Palm Oil yield potential of oil palm (*Elaeis guineensis*) seeds developed in a network by CIRAD and its partners

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Abstract

Over the last decade, there was very strong growth in the demand for vegetable oils and fats (+ 4.6% per year) and the oils extracted from oil palm fruits greatly contributed to satisfying those needs. Food demand continues to increase, as do traditional uses (cosmetics and oleo chemistry). A new demand for use as bio fuel also needs to be taken into account (1% of current consumption). For oil palm, high-yielding planting material that is as resistant as possible to diseases will be part of the answer proposed by breeders.

The breeding scheme primarily involves a reciprocal recurrent selection scheme (RRS) which has been adapted to the biological constraints of the oil palm. The RRS recommended by CIRAD uses, in the form of hybrids, the heterosis effect obtained by crossing origins with complementary characteristics (group A) x (group B). It is also possible to include pedigree selection phases (A self or B self), which cannot really be considered as part of RRS, but the two strategies are complementary.

In the oil palm, the general combining ability (GCA) for yield of a parent can only be known by assessing the value of the families it generates. However, some parental traits are heritable enough for it to be efficient to select them: vertical growth, mesocarp/fruit percentage, oil/mesocarp and the number of bunches produced.

In order to assess the parental combining ability, we propose a scheme that makes it possible to test all family and each parent. Such a design makes it possible to evaluate the value of all the crosses by removing the inherent trial effect, and the planting year effect. It makes it possible to compare all the parents used in the design with each other. The share of variability explained by an additive model has been calculated.

As an example, the Aek Loba design is described. Our study focuses on the mature period for the first 17 trials that have been observed up to 8 years (254 crosses, 114 parents in group A, and 112 in group B).

At the progeny level, when selection is strong (8%) the gain recorded for oil production in the mature phase is slightly over 14%. That gain is obtained in an almost balanced way through progress in the extraction rate (+6.5%) and in FFB production (+7.2%).

The average contribution of the best parents parent for oil production in the mature phase is around + 700 kg/ha/year. A cross carried out between two good parents leads to a gain of 1

400 kg/ha/year of oil. Some parents provide a significant gain, of more than 3 points, for the extraction rate (i.e. around +12% if the OER increases from 26% to 29%). The R^2 between the observed values and the predicted values is 0.9: a purely additive model explains a very large share of the variability observed.

Genetic gain will be maximum if we select parents for their GCA: even a moderate selection pressure (16%) leads to substantial genetic progress. In this case, the expected gains are 8% for the extraction rate, more than 9% for FFB production and 17 to 18% for palm oil production.

Introduction

Over the last decade, there was very strong growth in the demand for vegetable oils and fats (+ 4.6% per year) and the oils extracted from oil palm fruits greatly contributed to satisfying those needs. Firstly through the quantities produced (the oil palm is the world's leading source of vegetable oils and fats), but also through better than average growth compared to the other oil crops (+5.3% per year) (Oil World, 2005). Palm oil and palm kernel oil production now stands at 37 million tonnes and accounts for almost 30% of world vegetable oil production.

Current growth is especially down to Indonesia and Malaysia, but there is also great potential in other parts of the world. Food demand continues to increase, as do traditional uses (cosmetics and oleo chemistry). A new demand for use as bio fuel also needs to be taken into account (1% of current consumption). It will be impossible to cover new needs without increasing productivity per unit area cultivated. Moreover, it would not be desirable any other way, otherwise unbearable pressure would be brought to bear on areas that are not currently planted to oil palm, some of which are of great value for the biodiversity they shelter. Agronomists and geneticists need to pool their efforts to propose a sustainable increase in productivity.

Our responsibility, as breeders, is to offer farmers high-yielding planting material that is as resistant as possible to diseases. For a long time, CIRAD and its partners have been involved in a wide-ranging genetic improvement programme. The purpose of this paper is to show the potential of the commercial material proposed to growers today, and in the coming years, it describes the strategies implemented to select and transfer the genetic progress achieved to growers as quickly as possible. Our discussions will be based on the most recent example of the Aek Loba Timur project implemented in partnership by the Pobé station (INRAB, CRA-PP, Benin), CIRAD and the Socfindo company (Indonesia), which sets up plantations and carries out observations. Some of the results commented on here have already been presented, at the FEDEPALMA conference in Cartagena (Nouy *et al.*, 2006).

