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Oil Palm Planting Materials by ASD de Costa Rica

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Summary

The first oil palm seeds were brought to Tropical America from Malaysia, Indonesia and Sierra Leone by the United Fruit Company between 1926 and 1929. Seeds of some of these materials were distributed for the first commercial plantings in Central and South America for the early developments. Starting in 1967, through exchange programs, genetic materials were introduced by ASD to Costa Rica for further improvement and selection, from renowned oil palm breeding research stations such as Chemara, SOCFIN, MARDI, Banting, Dami, La Mé (IRHO), Lobe (Cameroon) and Kade (Ghana). The ASD germplasm pool has also been enriched with collections from Tanzania, Cameroon (Bamenda), Mobai, Sierra Leone, Uganda, Zambia and Malawi. The ASD breeding program's efforts have been concentrated mostly on improving advanced Deli *duras* introduced from the above five Asian breeding research stations, and the AVROS, Ekona and Calabar *pisifera* sources. As a result of this, significant progress has been achieved mainly with the Deli *duras* from Chemara and Dami, and with the Ekona and Calabar *pisifera* sources. ASD Deli x AVROS planting material was first used in commercial plantations in Costa Rica in 1976, whereas Deli x Ekona and Deli x Ghana (Calabar) seeds were initially sold in 1989. To date there are 181,000 hectares planted with ASD seeds in Latin America and 245,000 hectares in Southeast Asia and India. The fact that some experimental plots and small commercial plantations growing under very suitable environmental and management conditions have produced up to 40 tons per hectare in peak years, shows the high yielding potential of ASD planting materials. However, because most plantations in Latin America are located in regions with important climatic and soil limitations for oil palm cultivation, average commercial yields range from 20 to 30 tons of FFB per hectare per year. Based on carefully-followed pollination techniques, ASD guarantees 99.9% purity of *teneras*. ASD's current production capacity is around 35 million seeds per year.

Introduction

ASD de Costa Rica started the commercial and technological development of the oil palm on the American continent since the late 1920s, with the introduction of the first oil palm seeds of known origin. For about 50 years now, ASD's goal has been the development of the industry through continuous research. Under this scheme, ASD has gathered a broad germplasm collection of both *Elaeis guineensis* and *E. oleifera*. The results of these efforts and a strong commitment to achieve the highest quality standards that guarantee over 99.9% *teneras*, have made ASD a very reliable and successful international oil palm seed supplier, playing a key roll in the industry expansion worldwide.

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The history of germplasm introductions to Costa Rica

The first documented introduction of oil palm of known origin into the Americas goes back to 1926, when the Panama Division of the United Fruit Company (former ASD's parent company) brought the first seeds from Malaysia. In 1927 the Lancetilla Experimental Station in Honduras also imported seeds from Asia and Africa. Following these introductions, in 1929 the Guatemala division imported 1,000 seeds from Sierra Leone (Richardson 1995).

Starting in 1936, open-pollinated seeds from Lancetilla, Honduras were distributed to the first commercial plantings in Cuba, Guatemala, Costa Rica, Colombia, Ecuador and Peru. Despite these early developments, the oil palm industry in the Americas did not grow as much as in Asia.

Richardson (1995) describes in detail how ASD's genetic resources were introduced into Costa Rica for further selection and improvement. Most of these introductions were obtained through the exchange of *E. oleifera* from Central America for *E. guineensis* from the most important oil palm breeding stations in Africa and Southeast Asia. In December 1967 the following materials were introduced from Chemara Research Station Malaysia in cooperation with B. Gray, A. H. Green and J. J. Hardon:

- 6 crosses Deli x URT
- 6 crosses Deli x BM 119
- 2 crosses BM 119 x BM 119
- 1 cross URT x URT
- 3 crosses Chemara Delis
- 3 crosses H&C Delis

Exchange programs with Unilever (Cameroon) began in July 1967, when nine seed lots of wild palms from the Bamenda Highlands were shipped to Central America. In May 1969 G. Blaak sent 14 crosses, mainly of Ekona materials. These crosses included outstanding *pisifera* parents in the accession CAM 236 (2/2311T x 3AR/7239T).

The SOCFIN (Societé Financière de Caoutchomes) Research Department sent to Costa Rica pollen of Sibiti *pisiferas*, Deli *dura* seeds, Yangambi, and La Mé T x T crosses in October, 1970. In 1975 an extensive program of crosses of Central American' Oleiferas with pollen from the former IRHO (Institut de Recherches pour les Huiles et Oléagineux) was started. As a result of this cooperative project, five accessions each of La Mé, Yangambi, and Nigerian origin TxT and TxP crosses were delivered to the United Fruit breeding project in 1979.

Similarly, seed exchange programs were arranged with: i) S. C. Ooi of MARDI(Malaysia), in 1977; ii)Tam Tai Kin of Banting (Malaysia), in 1977; iii) E. A. Rosenquist of Dami (Papua New Guinea), in 1977 and iv) J. B. Wonkyi-Appiah of Kade (Ghana), in 1977.

