ENSURING THE CONTINUOUS IMPROVEMENT AND QUALITY OF DAMI SEEDS

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ABSTRACT

The sustainability of the oil palm industry not only requires the availability of high quality planting material but also its continuous improvement to remain competitive.

The short-term continuous improvement relies on large scale intensive progeny testing of pisifera and dura to estimate their combining abilities, allowing the exclusive selection of proven pisifera for seed production, and the multiplication of improved dura parents for the creation of new seed gardens

The long-term improvement requires the widening of the genetic base of the base populations to sustain continuous progress. The paper describes the germplasm sources developed at Dami in various breeding programs and the strategy followed to evaluate, multiply and incorporate these new germpalm into the breeding program.

Selection of palms for seed production relies on strict selection criteria, based on progeny testing results as well as family and individual phenotypes. Seed production procedures focus on achieving high productivity from selected palms to maintain high selection intensity. Blank pollinations and other stringent quality control guarantee extremely high levels of seed purity.

The seed production unit is organized in a way which guarantees full traceability of all Dami seeds and the NBPOL nursery and field planting procedures have been modified to maintain the pedigree integrity in the plantations. The resulting large-scale planting by identified progenies offers new opportunities for research and will help to select progenies better adapted to particular environments.

1. INTRODUCTION

The availability of high-grade planting material is a key aspect for the sustainability of an oil palm plantation company, as it is for any agricultural industry. The genetic potential of the planting material will indeed determine the maximum product yield potential, which the plantation industry will strive to achieve with minimum losses (N. Thompson, 2003). As such, the choice of planting material is indeed one of the earliest management decisions that will affect the profitability and sustainability of the operations.

Harisson & Crosfield realised the importance of securing the availability of A-grade planting material for its subsequent profitability, when it initiated the first oil palm development project in Papua New Guinea in 1967. Germplasm collections were imported from its existing breeding programme at Banting in Malaysia and the Dami Oil Palm Research Station (OPRS) was established to ensure the continuous improvement of oil palm and the production of high-grade seed for the expansion of the oil palm industry.

Thanks to the commitment and continuous support of the company, the breeding programme and seed production have expanded over the years. Seeds are now also produced in partnership with recognised industry leaders in Colombia, Indonesia and, soon, in Malaysia. Papua New Guinea is now renowned in the oil palm world for the quality of Dami seeds.

This paper describes some of the specific aspects of the Dami breeding programme and seed production techniques aiming to guarantee the continuous improvement of the seeds and planting material produced at Dami. Further information on the Dami Breeding programme can be sourced in papers recently presented at international conferences (Dumortier, 1996, 2000 and 2003), as well as other internal reports and newsletters.

THE BREEDING PROGRAMME

Breeding towards the ideotype palm.

The primary objective of the Dami breeding programme is to produce planting material with highest potential yields of total palm product per hectare. Particular focus is given on

- high early yields, giving cash-flow advantage
- high extraction rates, more stable across environments and involving no additional harvesting, transport or milling costs for the plantations.

A decrease in vegetative vigour and height is important to minimise inter-palm competition and allow longer replanting cycles, provided this is not achieved at the expense of yield.
The bunch or harvest index are useful criteria to breed for palms physiologically more efficient, e.g. with a higher proportion of total vegetative matter produced by a palm directed to bunch and oil production.

As oil palm cultivation rapidly expands into sub-optimal eco-climatic environments, the adaptation to local environments becomes increasingly more important and progenies need to be tested and identified with better tolerance to drought, pests and diseases or micronutrient deficiencies. These have now become important objectives of the breeding programme.

Long and Short term objectives of the Dami breeding programme

The classification of breeding activities according to their scope and objectives is presented in Table 1.

Table 1. Classification of breeding activities according to their scope.

Scope	**Long Term**	**Medium term**	**Short Term**
Output	Speculative	⟶	Non speculative
Aim	Widening of genetic Base	Development of ideotypes Concentration of desirable characters Elimination of undesirable characters	Development of base populations, used for seed production
Method	Germplasm aquisition	Evaluation through Top-cross & progeny tests	Progeny Testing
	Evaluation & Screening	Introgression	Multiplication of Elite palms
	BPRO Conservation	Re-combinations, Selfing, Inbreeding	Selection of Seed Palms
Selection	Family & Within family	Specific or General Combining abilities	General Combining Abilites Family & Within family selection of seed palms.

The methods of testing and selection differ according to the objective: Rigourous progeny testing designs and high selection intensity are required for the choice of parents to be multiplied and selected for seed production. At an early stage of selection, Family and Individual palm selection and large scale screening methods can however be more efficient for the evaluation of a wide germplasm base.

Short term improvement

The short term objective of the breeding programme **is** the continuous improvement of the base populations, used for seed production. This requires intensive progeny testing of pisifera and dura to estimate their combining abilities, the selection of best pisifera for seed production, and the multiplication of the best dura parents for the creation of new seed gardens. The selection of families and individual seed palms for seed production is very intensive to guarantee further breeding progress in most heritable characters and eliminate undesirable characters, better expressed in selfs and inbred crosses.

Longer term improvement

The widening of the genetic base of the base populations is an essential part of the breeding programme to sustain longer term progress. The incorporation of new germplasm into the breeding programme can be described in three phases:

1) In a first phase, specific breeding programmes are designed to evaluate and improve new germplasm obtained from other breeding companies.

2) A second phase consists in the family and individual selection of palms to assess their combining ability with an elite palm representative of each base populations (top-cross). The combining abilities of promising palms is also assessed more precisely through conventional progeny trials, based on incomplete North Carolina design II.

3) Palms transmitting desirable characters to their progenies in the second phase are then selected for complementary crossing, selfing and introgression into the base populations.