1 – Strategy

1.1 – Breeding scheme

The breeding scheme implemented by CIRAD is now well known (Meunier and Gascon, 1972). It primarily involves a reciprocal recurrent selection scheme (RRS) which has been adapted to the biological constraints of the oil palm. The scheme requires an assessment of parent and family combining abilities in progeny tests. Given the perennial nature of the plant, parents are kept for very long periods and can be used at all times to create varieties and/or continue breeding (T. Durand-Gasselin *et al.*, 1999).

The RRS recommended by CIRAD uses, in the form of hybrids, the heterosis effect obtained by crossing origins with complementary characteristics (group A) x (group B) (Bénard and Malingraux, 1965). Nowadays, only the Deli and Angola origins are used in group A, whilst we mostly work with the La Mé, Yangambi and Nigeria populations in group B, except for a few special or prospective programmes.

Recurrent selection involves alternating testing and recombination phases (AxA or BxB). It is also possible to include pedigree selection phases (A self or B self), which cannot really be considered as part of RRS, but more a preparatory phase for the creation of a quality variety. However, there is no objection to using parents chosen in the pedigree selection phases for the recombination phases. The two strategies are complementary.

Setting up a wide-ranging selection scheme is a lengthy process (at least ten years), so the results of a selection cycle are exploited as and when they are obtained. That leads to regular progress in the value of selected material.

1.2 – The test phases

1.2.1 Parent selection

In the oil palm, the inherent value of the parents, particularly yield, is poorly correlated to the value of the family (Meunier *et al.*,1970) (Corley and Tinker, 2003). The general combining ability (GCA) of a parent can only be known by assessing the value of the families it generates.

However, some parental traits are heritable enough for it to be efficient to select them: vertical growth, mesocarp/fruit percentage, oil/mesocarp and the number of bunches produced.

Our strategy is to first of all choose the within-group recombinations for which we wish to assess the GCA. In each of those families, a few parents will be chosen on the basis of their inherent value for the heritable traits.

1.2.2 Assessment of parental combining ability.

In theory, the best possible evaluation would be achieved if each parent chosen in one group were tested with all the parents in the other group. In practice, that is not possible because, apart from carrying out the vast number of crosses, assessing 100 parents from each group would require a plantation of around 6 700 ha! We propose a scheme (Table 1) that makes it possible to test each parent 3 times. Inside each group, each origin (A_i) is compared to several origins of the complementary group (B_x). To do that, each recombination of origin A_i (A_{ij}) is crossed with 3 recombinations of origin B_x (B_{xy}). Within the recombinations (A_{ij} or B_{xy}), each selected parent (A_{ijk} or B_{xyz}) will be used three times.

In the field, genetic trials are planted using conventional statistical designs (4 x 4 x 5, 5 x 5 x 6 lattice trials, or Fisher blocks with 6 replicates). However, care is taken with the links between the trials. Within the same planting years, several crosses are replicated in the different trials (figure 1).

Each cross is usually represented by 72 or 96 palms spread over 6 replicates of 12 or 16 palms. Bunch production is recorded palm by palm for at least 7 years, 3 years for the immature period and 4 for the mature period. Only the production of the tenera palms is taken into account. The planting density is 143, but only 135 palms are considered when calculating yields per hectare, to take into account unproductive palms (which are not observed) and roads (which companies usually include when calculating the areas planted).

Bunch analyses are carried out on around 40 tenera at a rate of two normal bunches per palm, one is carried out when the planting is 5 years old, the other at 6 years old.

The results of laboratory analyses are corrected by a factor of 0.855 to align them with the performances of the material under commercial operating conditions.

Such a well-connected design makes it possible to evaluate the value of all the crosses by removing the inherent trial effect, and the planting year effect. It makes it possible to compare all the parents used in the design with each other, by calculating the general combining ability of the tested parents for each parameter measured.

The share of variability explained by an additive model can be calculated by comparing the observed value for crosses with their value predicted by the model.

1.3 The Aek Loba Timur design

The Aek Loba design comprises 25 trials comparing crosses and 3 trials comparing clones. They were planted over 6 years (1995 to 2000) on 489 hectares. This paper does not cover the clonal trials. The Pobé station has prepared 18 trials and Socfindo 7 and, in all, 482 crosses (D x P or D x T) have been planted.