In 1978, G. Blaak prospected for oil palms in the Kigoma district of Tanzania. Some of these materials were characterized by "paper thin" shells, and most had good bunch composition. Five accessions of this origin were established at the ASD Coto Research Station. Seeds were also collected from palms in Mobai and Sierra Leone by G. Blaak in July, 1979. These palms were also established at the Coto research station. More recently, collections from the Entebbe Botanic Garden (Uganda), Zambia and Malawi have been added to ASD germplasm pool. The introductions made to Costa Rica since 1969 are summarized in Table 1.

Table 1. Iventory od ASD *E. guineensis* germplasm introductions from 1969

Source	Type	Year planted	Intro-ductions	Palms planted	Origin
Banting	Deli	1969	3	179	BM8,BM20
Chemara	Deli	1969	3	398	UR404, UR424, UR427, UR435
SOCFIN	Deli	1971	3	147	Johore Labis
Dami	Deli	1979	13	1604	BM8, BM20, UR404, UR435
MARDI	Deli	1979	1	64	0.102, UR932
S. Alejo	Deli (pollen)	1980	2	353	Lancetilla, 1926 introd.
Chemara	URT	1969	1	92	URT383 x 389
MARDI	URT	1979	1	97	0.99
Banting	AVROS	1969	2	164	BM119
MARDI	AVROS	1979	3	302	0.79
Banting	AVROS	1980	4	312	BM119
Highlands	AVROS	1982	2	130	BM385, BM387
SOCFIN	Yangambi	1971	2	112	Johore Labis
IRHO	Yangambi	1980	5	371	YA3, YA4, YA69
Ghana	Yangambi	1982	1	85	IRHO A 43-2-4T
Highlands	Yangambi	1982	1	19	126.4/7 P
Lobe	Ekona	1970	14	813	2/2311/T, 3AR/7239T, others
SOCFIN	La Mé	1971	1	57	21120 x 21131
IRHO	La Mé	1980	4	325	L2T, L7T, others
Highlands	NIFOR	1978	1	154	EWS 81/11T x NIF22T
Ghana	NIFOR	1979	6	288	Calabar, Ufuma, Aba
IRHO	NIFOR	1980	5	362	WA10, WA11
Ghana	NIFOR	1981	2	120	Calabar
NIFOR	NIFOR	1982	2	305	46/387T, 46/1012P
Ghana	NIFOR	1982	1	68	32.3005T
Ghana	Angola	1979	2	96	NIFOR Angola
Ghana	Angola	1981	1	60	NIFOR Angola
Ghana	Angola	1982	3	288	NIFOR Angola
Lancetilla	W. Africa	1969	6	118	Old introductions
S. Alejo	Deli-W. Africa	1970	2	136	San Alejo SP
MARDI	IRHO	1979	1	97	IRHO 1039
Dami	Composite	1979	17	1235	DM735, 736, 743, 774, 775
Lobe	Bamenda	1969	9	328	Wild
Tanzania	Kigoma	1978	5	275	Wild

ASD'S Breeding Populations

Deli *Dura* Mother Palms

The historical pathways of the different sources of Deli *duras* introduced to Costa Rica, denominated by Rosenquist (1985) as breeding populations of restricted origin (BPRO), are shown in figure 1.

The origin of the Costa Rican Delis goes back to the four original palms planted in the genetic garden in Bogor, Java in 1848. Seeds from these palms were planted along the roadside within the tobacco plantations in Deli, Indonesia. The seeds for the first commercial plantations in Sumatra, Malaysia and Honduras were originated from these ornamental palms.

Selected palms from commercial plantations formed the population base of Deli *duras* for further selection and genetic improvement in Sumatra (Bangun Bandar, SOCFIN), and Malaysia Harrison and Crosfield (H&C), Chemara and MARDI. H&C continued breeding Delis in Papua New Guinea until 1996 (Rosenquist 1985; Breure 1985). Advanced breeding materials from these programs were introduced to Costa Rica following different paths as shown in figure 1.

From the original introductions of Deli *dura* progenies, considerable breeding progress has been achieved at the ASD Palm Research Program in Coto, Costa Rica. On table 2, the characteristics of the germplasm originally received as compared with the following generations planted are presented. It is important to note how subsequent generations show much better bunch composition and yield potential than the original material.

Table 2. Selection gains of various sources of Deli *dura* introduced to Costa Rica. Data from 15 experiments collected during a 4-6 years period

Origin	Proge-nies	Palms/ progeny	kg/ palm/ year*	F/B	M/F	O/M	O/B	Oil[1]	Oil[2]	Gain (%)
Chemara[1]	3	136	105.4	70.4	62.2	46.6	20.5	21.6	3.1	
F1	12	150	108.4	71.9	69.2	48.8	24.5	26.5	3.8	22.6
F2	5	110	103	73.1	70.4	50.1	25.8	26.6	3.8	
SOCFIN[1]	3	100	100.6	71.6	62	44.1	19.4	19.5	2.8	
F1	3	100	89.7	67.1	66.2	50	23	20.6	3	7.1
Banting[1]	3	85	110.7	70.2	60.8	42.6	18.2	20.1	2.9	
F1	14	114	106.3	69.6	68.4	45.9	21.7	23.1	3.3	13.8
DAMI[1]	13	100	108.2	71.2	66.3	44.6	20.3	23.3	3.2	
F1	17	120	117.8	71.7	67.3	47.7	23.1	27.2	3.9	21.9