Considering the long process of testing and incorporating new germplasm into the breeding programme, the introgression and selfing of most promising palms can also be done at the same time as its progeny testing. In this way, pisifera and tenera are available from the selfs or complementary crosses as soon as superior palms are identified through progeny testing. A new improvement cycle of testing, selfing and backcrossing can then be repeated without delay.

Origin of Dami germplasm

The origin of Dami germplasm presented in Table 2 is organised by trial, according to the particular improvement programmes setup at the time of germplasm exchange or acquisition.

This includes:
- Dami Deli and Avros base populations, transferred from Banting, Malaysia.
- The Ideotpye breeding programme aims to develop the ‘ideotype’ palm by combining desirable characters from various germplasm sources obtained from Banting and other stations, or progressively developed at Dami.
- The Combined breeding programme includes material from the Binga and Lobe breeding programmes of Unilever.
- The Ex-Nifor programme evaluates material from Nifor, obtained from Ghana.
- The Oleifera germplasm at Dami is very limited and originates from ASD, Costa Rica.

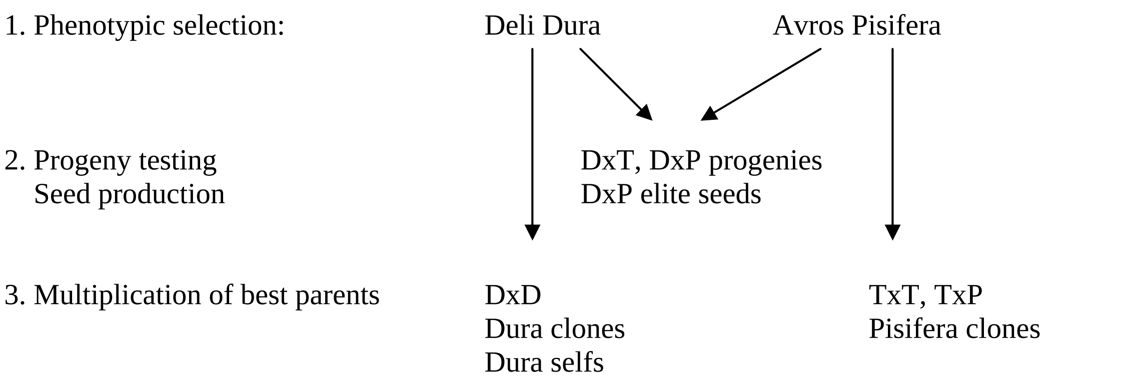
Table 2. Origin of germplasm in Dami breeding trials

Dami Trials & Programs	Type	Year Planted	No Crosses	Origin
Base Populations (Dura & Pisifera gardens)				
201, 210, 224 229, 239, 257, 267, 273, 275, 279, 303	Deli DxD	1968-2004		Deli dura - Banting (BM 8, BM 20) and Chemara (UR 404, UR 416, UR 427, UR 435)
204, 227, 281	TxT, TxP	1968, 1987, 2001	19	Avros origin - Banting (BM 29, BM 33, BM 118, BM 119)
Ideotype Pollen Sources				
202, 214	TxD, DxT	1968, 1983	21	Banting (BM 8, BM 29, BM 33, BM 89, BM 118) Chemara (UR 435, UR 416, UR 404, UR 427) Ndian (KL.14 / 25)
203	TxD	1968	11	Banting (BM 119), Chemara (UR 404, 416, 435, 427)
206	TxT	1968	8	Banting (BM 29, BM 30, BM 31)
208	TxP	1968	3	Banting (BM 119), Dami (DM 743, DM 742)
209	TxT	1978	22	Dami selections (ex DM 735, 736, 743, 775)
215	TxP	1982	10	Banting (BM 555), Dami selections & Fertile Pisifera sources (DM 742, 743, 735.408)
262	TxP,TxT	1996	36	Binga (N51, 312/3, Bg1103), Lobe (Lb144, 244), Cowan (1480TN), Bah Lias (BL238), Dumpy sources (DM775) and Dami selections
273, 274, 900	TxP	1999-2000	135	Avros introgression : Dami T x Avros P
281	TxP, TxT	2001	34	Avros introgression : Avros T x Ghana Pollen
291, 296	TxT, T Selfs TxP	2002, 2003	34	Lobe & Dami Conservation
Ideotype Dura Sources				
221	DxD	1984	30	Gunung Melayu (GM 10, 11, 12, 32, 35, 52, 53, 55, 56) Dami Deli x Gunung Melayu
264	DxD	1996	61	Lobe (Lb 328), Socfindo (SF3028), Bah Lias (BL250), Dami selections (DM108, 110, 112, 635, 711)
292	DxD	2002	49	Deli Introgression : Dami Deli x Ghana Pollen Gunung Melayu Conservation
Combined Breeding Program				
CBP No2: 227 – 236	TxT,DxT	1987-1989	146	Binga (Bg 030, 142, 143, 271, 414), Dami selections
CBP No10: 241	TxT	1981	16	Binga (Bg 3, 99, 120, 143, 194, 414, 424, 449, 469, 699)
CBP11-14: 242,243, 249, 250	TxT,TxD DxP	1990,1992	23	Lobe Breeding Program. Origins from Cowan, Nifor, Ndian, Calabar, Ekona (Lb130,158) and LaMe
Ex Nifor (Ghana)				
279	D Selfs	2001	19	Serdang, Angola, Chemara
279	TxT, TxP	2001	16	Aba, Angola, calabar, sibiti, Ufuma, Yangambi (ex Ghana)
Oleifera				
211, 293	Oleifera	1980	6	OxG, BC1

Continuous improvement of base populations

The continuous improvement of the base populations at Dami is based on a Reciprocal Recurrent Selection (RRS), aiming at improving continuously these populations for their mutual combining abilities. The three-step procedure, highlighted in Figure 1, is therefore performed on a continuous base.

