GENETIC RESOURCES

NEW DEVELOPMENTS IN OIL PALM BREEDING

Keywords : Genetic resources; Fatty acid composition; Yield; Height; Iodine; Iodine Yalue

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This paper outlines the use of the oil palm germplasm in oil palm breeding and improvement. A large amount of genetic material was collected in Africa and Central-South America. The material collected in Nigeria was evaluated in the field and the elite palms selected could yield oil up to 10-12 tonnes ha $^{-1}$ yr $^{-1}$ which is twice the current yield of 5 - 6 tonnes. These high yielding palms are also short with a height increment of only 20-25 cm yr^{-1} as compared to 45-75 cm yr^{-1} with the current planting material. The dwarf palms could reduce the cost of harvesting and at same time prolong the replanting cycle.

There is considerable variation for fatty acid composition in the Nigerian collection. A number of palms had oil with an iodine value (I.V.) exceeding 60. With additional fractionation of this oil, the olein should attain an I.V. close to 70. With this I.V. it would be possible to market palm olein as salad oil in countries with a cold climate.

The Nigerian palms with high yield, dwarf and high I.V. are being used to initiate entirely new breeding populations to produce planting material for high I.V. by 1995.

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INTRODUCTION

The oil palm, *Elaeis guineensis* Jacq., has become a major source of vegetable oil. World production of major oils and fats in 1986 was 70.73 million tonnes; soyabean oil accounted for 14.3 million tonnes (20.2%), followed by palm oil 7.5 million (10.6%), sunflower oil at 7.20 million (10.2%), butter at 6.5 million (9.2%), tallow and grease at 6.5 million (9.2%) and rapeseed oil at 6.3 million tonnes (8.9%).

World exports of major oils and fats amounted to 22.5 million tonnes in 1986. Palm oil was the major oil traded with 6.9 million tonnes (30.7%), followed by soyabean oil with 3.0 million (13.3%), tallow and grease with 2.5 million (11.1%), sunflower oil with 2.1 million (9.3%), coconut oil with 1.6 million (7.1%) and rapeseed oil with 1.4 million tonnes (6.2%).

Total world production of palm oil amounted to about 7.7 million tonnes in 1987 and exports of palm oil to an estimated 6.4 million tonnes. Malaysia is the world's largest exporter of palm oil, accounting for 4.2 million tonnes or 66% of world exports, followed by Indonesia at 710 000 tonnes (11%) and Papua New Guinea at 130 000 tonnes (2%).

Over the past 17 years PORIM has accumulat0ed a vast collection of oil palm genetic resources prospected in Nigeria, Cameroons, Zaire, Tanzania, Madagascar, and Central and South America (Rajanaidu *et al.* 1987). These collections are being screened to study the variation in FAC. Some results of this study are presented here.

DISTRIBUTION OF *ELAEIS GUINEENSIS*

E. guineensis is restricted in its natural distribution to the west coast of Africa within 20° latitude of the equator and to Brazil in South America. It is generally accepted that *E. guineensis* is of African origin (Zeven, 1964; Hartley, 1977) although Cook (1942) and Corner (1966) advocated a South American origin on the basis that most of the ralated palm species are indigenous to that region. Although *E. guineensis* occurs in Brazil, it has been suggested (Hartley, 1977) that the species had, in fact, been introduced during the movement of slaves from Africa.

E. guineensis occurs very extensively along the coast of West Africa as wild and semi-wild groves in a continuous belt from Senegal to Angola and further to the east in Zaire, Uganda and Tanzania (Zeven, 1967). The extensive distribution is reflected in the fact that in Nigeria alone, it is estimated that there are about 250 million adult palms (Zeven, 1967), while in Ivory Coast the number is placed at about 35 million (Meunier, 1969).

While the limits of distribution are known for *E.guineensis*, little information is available on the occurrence or distribution of variability within the regions. Chevalier (1943) on the basis of observed diversity of several qualitative characters proposed that the centre of origin of the species lies along the coastal belt between Liberia and Angola. Others have indicated the presence of variability in south-east Nigeria (Hartley, 1977) and Zaire (Desneux, 1957).