[1] Original material introduced to Costa Rica. * FFB; 1. Kg/palm/year; 2. t/ha/year

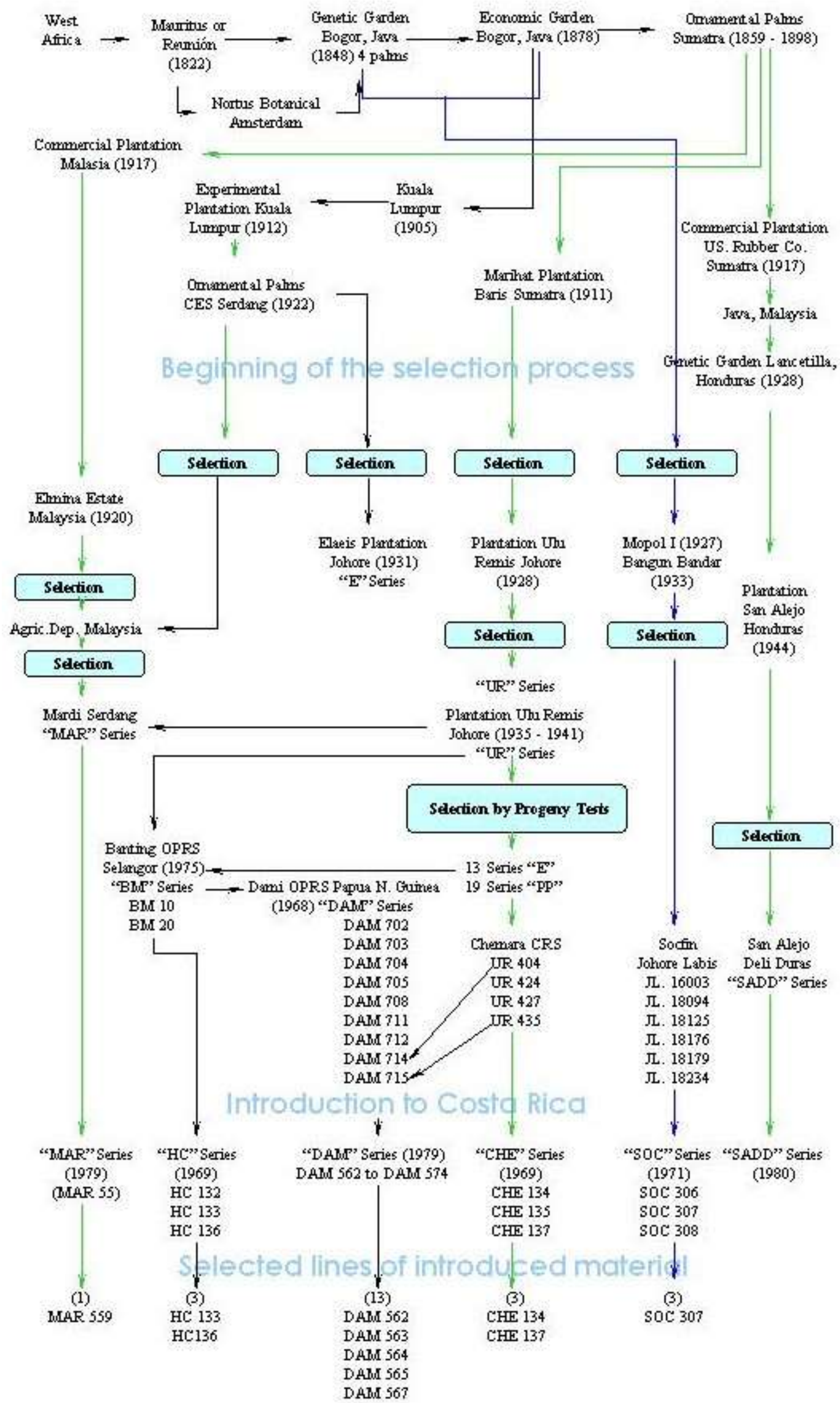

Fig. 1. Pedigree of ASD Deli *dura* mother palms

Chemara and Dami *dura* materials apparently carried much more variability for further progress in Costa Rica, since the selection gains were superior in these materials than the progress achieved with the Banting and SOCFIN germplasm. It is clear that considerable improvement can still be achieved within the Deli *dura* population, despite its narrow genetic base, as pointed out by Rosenquist (1985).

AVROS: an outstanding source of *pisiferas*

Materials from two AVROS sources were introduced into Costa Rica as shown in figure 2. One set of TxT crosses came from the Banting (H&C) program in Malaysia, known as the BM 119 series, and the second was originated from the MARDI program.