Figure 1. Three-step selection procedure.



Step 1. Intensive phenotypic selection.
In the seed gardens, dura palms are selected for seed production or progeny testing through intensive selection based on family and individual phenotypic performances (FIPs). Strict criteria are being applied for the most desirable and heritable characters, particularly low height increment, high oil and kernel extraction rates, superior early yield and the absence of crown disease. Secondary characters include high leaf area, lower frond weight and rachis length, high bunch index and excellent yield in relation to height. Leaf magnesium is also taken into account for the selection of pisifera.

Step 2. Selection review based on progeny test results.
The palms selected for progeny testing have been traditionally crossed according to a North Carolina II mating design and the progenies planted in a complete randomised block design. Improved crossing designs have been recently adopted (Meunier, 1987) and incomplete block designs are now also used when the number of progenies tested is high.
Yield recording of the progenies commences two years after planting. The selection of parents is based on General Combined Abilities (GCA) calculated for yield and bunch components, and vegetative characteristics. The selection is based on 5 years observations when comparing Deli x Avros progenies and 10 years when different origins are also included in the trials.

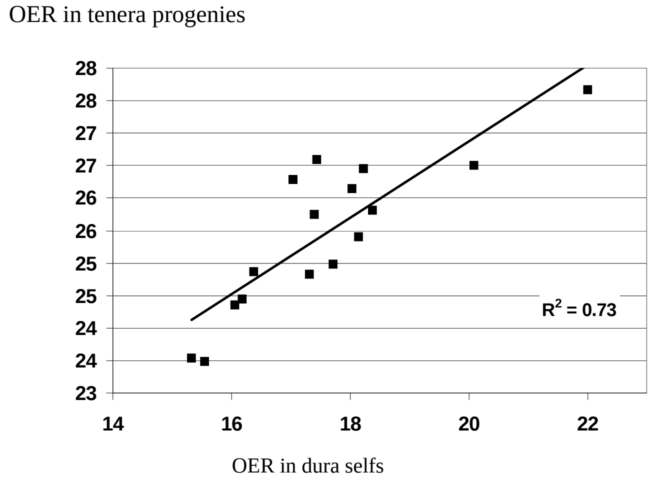
Step3. New seed gardens are created by inter-crossing parents with complementary characteristics. The parents are also selfed or cloned if they combine several desirable traits.

Improvement in Dami Deli dura population

The narrow origin of the Deli population has led many oil palm breeding programmes to the conclusion that further improvement in this population must be limited and does not justify intensive breeding efforts. In these programmes, the progeny trials aim essentially to test new pisifera lines. These are referred to as ‘Pisifera Progeny Trials’ (PPT).

Despite its theoretical narrow origin and the relative uniformity of the Deli population, substantial variability however still remains between and within the families planted in the Dami seed gardens. As an example, Figure 2 illustrates the variability in oil extraction rate for dura parents (average of selfs) and their corresponding progenies. Not only is the range of oil extraction rates in dura selfs very large (15.5%-22%) but the relationship with tenera progenies is also very strong (r^2=0.73), indicating that further significant progress can be achieved for this character.

Figure 2. Oil Extraction Rate (OER) of Deli dura selfs, in relation to corresponding tenera progenies



Progeny trials are therefore designed to systematically test both pisifera and dura, with the superior parents being multiplied for the creation of new seed gardens. One particularly promising dura was recently identified, with progenies giving up to 33.2% OER and 10.2 tonnes of oil and kernel (O+K) yields (Table 3). This dura has now been selfed and crossed in combination with other dura selections to produce seed gardens now being used for seed production.

Table 3. Progeny performances of dura 635.607 in trial 120 (planted in 1987).

	FFB Yield 1991-2002 t/ha/year	Oil /Bunch (%)	O+K Yield (t/ha/yr)	Height (% Tm)	Frond Weight (% Tm)	Leaf Area (% Tm)	Rachis Length (% Tm)
Trial mean:	28.5	30.2	9.4	100	100	100	100
Coef. Var:	3.4	4.4	4.4	6.9	7	4.8	2.9
Progeny means							
Min:	25.7	26.9	8.2	86	81	92	93
Max:	30.8	33.7	10.2	116	114	110	107
Elite dura 635.607D x P	**28.7**	**33.2%**	**10.2**	**95%**	**95%**	**92%**	**97%**