The origins tested are as follows:

Group A :

- Socfindo Deli (recombinations between BB126D, BB129D, BB150D, BB177D and BB206D)
- Socfin Deli (LM269D and LM404D in recombination with Dabou Deli palms).
- Dabou Deli (Ivory Coast): (recombinations between DA3D, DA5D, DA10D, DA115D, DA128D, DA300D, DA551D and DA767D or with Socfin Deli palms)
- Deli*Angola recombination derived from the self of LM5448T.

Group B:

- La Mé (Ivory Coast) (recombinations between LM2T, LM5T, LM9T, LM10T, LM13T and LM311P)
- Nifor selections (Nigeria) (recombinations between PO1876T and PO1879T)
- Yangambi and Sibiti (recombinations between LM238T, LM511P, LM718T, palm SI10T being recombined with LM2T)

At the moment, we do not have results for the total design, nor observations for the total mature period. Consequently our study will focus on the mature period for the first 17 trials that have been observed up to 8 years (254 crosses). For the record, we give the average results obtained for all the trials in the immature period. The material from Bangun Bandar (Socfindo) has still not been assessed enough in this design, so our study will be focused on the material prepared at Pobé. In group A, 114 parents can be compared and 112 in group B (Table 2).

Table 3 shows the number of partners for each parent in this sub-design, which is therefore slightly downgraded compared to the initial objective described in section 1.2.2, but the great majority of parents has been assessed twice or more, and the average is 3.2.

In group A, 13 combinations derived from 10 excellent parents identified in the first cycle are being studied, along with 14 combinations of 10 excellent parents from group B. The recombinations marked with an asterisk are undergoing an additional pedigree selection cycle (two in each group).

The mating designs implemented in this sub-design make it possible to compare the general combining ability of 83 group A palms and 104 group B palms.

2 – Estimating the value of crosses

Given the design, it is possible to calculate for each cross in the design a genetic value adjusted for the trial and planting year effects (which are combined).

Table 4 gives the average results for the 254 crosses, along with the comparative value of the best 20 and best 40 crosses selected for average oil production from 6 to 8 years.

When selection is strong (20 crosses, i.e. 8%) the gain recorded for oil production in the mature phase is slightly over 14%. That gain is obtained in an almost balanced way through progress in the extraction rate (+6.5%) and in FFB production (+7.2%).

A more detailed analysis shows that progress is mainly achieved for the most heritable traits: mesocarp/fruit percentage and bunch number. As the latter trait is strongly and negatively correlated with the average bunch weight, it is not surprising to see it decrease.

The standard deviation of the value for each cross is under 3%, showing the very good precision of the estimations obtained. The standard deviation for estimation of the average value for 20 crosses is thus around 0.6%

3 – Estimating the combining ability of parents

3.1 Value of the parents

In a mainly additive model, the best crosses are derived from crosses between parents with the best combining ability. As we have not, by far, carried out all the crosses between all the parents, it is likely that only a small number of the best recombinations have been tested in our design.

Our design makes it possible to calculate the GCA of the parents, and therefore assess the expected value of the crosses that could be carried out between those parents. We have restricted our calculations to parents that are well connected with each other.

Table 5 shows the GCA of some very good group A and group B parents for a few parameters. Apart from one parent of exceptional value (PO 4982P), the average contribution of each parent for oil production in the mature phase is around 700 kg/ha/year. A cross carried out between a group A parent and a group B parent from this list leads to a gain of 1 400 kg of oil per year; such is the case with cross PO 3174 D x PO 2766 P, which has been planted out and which produced, on average, 9.2 tonnes of palm oil per ha over the 6-8 year period, i.e. 1 460 kg/ha/year more than the mean of the experimental design.

It can be seen that a few parents provide a significant gain, of more than 3 points, for the extraction rate (i.e. around +12% if the OER increases from 26% to 29%). Other parents make more of a contribution to FFB production.

Only PO 4982 P seems to provide a gain for both FFB production and the extraction rate, which makes it a really exceptional parent. It is not surprising that it is part of the best cross observed in the experimental design (PO 3360 D x PO 4982 P).

3.2 Predicting the value of crosses

GCA calculation makes it possible to predict the value of crosses. First of all, it can be checked what share of variability is explained by the proposed model. The R^2 between the observed values and the predicted values is 0.9: a purely additive model explains a very large share of the variability observed. Table 6 gives the observed values and predicted values for the best three crosses in the experimental design, then for 1 out of 25 crosses taken at random. The quality of the predictions is remarkable, be it for oil production, FFB production or the extraction rate.

