 20% and 40% in some second cycle crosses, where the average CV was estimated to be 0.2. Under these conditions the intensity of selection is 1.4 (20 %) or 1 (40 %)

and the mean progress expected for yield ($R = i * CV * h^2$, according to Falconer's formula (1960)) is rather low: around 6 % compared to the mean value of the cross with a 0.15 heritability (Meunier *et al*., 1988). This progress could have been masked by environmental effects which did not make it possible to detect such small differences, in accordance with Soh *et al*. (2001) who demonstrated that, for oil production, environmental effects mask the genetic differences between individuals, making phenotypic selection inefficient.

Moreover, if the clones were to be compared to the best crosses which would be available by the time the clonal test results are available, their advantage would be much reduced (Soh *et al*., 2003a). It is what can be seen here: the best clones are on the same level as the best crosses assessed in nearby trials connected to the same genetic block at Aek Loba Timur. These results could be related to a low family selection. They show nevertheless that it is possible to get high-yielding clones without mantled abnormality which can reach virtually 9 tons of oil.

But we must consider also that our estimates of the control in some trials both at Aek Kwasan and Aek Loba Timur are not very accurate and do not make it possible to detect any superiority if it exists.

3. Somaclonal variation

Given the mantled abnormality existence which affects the formation of floral organs in both male and female flowers (Corley *et al*., 1986; Durand-Gasselin *et a*l., 1995), we can wonder whether the clone performances are related with other possible abnormalities induced by *in vitro* culture. If it is checked in trial AL-GP 05 that there is no relation between the frequency of the mantled abnormality of a clone and its bunch production level, one can not discard any other abnormality which would affect floral biology and could implicate, at least partially, an epigenetic basis (that is to say a phenomenon responsible for a modification of gene expression and not involving a change in the DNA sequence), like it has been widely assumed for the mantled abnormality.

Numerous studies have been and continue to be done towards understanding the cause of abnormal flowering. A few approaches are experimented at present, based on molecular genetics (Sharifah et Cheah, 2001; Corley and Tinker, 2003; Soh *et al*., 2003a) and more particularly on the degree of methylation of nuclear DNA which is known to be involved in the expression of homeotic genes controlling floral biology (Jaligot *et al*., 2000; Jaligot *et al*., 2002; Jaligot *et al*., 2004). The latter experiences demonstrate that there are differences in methylation polymorphisms correlated with the mantled somaclonal variation between normal and abnormal plants of various clones. Would it be possible that other abnormalities, that would be less visible than changes affecting the development of the stamens and staminodes of male and female flowers, interfere also with oil palm development? More studies must clearly be launched, on a molecular basis as well as on a physiological and biochemical basis.

Our question about other abnormalities is all the more pertinent since it is seen significant differences between clones from recloning. Two ramets of BC 68 (clone created in the IRD laboratories in Bondy from a nursery plant of DA 115 D self x LM 2 T self origin) were recloned by Socfindo's Bangun Bandar laboratory. The new clones, BC68-1 and BC68-2, although being of the same genotype and planted side by side in the same plot at Aek Loba Timur, show variations between them, notably for average bunch weight, average fruit weight and average kernel weight (Nouy *et al*., 2006). This matter obviously needs further investigation.

4. Consequences for breeding

Results presented here, added to those of Cochard *et al.* (2000), Soh *et al.* (2001) et Soh *et al*. (2003 a and b), suggest that :

- it is possible to get high-yielding clones that are abnormality-free,

- phenotypic selection within crosses is rather inefficient given the low heritability of oil yield and the poor amount of the within-family variability. As expected this one is increasing in progenies from more outbbred parents (Soh *et al*., 2003b).

- selection should first and foremost be based on the choice of crosses whose exceptional value has been proved in trials. In this respect it is important to work out very carefully the trial site, the experimental design and the conditions in which data are obtained (multiplication of analyses, data smoothing for individual weights of bunches, consideration of the effects of competition between palms). It is also necessary to have controls to compare the trials to each other.

- identification of high-yielding clones requires an evaluation phase in trials. As far as possible, several planting sites representative of different environments should be envisaged, as genotype x environment interactions exist (Corley *et al*., 1995; Soh *et al*., 1995; Soh *et al*., 2001).