GENETIC BASE OF CURRENT BREEDING MATERIAL

Palm oil is a multibillion dollar industry but it rests entirely on an extremely narrow genetic base, as is typical for most crops (Arasu and Rajanaidu, 1975; Arasu and Rajanaidu, 1976; Hardon and Thomas, 1968). The bulk of current planting material derives from four palms planted at Bogor Botanical Gardens in 1848. These four '*Bogor*' palms formed the basic stock which is known as the *Deli dura* population in oil palm breeding. Subsequently, a limited number of *tenera* and *pisifera* were brought to Malaysia from Africa.

The need for an adequate genetic base for effective selection in a breeding programme is well known. It is generally recognized that the narrowness of effective gene pools has been a major obstacle to rapid progress in selection. It was concern generated by this situation that provided the initial impetus for prospection for new oil palm genetic materials (Hardon, 1974).

In order to broaden the genetic base of oil palm breeding, a number of expeditions were mounted by early oil palm workers to collect genetic materials. After the Second World War, workers in the Belgian Congo (Zaire) sampled oil palm germplasm at a number of sites (Vanderweyen, 1952; Pichel, 1956). Between 1961 and 1965, plant breeders from the Nigerian Institute for Oil Palm Research (NIFOR) collected genetic material at local markets and through village chiefs. This material was established at NIFOR. Evaluation of 72 open-pollinated progenies had been concluded and outstanding palms were selected for introduction into the current cycle of the breeding programme (Okwuagwu, 1985). Blaak (1967) sampled material in the Bamenda Hills of Cameroons. The material was planted at Lobe, Cameroons and a part of it was distributed elsewhere. In Ivory Coast, French workers from the Institute de Recherches pour les Huiles et Oleagineux (IRHO) systematically evaluated palms in the wild and the selected palms were progeny-tested for their breeding value (Meunier, 1969; Meunier and Baudouin, 1985). Earlier, IRHO selected 38 palms at Pobe in Dahomey and four at Bingerville in Ivory Coast. These formed their basic *tenera* stock.

RECENT GENETIC COLLECTIONS

In 1973, the Malaysian Agricultural Research and Development Institute (MARDI) and the Nigerian Institute for Oil Palm Research (NIFOR) collected oil palm genetic materials at 45 sites in Nigeria; on average 20 palms per site and 200 seeds per palm were sampled. A total of 919 bunches (595 *duras* and 324 *teneras*) were harvested during the prospection. One bunch was harvested from each of the sampled palms and fruits from each bunch were kept separate until field planting. For the sampled palms, data on bunch weight, bunch length, bunch breadth, bunch depth, fruit diameter, nut diameter, kernel diameter, ratio of mesocarp to fruit (%), shell thickness, fruit weight and nut weight were recorded in the field (Obasola *et al.*, 1983, Rajanaidu *et al.*, 1979).

During 1974-1975, IRHO prospected material at Muyuka, Mamfe, Kendem, Numba, Dinkom and Widikum in West Cameroons. In 1984, the Palm Oil Research Institute of Malaysia (PORIM) with the co-operation of Unilever, collected material in both the western and eastern parts of Cameroons. Samples were collected at 32 sites distributed throughout the country. One to 15 palms were chosen at random at each site; the objective was to cover the whole country as far as possible. A total of 95 palms (58 *duras* and 37 *teneras*) were sampled during the prospection. The method of collection was similar to that adopted in Nigeria.

In Zaire, the collection of oil palm genetic material was carried out with the co-operation of Unilever. (Belgian workers had prospected for oil palm germplasm in the early twenties and in the fifties in the Congo on an *ad hoc* basis). During the recent expedition, samples were taken at 56 sites distributed throughout Zaire, *i.e.* in the provinces of Equator, Kivu, Kikwit-Kwango and Bas Zaire. In most sites 5 to 10 palms were sampled. A total of 369 bunches were collected (283 *duras* and 86 *teneras*).

In the past, collections were made in the main oil palm belt of West Africa, *i.e.* from Sierra Leone to Angola. The populations in Tanzania and Madagascar were considered basically fringe populations. The collections in Tanzania and Madagascar were carried out in 1986 with the co-operation of the Ministries of Agriculture in Tanzania and Madagascar and with a partial financial grant from the International Board for Plant Genetic Resources (IBPGR).

In Tanzania, samples were collected at 13 sites located near Kigoma beside Lake Tanganyika. At each site one to seven palms were sampled and a total of 60 bunches (42 *duras* and 18 *teneras*) were collected. Dense palm groves were found at Ujiji, Mwandiga, Kiganza and Simbo. However, they were not as dense as those found in Nigeria, Cameroons and Zaire.