Given the highly additive nature of parental value transmission, it is possible to estimate the average value of the crosses that would be produced if a selection of group A parents were crossed with a selection of group B parents, based on the GCA values. Table 7 illustrates this type of calculation. We have selected 16% of the group A parents and 16% of the group B parents, based on palm oil production from 6 to 8 years.

The expected gains are 8% for the extraction rate, more than 9% for FFB production and 17 to 18% for palm oil production. Those three values are to be compared with the gains provided by the best 16% of crosses (5%, 6% and 11.5 %) or by the best 8% of crosses (6.5%, 7.2% and 14.3%) (Table 4).

The greater efficiency of GCA-based selection results from the fact that one virtually uses crosses that it has not been possible to test in trials. If pressure on the parents is reasonable (16%), in relation to the level of all the possible crosses, barely 2.6% are kept.

Genetic gain will be maximum if we select parents for their GCA: even a moderate selection pressure (16%) leads to substantial genetic progress. Such a selection pressure provides a large enough number of parents to set up seed gardens. That flexibility also makes it possible to work on other important selection criteria such as disease resistance or vertical growth.

The precision of GCA estimations is lower than the estimation of cross values (standard deviation of 4.5% as opposed to 3%). It will be slightly improved by using kinship between parents as a co -variable (BLUP analysis, see Soh, 1994 and Purba *et al.*, 2001).

4 – Discussion and conclusion

The Aek Loba Timur design is remarkable through the overall exploitation of the results it enables. First of all, the value of the crosses is estimated with a precision unequalled in our earlier designs. Of course, that comes from the quality of the observation work carried out, but also from the large number of links existing between the trials, whether or not they were planted the same year.

The general mating design was conceived in such a way as to enable GCA calculations for most of the parents. In practice, a few parents have to be discarded from the calculation because they are disconnected from all the other parents.

Selection of the best crosses planted suggests genetic progress of around 14% for oil production (selection of the best 8% of crosses). However, given the highly additive nature of the transmission of production traits, by basing selection on the GCA of the parents, and even with a low selection rate (16%), it is possible to predict even greater progress (17 to 18%).

The progress in oil production comes from a balanced improvement of the extraction rate (+8% on average) and of FFB production (+9%).

On a parental scale, the results need to be analysed with greater caution due to the precision of the estimations made. However, it can be seen that some parents contribute a lot to the extraction rate (e.g. the progenies of LM404D (Group A) or LM10T (Group B)), whereas others transmit good FFB production (progenies of DA10D (Group A) or of LM2T (Group B)). We have found an exceptional parent, PO 4982 P, derived from a combination between LM5T and LM10T, which seems to transmit both a good extraction rate and high FFB yields. Those qualities will have to be checked, whilst using it in the recombination programmes.

Precise knowledge of parent quality is an important asset for two major actions by breeders: setting up seed gardens and the recombination programme for the next selection cycle.

Given the ongoing presence of common crosses in all the experimental designs that CIRAD and its partners implement, it is possible to estimate the value of the seeds produced. As seed gardens corresponding to an experimental design are planted by anticipation, integration of the results from the Aek Loba Timur design, which has already made good headway, will be complete in two or three years' time. For the pedo-climatic and management conditions at Aek Loba Timur, figure 2 illustrates the variation in value for seeds in the CIRAD network. In the same figure, we have transposed that potential for a plantation that would be located in Ivory Coast with an average annual water deficit of 340 mm.

This ongoing progress can also be illustrated by comparing the yields recorded in the same plots generation after generation (Figure 3). That calculation is based on yields actually recorded but fitted to a model that smoothes the main annual effects. In that figure, the genetic progress is combined with the technical and agronomic progress achieved over the period.

The following selection cycle developed in our network will be partly based on parents selected from within-group recombinations carried out between the parents in the Aek Loba Timur design. Further genetic progress will be achieved, it should be of the same degree.