As a result, under conditions where family values are essential to create outstanding clones, one may in accordance with Soh *et al*. (2003a) recommend a selection method based of the reproduction of an elite cross and the propagation of a great number of individuals within this cross (as seedlings or adult palms). Another approach consists in cloning one or both parents in order to produce semiclonal (one clonal parent and one sexual parent) or biclonal (both clonal parents) hybrid seeds.

CONCLUSION

Our results from 42 clones planted in 3 trials together with crosses show that we can get high-yielding clones but that the value of the progress achieved is negligible not to say nonexistent, although there have been reports of markedly superior yields of clones over material grown from seed. But in the latter case comparisons were not made very often with appropriate individual crosses.

More generally, we need further studies to:
- clearly establish that clones without the mantled abnormality reproduce, on average, exactly the agronomic value of the crosses produced by seed from which they came,
- put a precise figure on the progress that cloning can provide. For instance, we do not have any estimation of within-family variance, parameter by parameter, for the different types of crosses that are being tested in recurrent reciprocal selection programmes, or in pedigree selection programmes, be they crosses between two

parents derived from selfing or crosses between two parents derived from a recombination (Nouy *et al*., 2006)

It is necessary to set up methodological trials comparing crosses and sets of clones and Cirad, with its partners, intend to do so as quickly as possible.

Annex 1

Identity and distribution of clones by trial

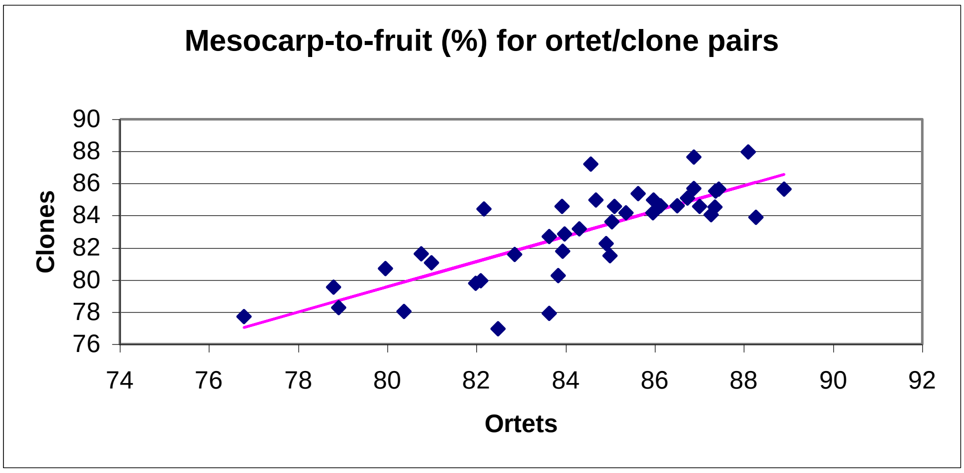
Serial number	Trial number at Aek Loba	Original cross at Aek Kwasan	Original trial at Aek Kwasan
SOC 1708	GP 05	LM 5399	GP 3
SOC 1806	GP 05	LM 5557	GP 8
SOC 2003	GP 19	LM 6061	GP 8
SOC 2004	GP 05	LM 6061	GP 8
SOC 2006	GP 22	LM 6061	GP 8
SOC 2007	GP 22	LM 6061	GP 8
SOC 2008	GP 22	LM 6061	GP 8
SOC 2106	GP 05/GP 19	LM 5373	GP 3
SOC 2503	GP 05	LM 5941	GP 8
SOC 2602	GP 19	LM 5412	GP 3
SOC 2704	GP 05	LM 6418	GP 6
SOC 2706	GP 05	LM 6418	GP 6
SOC 2708	GP 05	LM 6418	GP 6
SOC 2710	GP 05	LM 6418	GP 6
SOC 2803	GP 05	LM 6629	GP 6
SOC 2805	GP 05	LM 6629	GP 6
SOC 2807	GP 05	LM 6629	GP 6
SOC 2901	GP 05	LM 5809	GP 11
SOC 2910	GP 05	LM 5809	GP 11
SOC 2912	GP 22	LM 5809	GP 11
SOC 2917	GP 19	LM 5809	GP 11
SOC 2919	GP 05	LM 5809	GP 11
SOC 3001	GP 05	LM 6784	GP 11
SOC 3003	GP 05/GP19	LM 6784	GP 11
SOC 3004	GP 05	LM 6784	GP 11
SOC 3006	GP 22	LM 6784	GP 11
SOC 3008	GP 22	LM 6784	GP 11
SOC 3101	GP 19	LM 5783	GP 11
SOC 3110	GP 22	LM 5783	GP 18
SOC 3201	GP 05	LM 5922	GP 11
SOC 3202	GP 05/GP 19	LM 5922	GP 11
SOC 3203	GP 22	LM 5922	GP 11
SOC 3207	GP 22	LM 5922	GP 18
SOC 3208	GP 22	LM 5922	GP 18
SOC 3406	GP 05	LM 6143	GP 19
SOC 3408	GP 19	LM 6143	GP 19
SOC 3604	GP 22	LM 7380	GP 19
SOC 3607	GP 22	LM 7380	GP 19
SOC 3703	GP 05	LM 5885	GP 12
SOC 3704	GP 22	LM 5885	GP 12
SOC 3801	GP 05/GP 19	LM 6261	GP 12
SOC 4102	GP 19	LM 5559	GP 18