In Madagascar, palms were sampled at four sites and 17 samples were collected. At each site one to six palms were sampled. In Madagascar, the distribution of oil palm was very sparse. Most of the palm groves were noticed along the road from Miandrivazo to

TABLE 1.
HIGH YIELDING AND DWARF NIGERIAN *TENERA* PALMS

Trial No.	Family	Palm No.	Oil Yield per Palm (kg/year)	Oil Yield per hectare (tonnes/year)	Height Increment (cm/year)
0.149	28.17	12724	83.34	12.18	23.1
0.149	19.11	12279	75.94	11.24	21.5
0.149	13.05	12094	76.27	11.29	24.0
0.150	16.21	4352	70.39	10.42	24.9
0.150	19.13	3759	71.54	10.59	22.5
Current Planting Material				5-6	45-75

Malaimbandy. The palms were confined to sandy river valleys, intermingled with forest trees.

A general comparison of field data has been made between the populations studied in Ivory Coast (Meunier, 1969), Nigeria, Cameroons, Zaire and Tanzania. Although the Tanzanian collection is considered to come from a fringe population, it possesses bunch and fruit qualities comparable to those from Ivory Coast, Nigeria, Cameroons and Zaire. For instance, the ratio of mesocarp to fruit in both *duras* was close to that of Nigerian material and *teneras*. Richardson (1986) has also indicated the outstanding bunch and fruit qualities of Tanzanian materials planted and evaluated at Coto, Costa Rica. These palms were collected by Blaak in 1979 (personal communication).

IMPORTANCE OF OIL PALM GENETIC RESOURCES TO THE INDUSTRY

Based on 1987 prices and production, the oil palm industry's turnover is nearly US$2.7 billion. In order to maintain and improve the competitive edge of oil palm over other oils and fats, it is necessary to increase yield. Some of the Nigerian palms have a great potential; they could yield up to 10-12 tonnes of oil per hectare per year, which is double the current yield of 5-6 tonnes. In addition, these palms are short, with a height increment of only 20-25 cm per year as compared to 45-75 cm per year with the present planting material *(Table 1)*. Dwarf palms would be extremely useful to the industry because they would reduce the cost of harvesting. In addition, the replanting cycle could be prolonged if we were to establish a plantation with dwarf palms.

The fatty acid composition of palm oil produced from current planting materials limits its share of the market for liquid and salad oils. More than 3000 palms from the Nigerian collection were individually screened for the fatty acid composition of their oil, to examine their natural variation and the potential for exploitation. The mean composition and range are given in *Table 2* along with those of present day Malaysian palm oil. Many individual palms have oil with iodine values (IV) above

TABLE 2.
FATTY ACID COMPOSITION (%) AND IV OF CPO FROM NIGERIAN AND FROM CURRENT MATERIAL

	Nigerian Population		Current Breeding Material	
	Mean	**Range**	**Mean**	**Range**
C16:0	38.99	27.40 - 54.35	44.53	35.3 - 52.4
C18:0	6.14	2.50 - 12.60	4.51	2.9 - 7.9
C18:1	41.50	30.02 - 54.30	37.98	31.3 - 45.8
C18:2	10.76	6.60 - 16.50	11.36	6.0 - 15.7
IV	54.19	42.94 - 69.75	52.21	45.2 - 59.5

TABLE 3.
FATTY ACID COMPOSITION (%) OF CPO FROM NIGERIAN PALMS WITH HIGH IODINE VALUE

Palm No.	C14:0	C16:0	C18:0	C18:1	C18:2	IV
22	0.6	32.8	6.5	43.7	15.3	63.9
38	0.5	32.5	7.9	44.3	13.5	61.3
48	0.7	35.4	5.5	43.0	14.2	61.4
128	0.6	35.3	5.3	42.1	15.8	63.4
146	0.5	32.4	5.6	45.0	15.5	65.4
151	1.1	36.1	5.4	41.6	14.8	61.2
305	0.9	40.1	5.1	47.9	14.7	61.4
618	0.6	33.7	6.7	44.2	13.5	61.2
814	0.5	32.6	6.6	47.4	11.8	61.1
903	0.4	30.8	7.3	46.5	13.9	63.9
971	0.3	31.2	7.0	49.1	12.9	64.4
1861	1.4	37.0	6.4	36.2	17.6	61.4