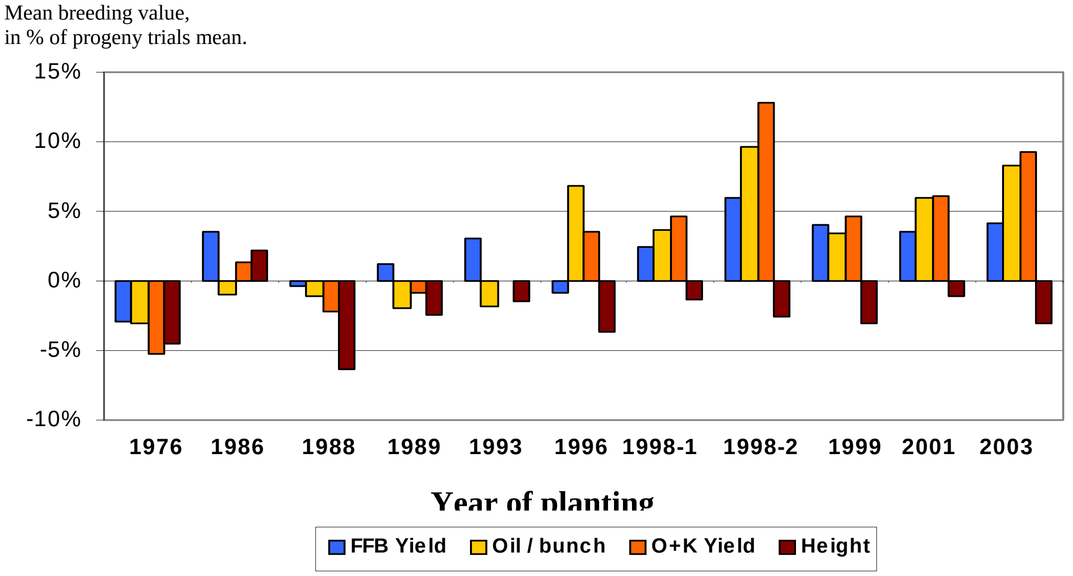
The improvement over successive seed gardens can be appreciated from Table 4 and Figure 3, based on average parental GCA values of the dura families planted in each seed garden and expressed in % of the progeny trials mean. Despite the narrow genetic base of the Deli population, the intensive progeny testing and selection work has enabled significant genetic progress in the Dami Deli population. The breeding values of parents multiplied in the latest 5 seed gardens ranged on average between +4.6% to +12.8% over trial means for O+K yield and +3.4% to +9.6% for Oil-to-bunch. In comparison, the breeding values of parents selected for the second seed garden planted in 1976 were on average -5.2% for O+K Yield and -3.1% for Oil-to-bunch.

Table 4 Average DxD family characteristics in Dami seed garden (*)
(calculated from the parental GCA values of the dura crosses)

Seed Garden	Planting	FFB Yield	Vegetative characteristics: Height	Frond Weight	Leaf Area	Rachis Length	% Oil /bunch	% Kernel /bunch	Oil +Kernel Yield
201	(1968)	-2.9	-4.5	1.7	2.0	-0.2	-3.1	-6.3	-5.2
210	(1978)	3.5	2.2	1.2	2.2	1.5	-1.0	4.7	1.4
224	(1986)	-0.4	-6.4	-2.4	-1.7	-0.7	-1.1	0.2	-2.2
239	(1989)	1.2	-2.5	-0.3	-1.1	0.6	-1.9	3.3	-0.8
257	(1993)	3.1	-1.5	1.2	2.5	1.1	-1.8	1.6	0.0
264	(1996)	-0.8	-3.6	-2.7	-3.8	-0.5	6.8	-4.6	3.5
267	(1998)	2.5	-1.4	0.6	1.2	0.6	3.6	3.1	4.6
273	(1998)	6.0	-2.6	-3.2	-3.2	-2.2	9.6	-8.9	12.8
275	(1999)	4.0	-3.1	1.8	1.1	0.2	3.4	-0.1	4.6
279	(2001)	3.5	-1.1	0.5	-2.9	-0.7	6.0	-4.1	6.1
303	(2004)	4.1	-3.0	-0.3	-0.6	-0.3	8.3	-4.9	9.3

(*) data expressed as percentage of progeny trials mean

Figure 3. Estimated breeding progress in successive Dami seed gardens.



The lower extraction rate potential of the earlier seed garden was recently confirmed by Breure (2002), comparing various dura sources with Dami dura available in Costa Rica, derived from selections made in the 1976 seed garden.

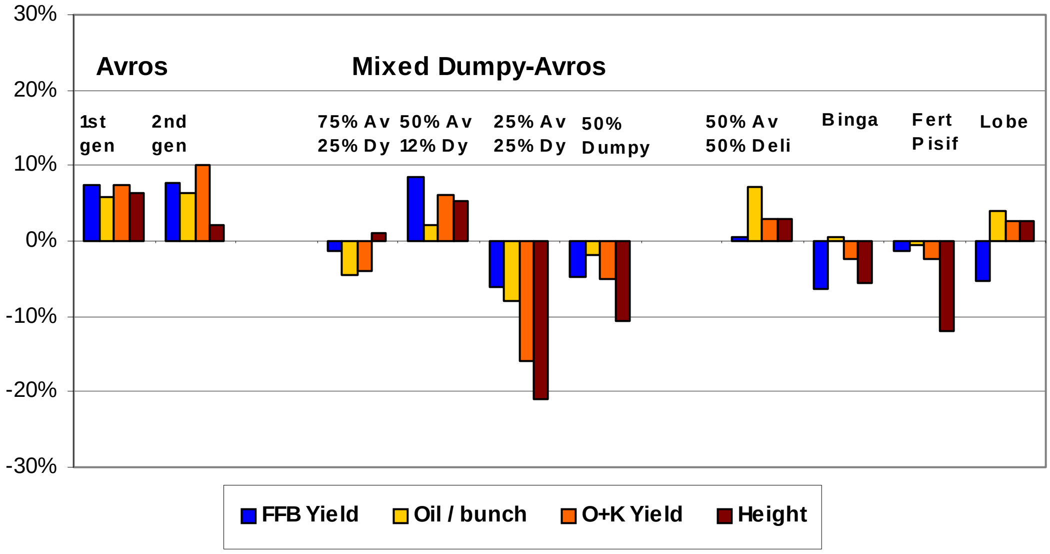
The highest O+K Yields and OER potential are obtained from the second seed garden planted in 1998. This seed garden was planted exclusively with the self of elite dura 635.607. The self of this elite dura was also planted in overseas seed garden. In Colombia, it was planted at Maria-la-Baja by Murgas y Lowe, as the 4^{th} seed garden.

Improvement of the Dami Avros pisifera population.

Figure 4 compares breeding values for various pollen sources tested in breeding trials planted at Dami. Several origins transmitting reduced height increment and mixed-dumpy and fertile pisifera origins also offer interesting yields in comparison to height. Whilst these origins are being further developed, seed production at Dami still concentrates on pisifera of Avros origin, which consistently gives higher oil yields. These pisifera also produce larger pollen quantities which means that only the very best individual palms need to be selected for seed production.