Annex 2

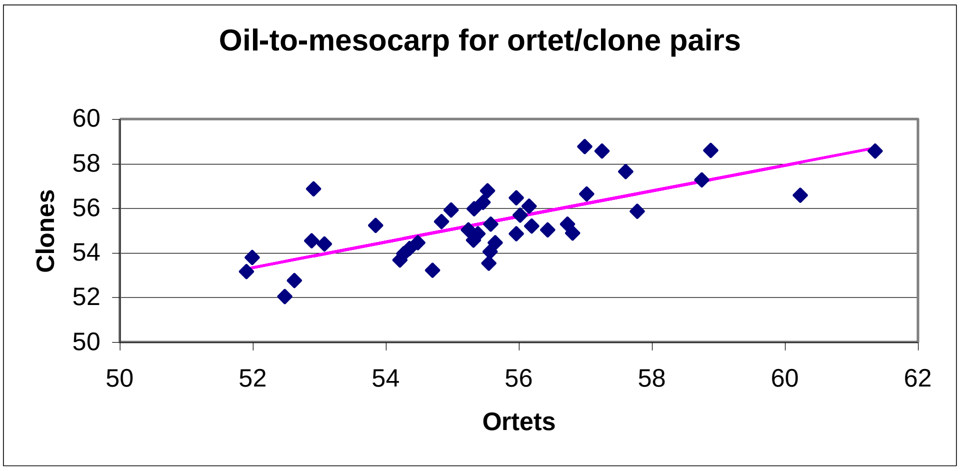
Oil production at 6-7 years (tonnes/ha/year) of the clones and their original cross