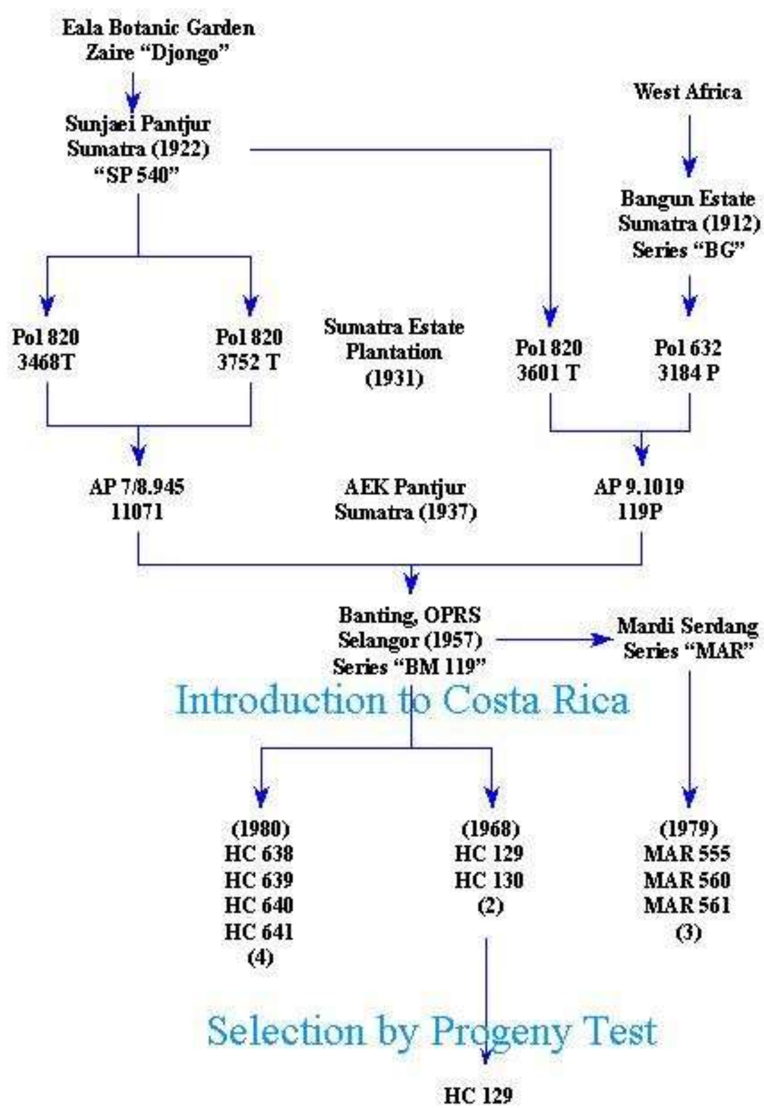

Fig. 2. Pedigree of AVROS (BM119) pollen source used by ASD

The origin of the AVROS (Algemene Vereniging van Rubber-planters ter Oostkust van Sumatra) *pisiferas* goes back to the Eala Botanical Garden in Zaire, where the famous `Djongo' (the best) palm was selected. Progenies of the `Djongo' palm were introduced into Indonesia in 1922 for further improvement, and the famous SP540 palm was selected. Lines were developed from the SP540 *pisifera*, and are widely used for seed production in Malaysia and Indonesia.

The H&C AVROS *pisiferas* introduced to Costa Rica carried genes from another germplasm source from Western Africa, which had been introduced in Sumatra (Bangun Estate), Indonesia, in 1922. Crosses derived from several selection cycles carried out in the Polonia and Aek Pantjur plantations in Indonesia were imported into Malaysia in 1957, where the progeny BM119 was bred at the Banting Experimental Station. Crosses of this origin were selected by J. J. Hardon and introduced in Costa Rica as the BM 119 series in 1968 and 1980. Another set of BM119 *pisiferas* came from the MARDI program in 1979 (Fig. 2).

Phenotypic evaluation of *tenera* siblings in T x T progenies for the next generation of *pisiferas* is carried out systematically in ASD's breeding program. From the gains made by the selection resulting in the F1 generation of TxT progenies, the potential of *pisiferas* to transfer good characteristics to their progenies in the progeny tests is demonstrated. In Table 3, the evaluation of bunch characteristics of different ASD sources of *pisiferas* is presented. It is interesting to note that within the AVROS population little progress has been achieved in terms of O/B (gain 2.7%) in the selection cycles performed in Costa Rica. This is not surprising, since ASD AVROS progenies are very uniform, as a result of seven cycles of selfing,six carried out in Indonesia and Malaysia, and one in Costa Rica. Hence, further genetic progress of the AVROS germplasm is restricted.