Fig 4. Breeding value of various pisifera populations.

Mean breeding value,
in % of progeny trias mean.

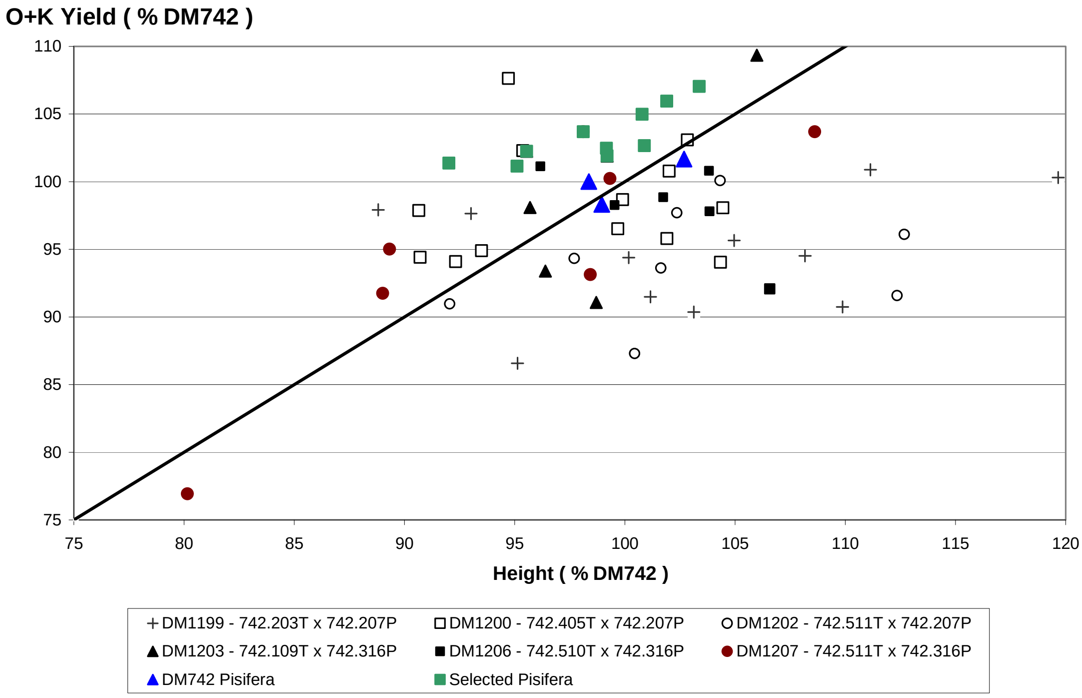


Testing and Selection of Avros Pisifera from 2nd generation.

The scope for further improvement in the Avros origin has been investigated with the large scale progeny testing of 61 pisifera derived from a second generation of Avros TxP crosses (planted in 1987), that involved the recording of over 500 DxP progenies planted in 1998.

Despite the very narrow genetic base of the Avros origin, some further improvement has been found possible, as illustrated in Figure 5 for the general combining for Height and O+K Yields, for the pisifera derived from 6 Avros TxP crosses. At this stage, 10 pisifera (highlighted with green squares) have been selected for seed production representing a minor but additional average improvement of +3.3% for O+K Yield and reduction of -1.4% for Height, compared with the three DM742 Avros pisifera from the 1st generation (highlighted in blue triangles). The new pisifera selections also all transmit very low levels of crown disease to their progenies, a character for which large differences were also found amongst DM742 pisifera (Dumortier, 1998).

Fig. 5 Combining Abilities for Height and O+K Yield of 2nd Avros generation.



Evaluation, Improvement and Introgression of new germplasm

The widening of the genetic base of the base populations is an essential part of the longer term improvement objectives of the breeding programme.
The evaluation and incorporation of new germplasm into the breeding programme relies on improvement & introgression cycles, based on the following strategy:

- Evaluation, improvement and conservation as a separate Breeding Population of Restricted Origin (BPRO). The material is evaluated at this stage on its own merit and the selection is based on Family & Individual Palm selection.

- Progeny testing to evaluate the combining abilities with the Deli and Avros Base population. It is normally done after a first round of germplasm evaluation and selection, but should also be initiated with any new pollen received.

  The two following testing options can be considered:
  * Large scale top-cross testing with a single dura or pisifera chosen as tester representative of the base populations. This method is particularly convenient to screen a wide range of germpalm. It requires limited resources for planting and recording and the crossing program can be rapidly completed. The pollen of elite dura 635.607D is generally used for the testing of tenera in TxD progenies.
  * Progeny testing in standard incomplete North Carolina II design. Requiring more land and labour to set-up and record, the design also provides better estimation of combining abilities to evaluate the most promising sources of germpalm.

- The selfing, complementary crossing and introgression into the base populations represent the third phase of the long-term improvement cycle with the objectives of conservation, elimination of deleterious genes and increase homozygocity (through selfing), development through accumulation of ideotype characters (complementary crossing) and incorporation into breeding population (through introgression and backcrossing).
  In order to save time, this third phase can be initiated more speculatively at the same time as progeny testing, with the initial selection based on Family and Individual palm then later confirmed by the results of progeny testing.

The Combined Breeding Programme.