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Table 1: Mating design for General Combining Ability study

			Group B parents												
			Origin B1				**Origin B2**				**…**	**Origin Bm**			
			B11	**B12**	**…**	**B1n**	**B21**	**B22**	**…**	**B2n**	**…**	**Bm1**	**Bm2**	**…**	**Bmn**
Group A parents	**Origin A1**	**A11**	●					●					●		
		A12		●			●					●			
		…													
		A1n				●				●					●
	Origin A2	**A21**				●	●					●			
		A22	●				●					●			
		…													
		A2n		●						●					●
	⋮														
	Origin Am	**Am1**				●		●					●		
		Am2		●						●					●
		…													
		Amn	●					●					●		

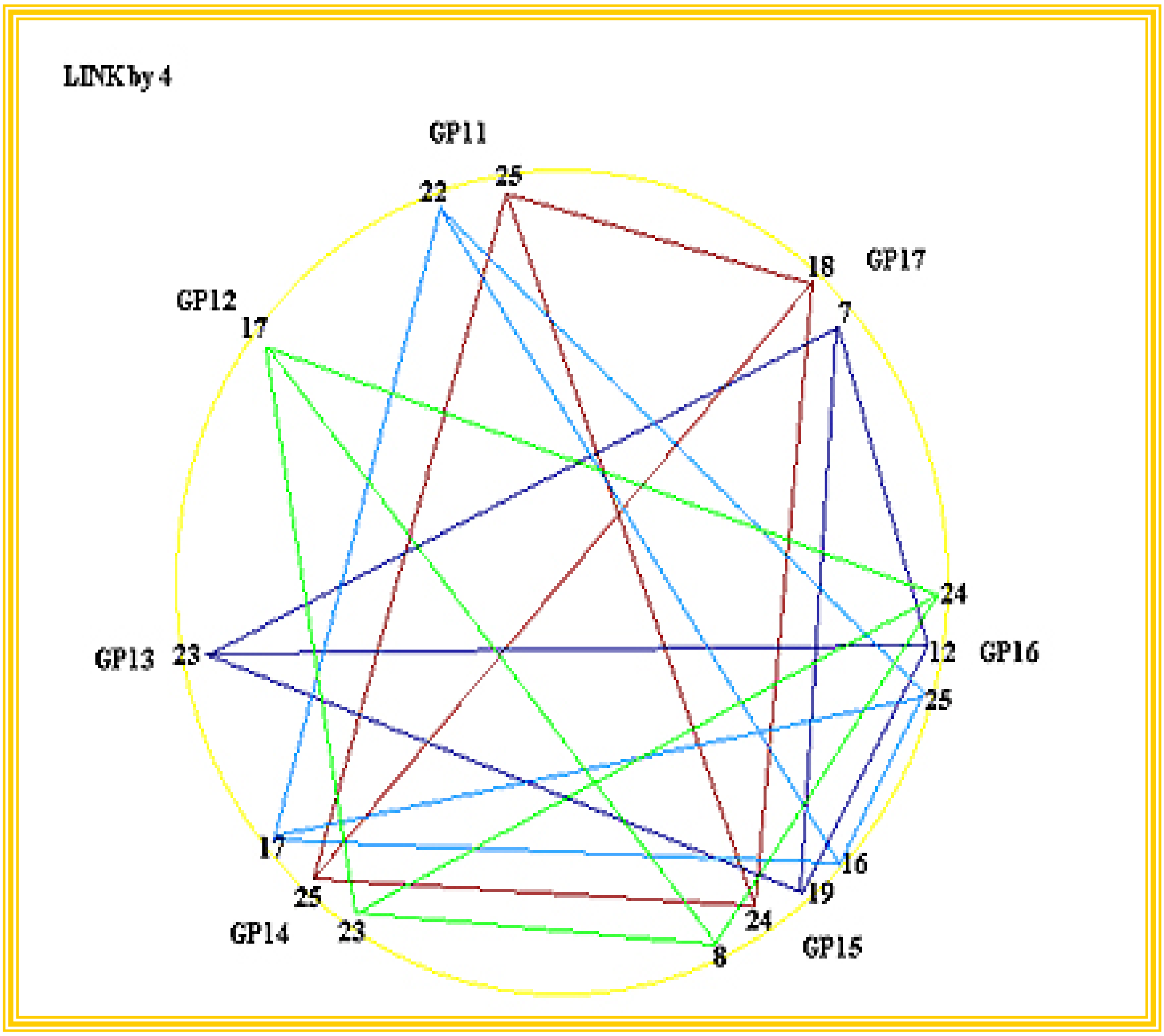

Figure 1 : Example of crosses replicated 4 times between trials in the same planting year (Aek Loba Timur project, Socfindo, Indonesia). There exist other links with crosses replicated 2 or 3 times. GP 00: trial name, 15: cross code within the trial.