Table 3. Selection gains of various sources of *tenera* pollen in Costa Rica. Data collected during years 4 to 6 after field planting, 20 related experiments planted in Coto, Costa Rica

Origin	Progenies	Palms/progeny	F/B	M/F	O/M	O/B (%)	O/B gain (%)
AVROS F1	10 30	100 60	64.1 62.8	85.5 88.8	47.5 47.9	26 26.7	2.7
Ekona F1	14 2	65 50	67 63.9	81.7 85.1	50.4 52.8	27.5 32.2	17.1
Calabar F1	10 6	50 80	64.3 65.9	83.1 88.1	47.8 49.8	26.6 28.9	8.6
La Mé	4	75	62.9	82.7	48.9	26.5	
Values of *tenera* sibling in related TxT crosses							

Deli x AVROS is the classic material sold by ASD, and also the best-known and most-widely used worldwide. Under good management and agro-climatic conditions, it starts yielding 22 to 26 months after field planting, and FFB yields often surpass 30 tons/ha/year in the 6th year. It produces good-sized bunches, and, with proper management of harvest and mill operations, oil extraction rates of 24 to 25% are common.

Ekona and Calabar *pisiferas* as new alternatives

The Ekona population was developed at Unilever's Lobe Breeding Program, in Came-roon. Fourteen progenies provided by G. Blaak were introduced into Costa Rica in 1970 (Fig. 3). This population was much more variable than AVROS, since considerable progress was achieved (17.1% gain in O/B) after the selection cycles carried out in Costa Rica. One important characteristic of the Ekona population is its high oil to bunch content (Table 3).

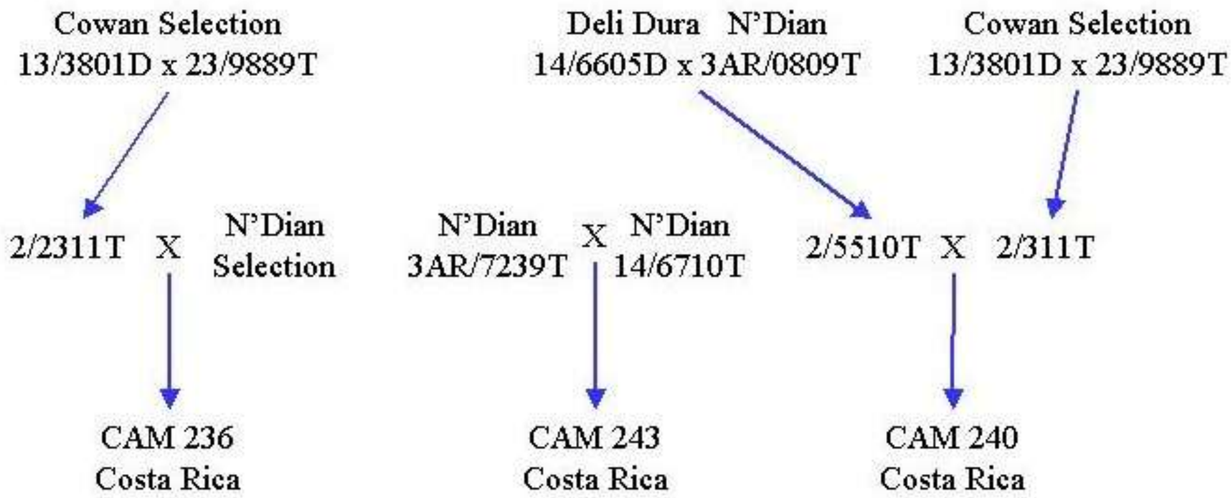

Fig. 3. Pedigree of ASD Ekona male parents

Table 4 shows the results of progeny test of different *pisifera* sources in Coto, Costa Rica. The superiority of Ekona material is confirmed in terms of oil per hectare.

Table 4. Progeny test results of different sources of male parents. Coto, Costa Rica

Type	Proge-nies	Palms/ progeny	FFB, kg /palm	F/B	M/F	O/M	O/B	Oil[1]	Oil[2]
Deli x AVROS	3	80	107.4	69.8	88.6	47.6	28.3	30.4	4.3
Deli x Ekona	4	80	116.2	72.6	87.8	52.2	33	38.3	5.4
Deli x Calabar	3	80	116.9	71	86.4	49.9	30.6	35.8	5.1
Deli x La Mé	4	80	121.8	72.9	80.3	50.1	29.4	35.8	5.1

Data collected during years 3 to 5 after field planting (1991). 80 palms evaluated per progeny.
1. kg/palm /year; 2. t/ha /year

The Deli x Ekona materials were released for commercial planting by ASD in 1989. The Ekona have other attractive characteristics such as moderately short trunks, large bunches and early high yielding. Some Deli x Ekona crosses have shown tolerance to *Fusarium* Wilt in a test conducted in Brazil, and have performed well in areas with three to four months of moderately dry and cold weather.

The Calabar population was introduced to Costa Rica in 1977 with the cooperation of J.B. Wonkyi-Appiah of Kade, Ghana. These materials were originated from the old West African Institute for Oil Palm Research (WAIFOR) in Nigeria. The pedigree of the most important Calabar progeny is shown in figure 4. The single grandparent of GHA648 (32.3005T) performed quite well as male parent on Deli females in the Sabah breeding program in Malaysia (Rajanaidu et al. 1985 and Chan et al.1985), the Kade program in Ghana (Wonkyi-Appiah, 1974), and in the NIFOR program in Nigeria (Okwuagwu 1985; van der Vossen 1974).