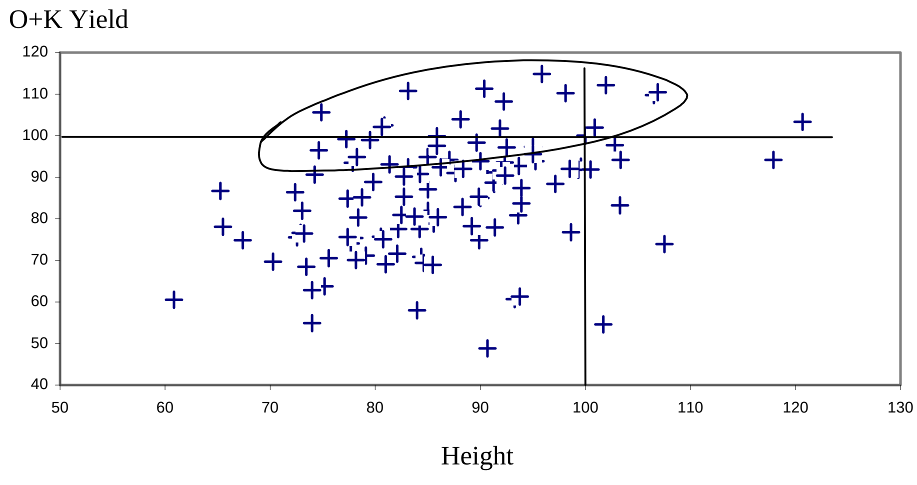
The Combined Breeding Programme (CBP) was established in the mid 1980's to exchange germplasm between Harisson & Crosfield and Unilever. Although no origin have yet been confirmed which is superior to the Avros origin, a high degree of variability has been generated and this variability is now exploited to introgress new genes in the Avros populations. The results also confirmed that best yields were obtained in combination with the Deli origin (Dumortier, 2003). It is therefore important to evaluate new germplasm for their combining abilities with that origin, in order to adequately evaluate its breeding potential.

The Avros introgression program

The Avros introgression program aims to introduce desirable characters in the Avros population, including material from diverse origins. For this, a wide range of origins was included to ensure that the genetic variability is not lost and a total of 135 tenera were selected from 94 families.

This program was designed to evaluate the combining ability of these tenera with the elite dura 635.607D, and to cross these with pollen from Avros commercial pisifera to generate TxP crosses as pollen sources. As a result, 108 TxD progenies and 128 TxP crosses were field planted in 1998 and 1999. The early results of the TxD trials are encouraging and indicate that a number of these tenera transmit better yields and reduced height, in comparison to the Avros pisifera (Figure 6). Pisifera and tenera are currently being selected in the corresponding TxP families for a second round of progeny testing, while they are simultaneously further improved and conserved through complementary crossing, tenera selfings and backcrossing.

Fig. 6 Oil and Kernel Yield and Height of TxD progenies.
(data expressed in % of Std crosses using Avros pisifera pollen)

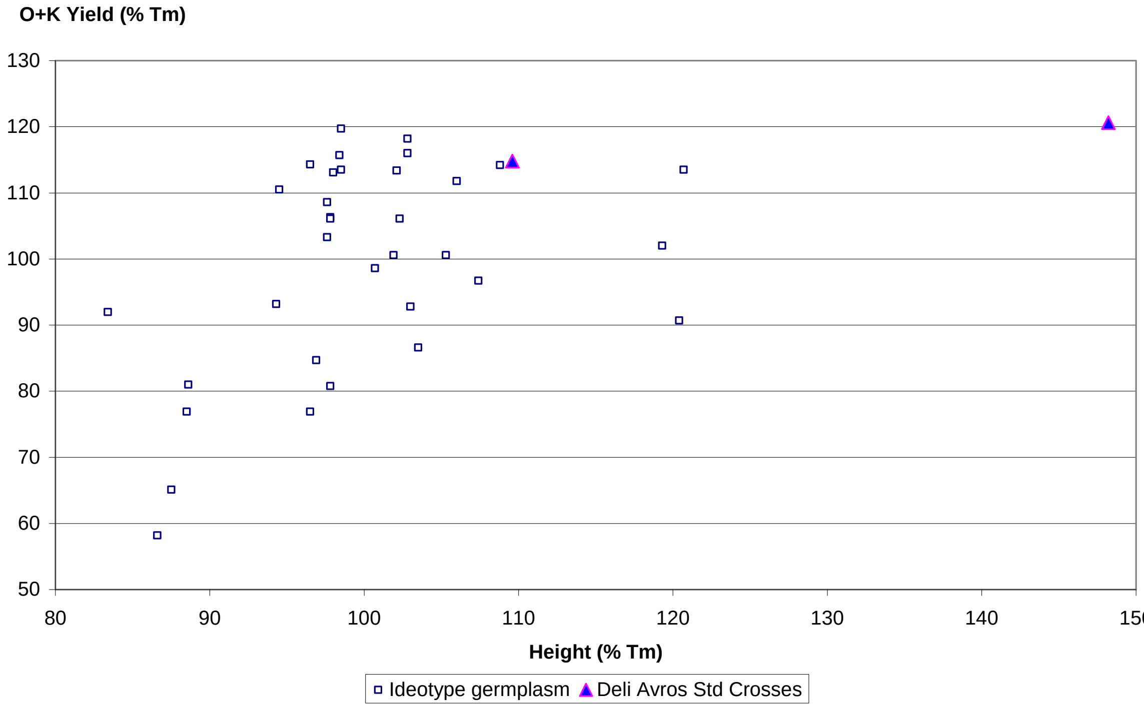


The Ideotype Breeding Programme

The Ideotype Breeding Programme (IBP) combines origins with desirable characteristics to develop populations with good yields and extraction rates on more compact palms. Ideotype dura and pisifera sources have been developed as separate populations.

Figure 7 presents the results for O+K yields in relation to height, for TxT progenies planted in trial 262, in 1996. A number of progenies transmit interesting oil yields with reduced height and vegetative vigour in comparison to the standard crosses (highlighted with blue triangles), but a comparative assessment between progenies is difficult as the trial is not linked and the level of inbreeding varies. In this respect, it is difficult to apply the original concept of Family and Individual palm selection and the material is now also being evaluated for its combining ability values with the base populations, through progeny testing.