Table 2: Number of parents selected per origin

	Origins	**Number of parents tested in trials at Aek Loba Timur**
GROUP A	DA 5 D x DA 3 D (*)	18
	DA 10 D x DA 3 D	7
	DA 10 D x DA 115 D	8
	DA 115 D self	8
	DA 115 D self (*)	13
	DA 115 D x DA 3 D	8
	DA 300 D x DA 128 D	7
	DA 551 D x DA 767 D	7
	LM 269 D x DA 115 D	8
	LM 269 D x DA 128 D	16
	LM 404 D self	5
	LM 404 D x DA 3 D	3
	LM 404 D x DA 10 D	6
		114
GROUP B	LM 2 T self	20
	LM 2 T self (*)	11
	LM 2 T x LM 5 T	12
	LM 2 T x LM 9 T	4
	LM 2 T x LM 10 T	8
	LM 2 T x SI 10 T (*)	6
	LM 5 T self	11
	LM 5 T x LM 10 T	9
	LM 5 T x LM 311 P	6
	LM 9 T x LM 13 T	6
	LM 10 T self	5
	LM 13 T self	3
	LM 238 T x LM 511 P	5
	LM 718 T self	1
	LM 718 T x LM 238 T	5
		112

(*) A further pedigree selection cycle.

Table 3: Number of parents depending on the number of partners. (Aek Loba block)

Number of partners	Group A parents		Group B parents	
	Number	%	Number	%
1	23	20	19	17
2	23	20	19	17
3	21	18	31	28
4	23	20	26	23
5	14	12	9	8
6	5	4	4	4
7	4	4	1	1
8	1	1	3	3

Table 4: Average characteristics of the crosses **selected for oil production from 6 to 8** years after a selection pressure of 8 % or 16% (20 or 40 crosses out of 254)

Parameters	Deli x La Mé and Deli x Yangambi crosses				
	Mean	Values of selected crosses			
		Selection pressure: 16%		Selection pressure: 8%	
		Value	Gain %	Value	Gain %
Bunch analyses					
Fruits / Bunch	66.5	67.1	+ 0.9%	67.0	+ 0.8%
Mesocarp / Fruit	82.3	84.5	+ 3.9%	85.9	+ 4.4%
Oil / Mesocarp	56.1	57.0	+ 1.6%	56.9	+ 1.4%
Lab. extraction rate	30.8	32.3		32.7	
Oil. extraction rate*	26.3	27.6	+ 4.9%	28.0	+ 6.5%
Yields, young palms 3-5 year period					
Bunch number	28.4	29.1	+ 2.5%	29.0	+ 2.1%
Average weight (kg)	5.8	5.9	+ 1.7%	5.9	+ 1.7%
Total bunch weight (kg)	158.6	164.6	+ 3.8%	164.8	+ 3.9%
Oil per ha in trials	7.0	7.57	+ 9.2%	7.67	+10.6 %
Oil per ha ind. (tonnes) **	5.62	6.14	+ 9.2%	6.22	+ 10.6 %
Yields, mature palms 6-8 year period					
Bunch number	18.8	19.8	+ 5.3%	20.1	+ 6.9%
Average weight (kg)	12.0	11.9	- 0.9%	11.8	- 1.7%
Total bunch weight (kg)	215.4	228.5	+ 6.1%	231.0	+ 7.2%
Oil per ha trials	9.6	10.7	+ 11.5%	10.96	+ 14.3%
Oil per ha ind. (tonnes) **	7.75	8.64	+ 11.5%	8.86	+ 14.3%