Fig. 4. Pedigree of ASD Ghana (Calabar) male parents

The Calabar germplasm has considerable variability for further improvement (8.6% gain in O/B, Table 3), and in progeny tests has yielded slightly better than Deli x AVROS in terms of oil per hectare (Table 4). This material, which was released for commercial planting by ASD in 1989, has shorter trunk and leaves than Deli x AVROS, which makes it possible to reduce the plant spacing to only 8.5 x 8.5 m (160 plants per hectare). It also shows high early yields, but smaller bunches. Its bunch oil content is as good as that of Deli x AVROS. Besides having good production characteristics, this planting material has performed quite well in regions with a three to four month dry season and periods of low sunlight.

Other breeding populations

The La Mé population (Fig. 5) was developed by IRHO in Ivory Coast, from 21 *teneras* coming mainly from Bret Plantation. Seeds from L2T, a well known line of this population, which transmit high yielding characters and short trunks, have been introduced to Malaysia, Indonesia, Costa Rica and other countries. Though the best La Mé lines were introduced to Costa Rica in 1980, progeny testing of these male parents was initiated in 1991.

A relatively unknown source of plants was prospected in the Kigoma district of Tanzania in 1978. These palms were evaluated as open-pollinated progenies of wild origin and showed excellent yield and remarkable bunch quality characteristics for unselected materials. Besides, the Kigoma lines gave the highest iodine index values among the *E. guineensis* origins tested by ASD.

Progeny testing of Kigoma materials was initiated in 1989. When crossed with Deli *duras*, the progenies showed high early yield and reduced vegetative growth. Because such materials were collected at high altitude, they are likely to be tolerant to cool temperatures.

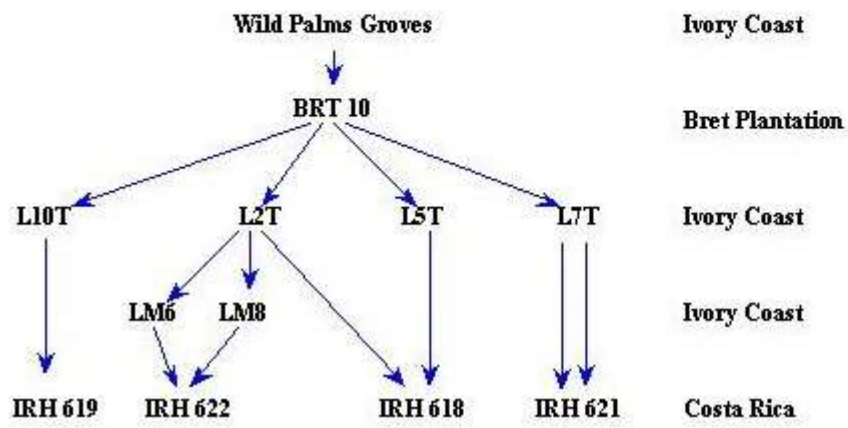

Fig. 5. Pedigree of ASD La Mé male parents

Commercial yields of ASD planting material

Besides genetic potential, climatic and soil factors largely determine the oil palm production (Ferwerda 1977; Ong 1982; Ochs and Daniel 1976; Olivin 1968; Ng 1968). Also, crop management practices play an important role in current yield levels. Therefore, the production potential of any planting material in commercial plantations is always reduced to a variable extent when compared to experimental results.

Though there is quite a large area planted with ASD material in Latin America (191,000 hectares), not many plantations provide reliable and accurate long-term production records. Some plots and small plantations growing under very good environmental and management conditions have produced around 40 tons of FFB in peak years, a fact that reflects the high yielding potential of ASD Deli x AVROS material. However, due to the factors mentioned before, the yield figures obtained from large areas in several countries are normally lower and very variable, as shown in Table 5. The yield patterns are shown in (Figs. 6-8).

Monte Plata, Dominican Republic. Located at 18o North, there is a 3-month cold and dry season. During that time, rainfall is less than 40 mm per month and minimum temperatures fall below 16°C. Soils are red-clay Latosols, shallow to moderately deep, of very low fertility, on a rolling landscape.

Quepos, Costa Rica. Located at 9° 30' North. It has a 3- to 5-month dry season, with an average annual water deficit of around 325 mm. Soils are mainly alluvial shallow to deep, silt loamy, somewhat poorly to moderately well-drained, with very high calcium and magnesium content, on flat lowland.

Table 5. Yield of ASD Deli x AVROS material in some commercial plantations in Latin America as compared to Deli AVROS commercial plantations in Malaysia					
Location	t, FFB/ha/year			Years recorded	Area (hectares)
	Source	Mean	Maximum		
Malaysia - Inland	local[1]	24.1	31.4	4 - 15	2,337
Malysia -Coastal	local[1]	28.8	32.7	4-15	5,119
Guatemala - Tecum Uman	ASD	28.6	38.5	4-9	4,335
Colombia - Santa Marta	ASD	26.8	38.4	5-15	525
Costa Rica - Laurel (smallholders)	ASD	17.5	32.5	4-6	3,500
Costa Rica - Quepos	ASD	20.9	36.2	4-20	3,535
Costa Rica - Coto	ASD	20.6	30.3	4-20	3,876
Costa Rica - Palmar	ASD	24.1	31.0	4-8	555
Source: [1] Lee, C.H. and Toh, P.Y. 1991. Yield performance of Golden Hope OPRS DxP planting materials. The Planter 47: 317-324.					