TABLE 4.
FATTY ACID COMPOSITION (%) OF CPO FROM SOME FURTHER NIGERIAN PALMS.
PALM NUMBERS AND THEIR NOTABLE CHARACTERISTICS

	1941	849	1405	2247	2360	
Fatty Acids	**Low C16 (<37%)**	**High 18:0 (> 8.0%)**	**High 18:1 (>47%)**	**High 18:2 (> 12%)**	**High 18:2 (> 12%)**	**Range for Commercial Palm Oil**
C14:0	0.5	_	_	_	_	0.6 - 1.7
C16:0	*31.6*	27.4	30.4	35.3	45.8	41.1 - 47.0
C18:0	8.9	*14.7*	6.8	5.3	3.2	3.7 - 5.6
C18:1	48.2	38.6	*52.2*	42.1	36.0	37.3 - 43.5
C18:2	9.6	14.8	7.0	*15.8*	*12.5*	6.6 - 11.9
Slip point (°C)	21.0	23.5	27.7	23.5	_	30.8 - 39.0

60 *(Table 3)*. With further fractionation of CPO, the olein should attain an iodine value close to 70. With this IV, it would be possible to market palm olein as salad oil in countries with a cold climate. Also, the nutritional properties of the oil would be improved.

While the emphasis in oil palm breeding is towards greater unsaturation of the oils, mass screening should not overlook palms which could yield oils of an interesting composition suitable for other end-uses. *Table 4* gives the fatty acid compositions of some of the oils analysed from the Nigerian collection. The palms producing CPO with a higher level of stearic acid (C18:0) could be examined for their potential in the manufacture of cocoa butter substitute.

The groups in *Table 4* (low C16, high 18:0, high 18:1, high 18:2) are defined in relation to the composition of present-day commerical palm oil. As would be expected, the variation with the Nigerian material is much greater than in the present day palm oil. The points of interest are :

i. The high content of C18:0 acid in some samples.

ii. The low content of C16:0 in some samples.

iii. The low melting points of some of these samples.

There is a good posibility of breeding for oils of low C16:0 acid content and of high C18:0 using the Nigerian palms with the right attributes.

As with the fatty acid composition, the triglyceride compositions of the samples considered show a big variation from that of commercial palm oil. Most of these samples show a triglyceride composition quite similar to that of oil from the hybrid *E. guineensis* x-*E. oleifera*, in that the concentration of triglycerides is in C52 and C54. Another point of interest is the contrasting composition shown by sample 2360, which has a high C50 triglyceride content; this could be developed further to produce specialty fats such as cocoa butter substitute *(Table 5)*.

TABLE 5.
TRIGLYCERIDE COMPOSITION (weight %) OF CPO FROM SOME NIGERIAN PALMS

Carbon No.	Triglyceride*	Palm Numbers					Range for Commercial Palm Oil
		1941	849	1405	2247	2360	
C46	MPP	_	0.2	0.1	0.1	0.4	0.4-1.4
C48	PPP	1.5	1.5	1.5	2.0	4.7	4.5-10.3
C50	POP, PLP	22.8	18.2	23.1	30.8	52.9	39.4-44.7
C52	POP, POS	52.5	50.8	51.4	51.2	37.9	38.9-44.4
C54	OOO, OOS, OLO	22.7	28.8	23.6	15.5	3.9	6.7-11.9
C56		0.5	0.5	0.3	0.3	0.1	_

* M = myristic acid P = palmitic acid S = stearic acid O = oleic acid L = linoleic acid

The Nigerian palms will also be used to initiate entirely new breeding programme with the objective of producing superior alternatives to current breeding populations, *e.g.* the *Deli duras* and modern *teneras*. The presence of very high-yielding *teneras* in the Nigerian population suggests that such alternatives are possible. Judiciously selected Nigerian *duras* and *pisiferas* will form the future breeding material to produce high yielding *teneras*.

With the development of tissue culture techniques for oil palm, it should be easier to multiply the palms with the desirable attributes rapidly. Within one generation of evaluation, it was possible to identify palms which are high yielding, short and which produce oil of good quality *(Table 6)*. With conventional breeding methods, it would have taken three generations (30 years) to incorporate all these traits in a single palm.