Fig. 7 O+K Yields in relation to Height for Ideotype TxT progenies (Trial 262, 1996)
(Results expressed in % of Trial mean)



Ex-Nifor germplasm.

The ex-Nifor pollen sources available at Dami is represented by the planting in 2000 of 17 crosses from various pollen sources, including Aba, Angola, Ufuma, Calabar, Sibiti and Yangambi. In addition to this material conserved as BPRO, pollen from 25 palms was also received.
This pollen has been used for the crossing

i) with Deli dura, to evaluate general combining abilities as pollen source
ii) and with Avros tenera, for introgression and creation of mixed Avros-Nifor pollen sources.

The dura germplasm obtained from Ghana includes 20 crosses from Serdang, Angola and Chemara origins.

Table 5. ex-Nifor Germplam Collection at Dami.

Tenera / Pisifera Source		
Origin	No of crosses	No of pollen
Aba x Angola	2	2
Aba x Ufuma	4	5
Calabar	6	11
Sibiti	2	1
Ufuma	1	1
Yangambi	2	3
Others	-	2
6 origins	17 crosses	25 pollen

Dura source		
Serdang	5	5
Angola	11	11
Chemara	4	4
Deli	-	3
4 origins	20 crosses	23 pollen

SEED PRODUCTION

Selection of elite palms for seed production.

Selection of elite palms for seed production relies on the results obtained from progeny testing trials, currently covering over 1,000 hectares in Papua New Guinea and overseas.

Estimate of general combining abilities calculated from these trials are used to confirm pisifera as pollen sources and also to help in the selection of the best dura families to be used for seed production. Further intensive selection is applied to select individual seed palms, based on their Family and Individual Phenotypes (FIP), resulting in less than 20% of the dura being used for seed production.

This phenotypic selection has proven justified, considering the excellent relationship found between dura and their tenera progenies, as demonstrated by the high correlations obtained between dura selfs and corresponding tenera progenies (Table 3).

Family and Individual Phenotypic Selection (FIPS) is achieved as followed:

At family level:
- Above average GCA values, based on parental GCA values for O+K Yields, Oil/bunch and Height (expressed in % of progeny trials mean)
- Mean family Oil / bunch > 18.5% and good O+K Yield in relationship to Height.

At individual palm level:
- Oil-to-Bunch ratio > 20%, based on a minimum of 5 bunch analysis, with figures above trial mean for Mesocarp-to-Fruit and Oil-to-Mesocarp.
- Mean Fresh Fruit Bunch (FFB) over first 2 years > 80% of trial mean
- Rachis Length < 105% Tm and Frond Weight < 110% of trial mean
- Maximum Crown Disease score (0-5) <= 2, from monthly crown disease surveys undertaken from 6 to 18 months after planting.
- Absence of visual negative characteristics, such as orange spotting, magnesium or boron deficiencies.

Table 3. Correlation between dura selfs and tenera progenies (*)

	Character in tenera progenies			
character in dura selfs	*Same character*	*FFB Yield*	*Oil /bunch*	*O+K Yield*
% Crown Disease	0.69	-0.63	0.15	-0.41
FFB 3-4 YAP	0.86	0.68	0.00	0.51
Leaf Mg	0.54	0.01	0.66	0.56
Height	0.90	0.26	0.64	0.64
Frond Weight	0.89	0.61	0.15	0.60
LAR	0.66	0.18	-0.47	-0.23
% Oil-to-bunch	0.85	-0.13	0.85	0.47
% Mes-to-fruit	0.72	-0.12	0.21	-0.08
% Fruit-to-bunch	0.93	-0.15	0.77	0.54
% Fruit set	0.75	0.03	0.82	0.66

(*) *Values for tenera progenies are GCA estimates obtained from 16 dura crossed with 5 pisifera*

Seed production productivity.

In most operations, the primary objective is to achieve high productivity in order to maintain low production cost. For seed production, the production costs remain secondary to qualitative objectives. However, seed productivity remains an essential objective as the plantation seed requirements are to be satisfied using only superior A-grade seed.

On average, seed palms are expected to give 10-12,000 seeds per year, with the following aspects receiving particular attention:

- Additional fertiliser or compost applied to the seed palms.
- Maximum number of fronds retained on the palms, generally up 2-3 fronds below the harvested bunches.
- Survey of seed palms twice a month to monitor the production of new young inflorescence.
- Correct bagging technique, to ensure that the inflorescence is not damaged and that the various operations are performed at the right stage.
- Use of fresh pollen, less than 6 months old, at the rate of one gram used per 10 inflorescences.
- Repeat pollination the next day following the commencement of anthesis.

The seed processing procedures must also be closely implemented and monitored to ensure maximum germination rates are obtained and the target of over 80% seeds available for dispatch is reached. These germination levels are now routinely achieved (Table 4) but require continuous management input, to control the following factors:

- **Minimum seed stock.** Seed production needs to be adapted to expected seed sales, in order to maintain minimum seed stock levels.
- **Maintain seed quality standards**. Avoid and discard seeds damaged through depericarping. Also reject very small or completely white seeds.
- **No fungal contamination**. Seed storage and processing room must are kept very clean and staff must be able to visually assess correct moisture levels.
- **Excellent germination** and low rejection rates. This requires strict application of the seed production procedures. Significant progress has been achieved since additional oxygen is provided in hot room by aerating the seeds on a fortnight basis. Seed disturbance also needs to be minimised during germination and seed sorting, to avoid abnormal germination development.

Table 4. Details of Germination results at Dami OPRS.