Serial number	Trial number at Aek Loba	Original cross at Aek Kwasan	Clone value	Cross value	%clone/cross
SOC 1708	GP 05	LM 5399	6.6	8.70	75.7
SOC 1806	GP 05	LM 5557	7.9	8.64	91.2
SOC 2003	GP 19	LM 6061	5.6	8.18	68.8
SOC 2004	GP 05	LM 6061	7.8	8.18	95.0
SOC 2006	GP 22	LM 6061	7.0	8.18	85.4
SOC 2007	GP 22	LM 6061	7.2	8.18	88.5
SOC 2008	GP 22	LM 6061	8.4	8.18	102.8
SOC 2106	GP 05/GP 19	LM 5373	7.2	8.05	89.6
SOC 2503	GP 05	LM 5941	7.9	8.16	97.1
SOC 2602	GP 19	LM 5412	6.1	7.89	77.3
SOC 2704	GP 05	LM 6418	7.9	7.97	99.3
SOC 2706	GP 05	LM 6418	7.5	7.97	93.9
SOC 2708	GP 05	LM 6418	8.6	7.97	107.3
SOC 2710	GP 05	LM 6418	7.2	7.97	90.3
SOC 2803	GP 05	LM 6629	7.1	8.48	84.2
SOC 2805	GP 05	LM 6629	6.9	8.48	80.8
SOC 2807	GP 05	LM 6629	8.6	8.48	101.6
SOC 2901	GP 05	LM 5809	8.0	8.72	91.5
SOC 2910	GP 05	LM 5809	6.5	8.72	75.1
SOC 2912	GP 22	LM 5809	7.7	8.72	88.5
SOC 2917	GP 19	LM 5809	8.1	8.72	92.6
SOC 2919	GP 05	LM 5809	7.1	8.72	81.0
SOC 3001	GP 05	LM 6784	7.4	8.39	88.6
SOC 3003	GP 05/GP19	LM 6784	7.6	8.39	90.6
SOC 3004	GP 05	LM 6784	7.7	8.39	91.4
SOC 3006	GP 22	LM 6784	7.6	8.39	90.6
SOC 3008	GP 22	LM 6784	7.0	8.39	83.4
SOC 3101	GP 19	LM 5783	6.5	8.01	81.6
SOC 3110	GP 22	LM 5783	7.3	7.53	96.5
SOC 3201	GP 05	LM 5922	7.3	7.90	92.3
SOC 3202	GP 05/GP 19	LM 5922	7.7	7.90	97.7
SOC 3203	GP 22	LM 5922	8.6	7.90	108.3
SOC 3207	GP 22	LM 5922	8.0	7.42	107.9
SOC 3208	GP 22	LM 5922	8.6	7.42	116.4
SOC 3406	GP 05	LM 6143	6.5	8.70	74.4
SOC 3408	GP 19	LM 6143	7.5	8.70	85.9
SOC 3604	GP 22	LM 7380	8.5	9.45	89.6
SOC 3607	GP 22	LM 7380	8.9	9.45	94.6
SOC 3703	GP 05	LM 5885	8.2	8.44	97.1
SOC 3704	GP 22	LM 5885	8.0	8.44	94.9
SOC 3801	GP 05/GP 19	LM 6261	8.1	8.61	94.3
SOC 4102	GP 19	LM 5559	8.5	8.03	106.1
Mean			**7.6**	**8.31**	**91.4**

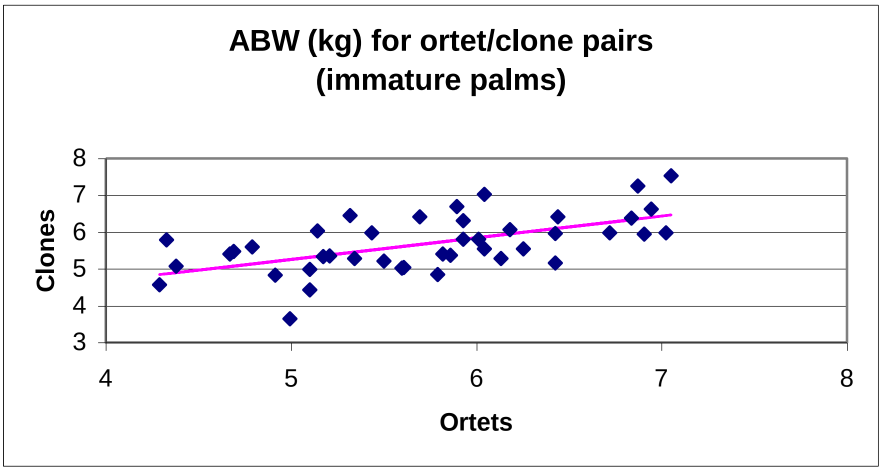
Annex 3



Mesocarp-to-fruit (%) for ortet/clone pairs
Clones
90
88
86
84
82
80
78
76
74
76
78
80
82
84
86
88
90
92
Ortets



Oil-to-mesocarp for ortet/clone pairs
Clones
60
58
56
54
52
50
50
52
54
56
58
60
62
Ortets



ABW (kg) for ortet/clone pairs
(immature palms)
Clones
8
7
6
5
4
3
4
5
6
7
8
Ortets

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