* Industrial extraction rate = laboratory rate x 0.855

** Oil/ha ind = Oil/ha trial * 0.855* correction over density (135/143)

Table 5: CGA of 4 good parents from group A and 4 good parents from group B

	Parents	**Combination**	**OER**	**FFB 3 to 5 years**	**Oil 3 to 5 years**	**FFB 6 to 8 years**	**Oil 6 to 8 years**
			Gain %	**Gain kg/ha**	**Gain t/ha/y**	**Gain kg/ha**	**Gain t/ha/y**
Group B	PO 4982 P	LM 5 T x LM 10 T	**+3.16**	+1.74	+0.72	+18.08	**+1.41**
	PO 2766 P	LM 10 T self	+2.29	+2.16	+0.63	- 1.19	+0.67
	PO 4922 T	LM 5 T self	+2.20	+22.80	+1.37	+2.55	+0.73
	PO 4963 T	LM 2 T self	+0.21	+32.98	+1.25	+21.87	+0.69
Group A	PO 2580 D	LM 404 D x DA 10 D	+0.71	- 3.98	-0.03	+13.22	+0.67
	PO 3584 D	LM 404 D self	**+3.25**	+2.82	+0.92	+1.99	+0.81
	PO 3600 D	LM 404 D self	**+3.39**	- 2.01	+0.60	- 2.14	+0.75
	PO 3174 D	DA 115 D self	+0.91	+7.67	+0.48	+9.47	+0.51

Table 6 : Comparison of observed values and values predicted by the GCA of a few crosses, 6-8 year period.

Cross	**Values observed in trials**			**Values predicted by GCA**			**Classification Out of 254**
	FFB kg/a	**OER %**	**Oil t/ha/yr**	**FFB kg/a**	**OER %**	**Oil t/ha/y**	
PO 3360 D x PO 4982 P	234	29.6%	9.45	232	29.4%	9.52	1
PO 3174 D x PO 2766 P	230	29.1%	9.22	226	29.4%	9.02	2
PO 3600 D x PO 2762 P	221	30.5%	9.21	225	30.8%	9.25	3
PO 2580 D x PO 2980 T	233	26.8%	8.53	236	26.4%	8.41	25
PO 3052 D x PO 2761 P	230	26.2%	8.28	216	26.3%	7.75	50
PO 3062 D x PO 4740 P	206	28.9%	8.06	208	28.4%	8.10	75
PO 3170 D x PO 3636 P	199	29.0%	7.90	206	27.7%	7.92	100
PO 2995 D x PO 3277 T	228	24.8%	7.72	220	24.3%	7.33	125
PO 3064 D x PO 3253 T	223	24.7%	7.60	220	25.1%	7.60	150
PO 4840 D x PO 2972 T	196	27.8%	7.45	203	27.8%	7.61	175
PO 4844 D x PO 3351 P	226	23.4%	7.31	221	23.8%	7.21	200
PO 3127 D x PO 4799 P	200	26.0%	7.12	206	26.3%	7.37	225
PO 3971 D x PO 3660 P	198	25.2%	6.78	196	25.4%	6.74	250

Table 7: Estimated gains if 16% of the group A and group B parents are selected based on their combining ability value.

Parameters	**General mean of ALT project**	**Average GCA values for the best 16% of group A**	**Average GCA values for the best 16% of group B**	**Theoretical values of crosses between the best dura palms and T/P palms**	
Bunch analyses					
Fruits / Bunch	66.1	+ 0.8	+ 0.2	67.0	+ 1.4%
Mesocarp / Fruit	82.8	+ 2.1	+ 1.7	86.6	+ 4.6%
Oil / Mesocarp	55.9	+ 0.2	+ 0.7	56.9	+ 1.7%
Ind. extraction rate*	26.2	+ 1.1	+1.0	28.3	**+ 8.0%**
Yields, young palms					
3-5 year period					
Bunch number	28.7	+ 0.3	+ 0.6	29.6	+ 3.3%
Average weight (kg)	5.7	+ 0	+ 0.2	5.9	+ 3.0%
Total bunch weight (kg)	159.0	+ 0	+ 8.9	167.9	+ 5.6%
Oil per ha (tonnes) **	5.62	+0.22	+ 0.55	6.37	+ 13.4%
Yields, mature palms					
6-8 year period					
Bunch number	19.0	+ 0.9	+ 1.0	20.9	+ 10.0%
Average weight (kg)	11.8	- 0.2	+ 0.0	11.6	- 1.4%
Total bunch weight (kg)	215.2	+ 7.7	+ 2.1	235.0	**+ 9.2%**
Oil per ha (tonnes) **	7.76	+ 0.59	+ 0.76	9.13	**+ 17.7%**