Incremental values

Sorting	% Germ.	% Reject.	% Non Germ.
1st	*80.9%*	*1.6%*	
2nd	*5.0%*	*0.8%*	
3rd	*1.4%*	*0.2%*	
Final		*4.7%*	
at dispatch	*82.6%*	*7.3%*	*10.1%*

(*) estimation over: 34 Batches
3.5 Millions seeds

Cumulative values

Sorting	% Germ.	% Reject.	% Non Germ.
1st	*80.9%*	*1.6%*	*17.6%*
2nd	*85.9%*	*2.3%*	*11.8%*
3rd	*87.4%*	*2.5%*	*10.1%*
at dispatch	*82.6%*	*7.3%*	*10.1%*

Seed purity.

Dura contamination is a continuous source of concern for oil palm seed producers. This results in seed embryos which develop into the thick-shelled dura variety. In the absence of molecular marker techniques currently available to assess seed purity, these contaminated seeds cannot be detected until the palms start to bear fruit. At this stage replacement is too late and this translates into lower extraction rates at the mills and reduced economic return to the company.

Strict procedures are followed at Dami to guarantee the highest standard of seed purity.

- **Quality of the controlled pollination.** Only top quality Terylene ® pollination bags are used for controlled pollination. These bags combine strength and flexibility which ensure complete closure thus avoiding pollen contamination. The bagging techniques have proven very effective in eliminating the introduction of foreign pollen by crawling insects.

- **Pollen purity.** Pollen collections use similar quality bags and processing is done within a dedicated pollen laboratory, with isolation and disinfection measures designed to avoid contamination by foreign pollen. A separate and distinct breeding laboratory handles all non-commercial pollen for breeding purposes.

- **Blank pollinations**. Blank pollination is performed using talcum powder to monitor the occurrence and level of possible contamination. Contamination results in the development of fertile fruits that are checked and counted three months after pollinisation. These are then scored as a percentage of the total number of flowers. Blank pollinations are performed at the rate of 1 for 100 bagged inflorescences, for each individual bagger. Current contamination rate for the year averaged 0.025%, which is lower than our internal acceptable standard set which has been set at 0.1%. Our target is however 0% contamination level.

- **Seed storage and handling.** Commercial and breeding seeds are physically processed and kept in separate rooms to avoid possible mixing.

Traceability and Planting by identified progenies.

At Dami, efforts are made to produce, process and dispatch all seeds by identified progenies. This allows full traceability of the seeds produced from individual parents.

For this purpose, a specifically designed computer program is being used to record the pedigree details as well as all other controlled pollination and processing details for all seed bunches, which are identified by a unique code. The programme monitors the status of each seed bunch individually and prints daily work list according to the procedures detailed in the seed production management guidelines.

Dami OPRS always recommends planting the seeds by identified progenies in the nursery, in order to increase uniformity and facilitate culling by allowing possible differences in progeny development to be recognised. The nursery culling data are also reported separately by progeny, so that progenies which are consistently performing poorly can be identified.

These nursery procedures have been recently reviewed to maintain the progeny integrity throughout the transplanting in the main nursery and planting in the field (Hoare & Dapey, 2004). At NBPOL, this has become routine procedures for all new plantings and re-plantings since 2001 and, since then, over 5,000 hectares have already been successfully established using this technique.

Large-scale planting by identified progenies in the plantation has created many new opportunities for the breeding programme. For the first time it allows a systematic screening of all progenies produced by the seed production unit, so that the list of seed palms can be reviewed accordingly.

In addition, fertiliser trials can also be made more efficient by including the genetic origin in their designs, which will also GxE interactions to be taken into account in fertilizer recommendations.

Finally, the systematic planting by identified progenies also offers a unique opportunity to associate the plantations into the extensive screening efforts necessary to identify progenies better adapted to particular environments.

- At NBPOL, for example, this screening can help in selecting progenies which are more tolerant of Mg or other micro-nutrient deficiencies.
- At Sinar Mas, the planting by identified progenies has commenced with the plantations worst affected by Ganoderma, but once the concept is extended to the other plantation companies within the group, it will be possible to screen progenies over a very wide range of environments.
- At Las Flores in Colombia, the replanting with identified progenies will greatly contribute to identify progenies with superior drought tolerance, given the severe water deficit experienced in that part of the country.

CONCLUSION

The Dami breeding programme aims to secure both short term and long term improvement of its planting material. Short term improvement are made by exploiting the remaining variability available in the base Deli and Avros populations and selecting new pisifera and dura selections based on the results of intensive progeny testing trials. Dura transmitting higher extraction rates have been multiplied to create new seed gardens which are now used for seed production. Although the scope for progress is more restricted in the Avros population, new pisifera from a second generation are also now being used to transmit improved oil and kernel yields and reduced height increment.

Much effort has also been allocated to widen the genetic base of the Dami breeding populations. These include the evaluation of germplasm originating from breeding stations in Congo, Cameroon and Nifor. The systematic testing and usage of this germplasm follows a clear procedure to evaluate its combining abilities with the base Deli and Avros populations and to conserve and incorporate . Early results are encouraging and indicate good scope to identify improved sources of dura and pisifera for seed production.

Strict criteria are followed to select the best individuals to be used for commercial seed production, resulting in very high selection intensity. Procedures have been developed to ensure that the best seed productivity can then be obtained from these seed palms, with production averaging 10-12,000 seeds per palm per year and over 80% germinated seeds available after sorting. Seed production and blank pollination tests are closely monitored to ensure near-zero levels of dura contamination.

A computer program has been specifically developed to assist with the organization of field operations and seed processing activities and allows full traceability of the seeds produced. Since 2001 nursery and field plantings have been by identified progeny, which offers new opportunities to improve the efficiency of fertilizer trials and investigate GxE interactions. It will also greatly contribute to identify progenies better adapted to particular environments.

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