SPECIAL BREEDING PROGRAMME TO RELEASE DxP PLANTING MATERIAL FOR HIGHER UNSATURATION (IV)

In oil palm, the inheritance of bunch number and bunch weight is generally additive in nature. The high IV *tenera* palms (*e.g* 128 T) are being crossed to a number of high IV *duras*. With certain *duras* the progeny are expected to yield 30-38 tonnes of FFB per hectare per year on inland soils. When palm 128T is crossed to *dura* 814, the expected yield of the DxT progeny can be calculated as follows:-

TABLE 6.
CHARACTERISTICS OF NIGERIAN PALMS WITH OIL OF HIGH IODINE VALUE

Palm No.	Yield (1982 - 87)			Bunch Analysis						Fatty Acid Composition %					IV	Height Increment (m) (at 9th yr)
	FFB (kg p^{-1} yr^{-1})	B No.	B Wt. (kg)	F/B	M/F	O/B	K/F	S/F	MFW	C4:0	C16:0	C18:0	C18:1	C18:2		
22D (4105)	142.2	11.5	14.4	60.2	42.8	13.0	13.1	44.2	9.3	0.6	32.8	6.5	43.7	15.3	63.9(1)	3.13
38D (3908)	107.6	14.2	8.1	66.4	35.0	15.1	12.8	52.3	7.2	0.5	32.5	7.9	44.3	13.5	61.1(2)	4.17
48D (4204)	103.3	16.3	8.0	57.7	39.6	9.9	15.5	44.9	7.6	0.7	35.4	5.5	43.0	14.2	60.5(2)	3.11
128T (1403)	226.3	20.5	12.1	67.5	80.8	27.2	7.2	12.1	7.2	0.6	35.3	5.3	42.1	15.8	63.4(1)	2.57
146D (3216)	114.5	6.8	17.1	72.6	42.9	13.8	10.6	46.4	11.6	0.5	32.4	5.6	45.0	15.5	62.5(2)	2.04
618D (1403)	163.0	14.8	12.3	61.6	39.2	9.9	16.1	44.7	10.2	0.6	33.7	6.7	44.2	13.5	61.2(1)	2.42
814D (2102)	171.8	8.8	23.3	54.8	46.7	12.5	12.5	40.8	12.2	0.5	32.6	6.6	47.4	11.8	61.1	2.96
871D (2002)	215.9	18.2	12.7	62.6	45.8	12.8	12.8	41.4	11.3	0.3	31.2	7.0	49.1	12.9	60.7(3)	3.66
1861D (1816)	161.9	11.7	15.4	64.4	46.2	12.9	11.9	42.0	7.6	1.4	37.0	6.4	36.2	17.6	61.4	2.28

FFB = Fresh Fruit Bunches
B No. = Bunch Number
B Wt. = Average Bunch Weight
F/B = Fruit/Bunch (%)
M/F = Mesocarp/Fruit (%)
O/B = Oil/Bunch (%)
K/F = Kernel/Fruit (%)
S/F = Shell/Fruit (%)
MFW = Mean Fruit Weight (g)

Palm No.	Bunch Number		Average Bunch Weight (kg)
814	D8.8		23.3
128T	20.5		12.5
Average	14.65	x	17.7 = 259.3 kg per palm per year (38.4 tonnes per hectare per year)

The Nigerian palms with high iodine value will be exploited on a large scale to confirm their yield potential and superior oil quality. A number of *duras* and *teneras* with high IV will be progeny-tested as D x T crosses and at the same time selfs of *duras* and *teneras* will also be field-planted to produce D x P planting material of high IV. The approximate time scale to realize this programme is given below:

Item	Time
Evaluation and Identification	1982 - 1987
Pollination and Crossing	1987 - 1988
Harvesting and Germination	1988 - 1990
Nursery	1989 - 1990
Field planting	1990 - 1991
Yield Recording and Bunch Analysis	1992 - 1995
Fatty acid composition analysis	1992 - 1995
D x P seeds for high IV available in	1995

Initially 100 D x T crosses, 100 *dura* selfs and 100 *tenera* selfs will be evaluated in the field. We expect a selection intensity of 10 per cent. The use of about 30 palms from each of the 10 selected progenies will provide about 300 mother palms; these, at the rate of six bunches per year, should produce about 1800 bunches, providing about 1.8 million seeds per year for commercial planting.

As already indicated, this programme is expected to lead ultimately to the commercial production of palm oil with high unsaturation (IV). Such oil could be marketed as a special product under a brand name, in the same way as rapeseed oil of low erucic acid content is marketed as 'Canola'.

ACKNOWLEDGEMENT

The authors wish to thank the Director-General of PORIM for permission to publish this paper.

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