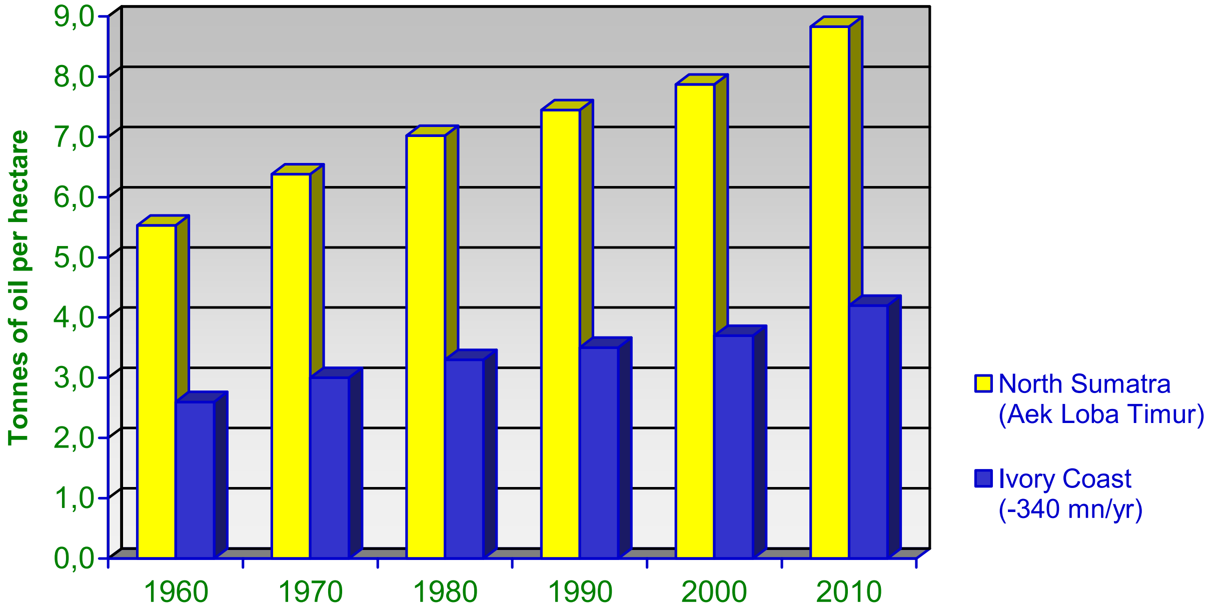

Figure 2: Variation in the production potential of seeds marketed by CIRAD and its partners from 1960 (introduction of D x P seeds) to date. The values are given for two contrasting environments.

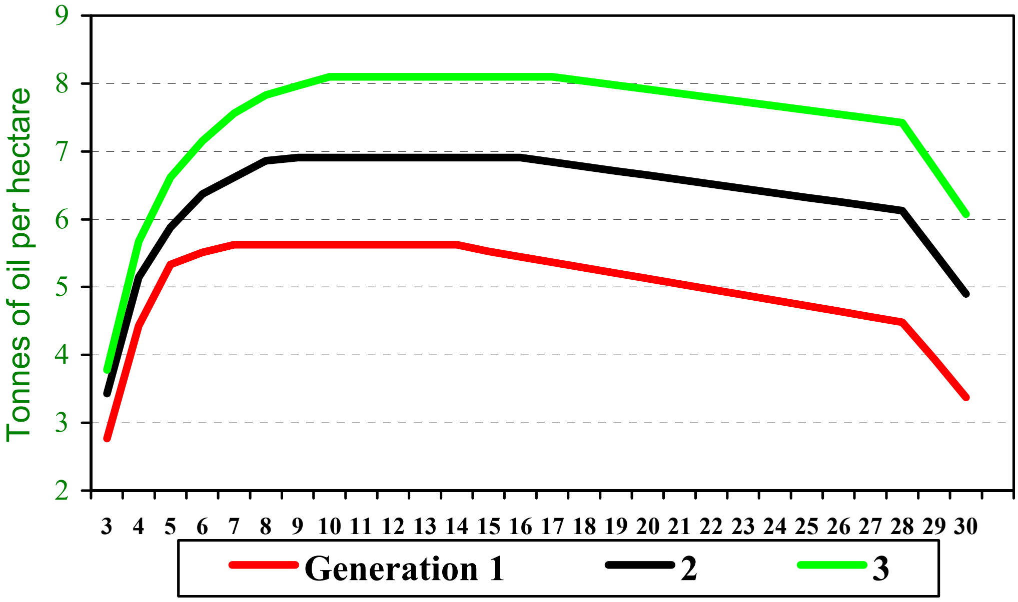

Figure 3: Production trends recorded at the Socfindo estate generation after generation (mean of the potential of all the plantations combined).