The main agroecological conditions in the regions where the above plantations are growing are the following:

Coto Costa Rica. Located at 8° 30' North, this area has a mild dry season with an average annual water deficit of less than 100 mm. However, owing to heavy cloudiness, sunlight is low to very low during most of the year. Soils there are mostly alluvial, deep loamy to clayey, poorly to moderately well drained, with very high calcium content, on flat lowland. However, there is an important area with volcanic soils (Andosols), which are shallow, loamy moderately well-drained, of low fertility and high phosphorus fixing capacity, on flat to gently-sloping landscape.

Quininde, Ecuador. In this region, at 0° latitude, there is a 4- to 5-month dry and cold season. Though it rains below 50 mm per month during that time, due to persistent heavy cloudiness the average sunlight is less than 50 hours per month, and the minimum temperature drops below 17°C. The soils are volcanic (Andosols), deep, loamy, well-drained, of medium to low fertility and high phosphorus fixing capacity, on undulating land.

Tecun Uman, Guatemala. This zone, located at 14° 30' North, presents a 4- to 6-month dry season, with an average annual water deficit of around 500 mm, conditions which make oil palm cultivation possible only with irrigation. Soils are volcanic and alluvial, moderately deep to deep, well-drained, sandy loamy to light clayey, moderately fertile, on rolling and gently-sloping landscape.

Tiquisate, Guatemala. This area, located at 14° 15' North, has a 4- to 6-month dry season, with an average annual water deficit of 500 mm, which makes oil palm cultivation possible only with irrigation. Soils there are alluvial, deep, loamy to sandy loamy, well-drained, very fertile, on flat landscape.

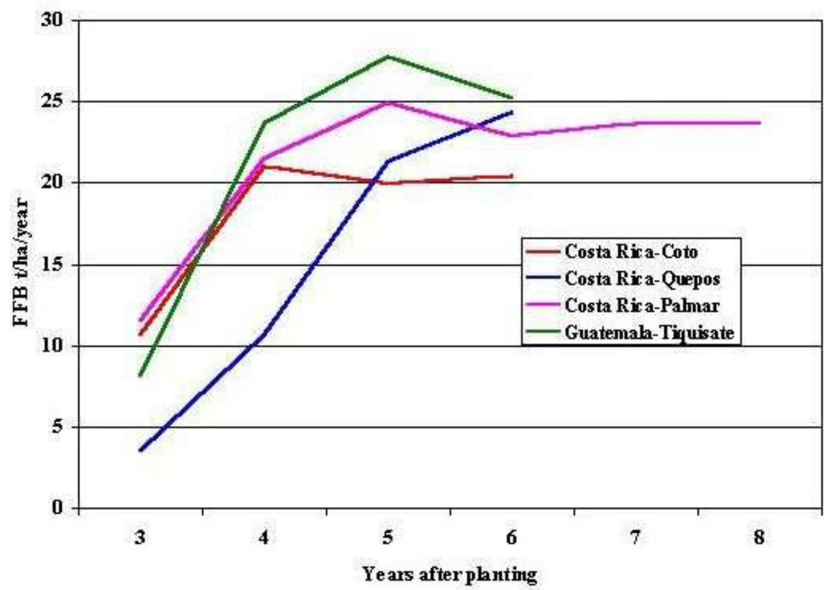

Fig. 6. Deli x Ekona mean yield patterns from different plantations in Costa Rica and Guatemala

Santa Marta, Colombia. This region, located at 11° North, has a 5- to 6-month dry season, which makes oil palm cultivation possible only with irrigation. Soils are mostly alluvial, deep, moderately well- to well-drained, loamy to clay clay-loamy, slightly alkaline, on flat landscape.

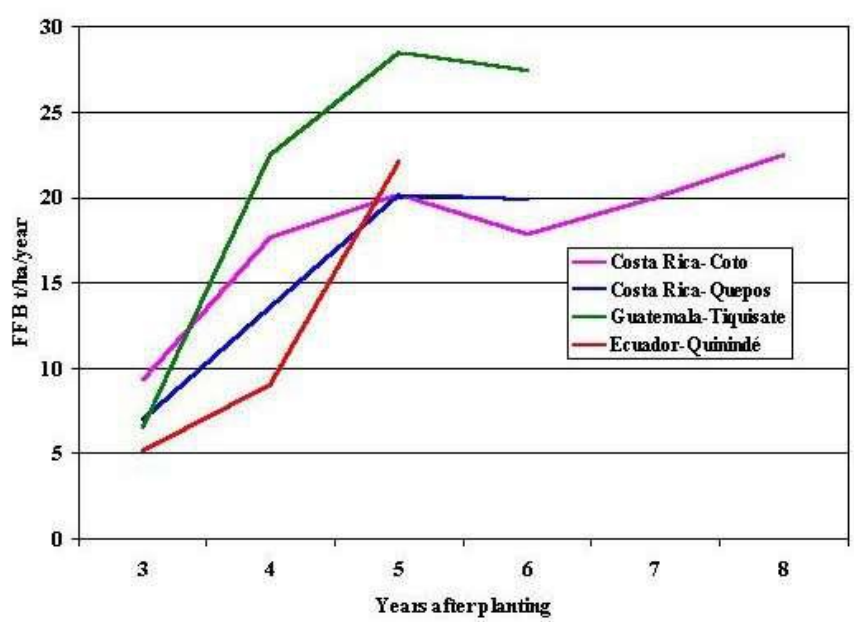

Fig. 7. Deli x Ghana yield patterns from different plantations in three countries in Latin America

Though in all the areas described above there are important climatic and soil limitations for oil palm cultivation, the average FFB yield records of plantations with ASD materials are very good. It is also clear that limitations such as severe water deficit and cold temperatures not only suppress yield, but also cause high variability of FFB yields between years. Other limitations, such as low sunshine during some months and poor drainage, significantly depress yields. However, the impact of most of these adverse factors can be partially reduced with good management, as is the case in Tecun Uman, Guatemala, where yields up to 38.5 tons of FFB/ha/year have been achieved from irrigated 8-year old plantations.

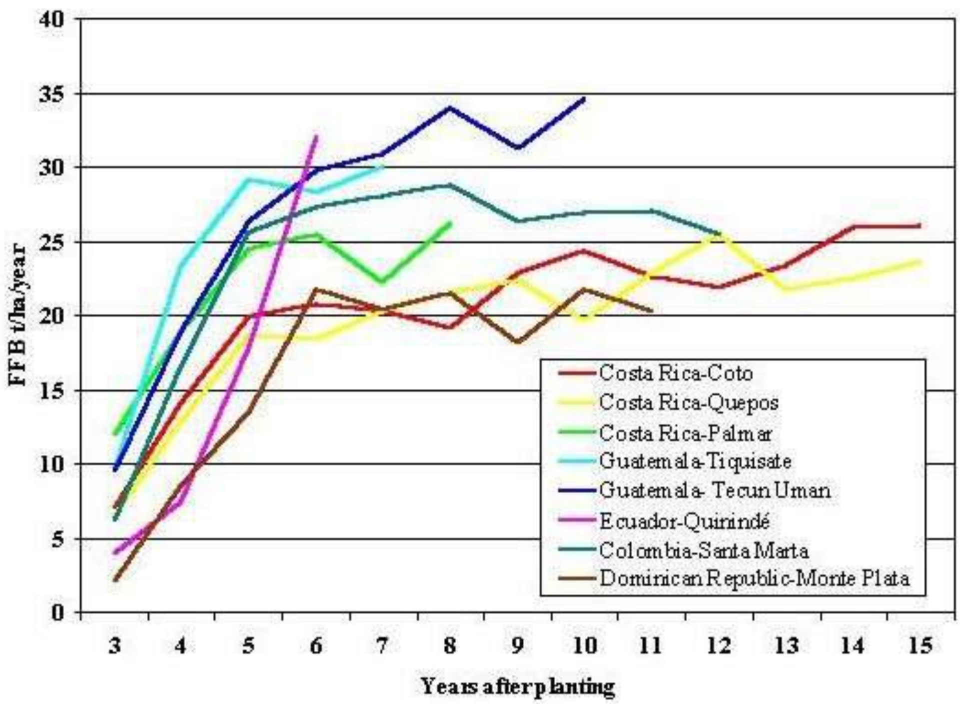

Fig. 8. Deli x AVROS yield patterns from different plantations in several countries in Latin America

Quality of ASD's planting material

When talking about oil palm seeds, quality can be assessed in two ways; the genetic and physical aspects. The breeding program must guarantee a planting material that carries all the yield characteristics expected by the planter. The physical aspects are ensured by taking the necessary precautions to offer a product which meets all phytosanitary standards and has an excellent appearance.

The significance of genetic quality involves the guarantee of purity, also referred as the legitimacy of the seeds. For ASD, this matter is of top priority, because it is closely linked with reproducing, at commercial level, the results observed in the breeding experiments. ASD seeds are guaranteed at 99.9% genetic purity. Quality is systematically evaluated while monitoring seed production. A systematic sampling of 100 commercial hectares in 1987, produced seven *duras* (99.9% purity). In 1991, the evaluation of 300 hectares showed no *duras*, a result which was again obtained in 1995 when 400 hectares were evaluated.

As a result of maintaining high quality standards, the costs of seed production are invariably high. Pollination techniques require costly materials and manpower if the goal is to guarantee quality without cutting corners. ASD follows a standard methodology, established in 1976 in cooperation with the IRHO. Expensive pollination bags are imported to guarantee 99.9% *teneras*, because no reliable local substitute has been found yet.

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