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THE GENETIC IMPROVEMENT OF THE DELI DURA BREEDING POPULATION OF THE OIL PALM *ELAEIS GUINEENSIS* JACQ.

Keywords: *Elaeis guineensis* Jacq.; oil palm; Deli *dura*; African *dura;* breeding; fresh fruit bunch yield; bunch yield components; heritability.

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The Deli dura *breeding population of* Elaeis guineensis *has a restricted genetic base, with limited heritable genetic variation for the improvement of bunch yield and its two components, mean annual bunch number and single bunch weight. The introgression among Deli sub-populations as a means of improving heritability is here investigated.*

*Analysis of variance with the estimates of the expectation of mean squares was carried out on three populations: intra-Deli, inter-Deli and inter-*dura. *Estimates of total and heritable genetic variance (V_G and h^2 respectively) for total bunch yield and the two components were obtained for the three populations.*

*Over a four-year period total yield was highest in the inter-dura population (80.3 kg/palm/year) and least in the inter-Deli population (42.4 kg/palm/year). V_G was absent for total yield and its two components in the intra-Deli population, but highly significant for all three traits in the inter-Deli and inter-*dura *populations. For average bunch number h^2 was highly significant and accounted for most of the genetic variation for these two populations. Similarly, for single bunch weight in the inter-*dura *population, h^2 accounted significantly for the V_G. In the inter-Deli population h^2 and non heritable genetic variation significantly determined the average bunch weight. The total yield of fresh fruit*

*bunches was determined mainly by non heritable genetic variation in the inter-Deli population, while h^2 was high and significant in the inter-*dura *population.*

*The continual exploitation of the Delis in the various breeding programmes will not result in genetic improvement for bunch yield. Future progress must rely on the creation of new high yielding populations with a broad genetic base for which heritability for total yield can become significant, as is the case with the inter-*dura *population evaluated in this study.*

INTRODUCTION

In the oil palm *Elaeis guineensis* Jacq., the commercial planting material is the thin shelled *tenera*, which is a single cross hybrid between the thick shelled *dura* as the seed tree and the shell-less *pisifera* as the pollen parent. There are two distinct types of the *dura* which are, the African *dura* and the Deli *dura* of the Far East. The Deli *dura* palms have characteristically better fruit quality and produce fewer but heavier bunches, which complements the high sex ratio of the *pisifera* or *tenera* in their *tenera* hybrids. The Deli *dura* has thus assumed great importance in oil palm breeding and commercial seed production in West Africa and even more so in the Far East, where the Delis presently constitute the entire *dura* population.

The availability of heritable genetic variation in a population is essential if genetic improvement in the character of interest is to be attained. While natural groves of wild and semi-wild palms abound to provide valuable sources of variation for the genetic improvement of the African *dura* breeding population, there is no known natural relatives of the Delis as they are all descended from four seedlings planted in Bogor (Indonesia) in 1848, whose origin has remained uncertain (Belgarric, 1951; Hardon and Thomas, 1968). Hardon and Thomas (1968) showed that the Deli *dura* population of major oil palm breeding programmes in Malaysia had evolved from reproduction within a small effective population size for at least three generations prior to the commencement of systematic breeding. This resulted in random fixation and loss of genetic variability in the Deli breeding population. Ooi *et al.* (1973) examined the extent of genetic variability in the Deli population in Malaysia and recorded no heritable genetic variation for total yield of fresh fruit bunches and its two components which are mean annual bunch number and average single bunch weight. This confirmed earlier suggestions by Hardon and Thomas (1968) that improvement in the Deli *dura* population was likely to be limited for these bunch yield traits and that introgression among Deli materials from different sources to create a genetically more variable population would be essential for future progress in selection.

Sparnaaij and van der Vossen (1980) reviewed the justification for the continual exploitation of the Deli populations in oil palm breeding despite their narrow genetic base. They noted that heterosis, which is characteristic of Deli x African *tenera* or *pisifera* crosses, and which was ascribed to 'inter-origin effect' by Gascon and Brechoux (1964), has perpetuated breeding within the Deli *dura* population with the hope of creating better combiners with the African *tenera* or *pisifera*. Furthermore, although heterosis in Deli x African *tenera* or *pisifera* crosses has also been attributed to the effect of inbreeding in the parent population rather that 'inter-origin effect' (Hardon, 1970), Sparnaaij and van der Vossen (1980) proposed the complementation of the two components of bunch yield which are, single bunch weight and mean annual bunch number for which the two parent populations are divergent, to account for the observed heterosis. Accordingly, further exploitation of Deli x Deli crosses, especially under West African growing conditions, was considered unnecessary, while introgression with African material was viewed as essential for future progress.

The need for introgression as a means of increasing heritable variation in the Deli *dura* breeding population was highlighted by Rosenquist (1985). He noted that although the Delis *dura* generally considered to have a narrow genetic base, their population had reached several million before the advent of systematic breeding in both Malaysia and Indonesia. Subsequently, with the various research organizations independently following their own selection criteria, various sub-population of the Delis have evolved for which there has been fixation of different groups of genes that control the major economic traits. These sub-populations, which can trace their origin to a few palms in at least two or more legitimate generations of selection, are what Rosenquist described as a 'breeding population with restricted origin' (BPRO). Subsequent introgression among these BPROs would result, he expected, in the build-up of the heritable genetic variability essential for future progress in selection of the Delis.

The objective of the present study was to evaluate the levels of total and heritable genetic variability for the yield of fresh fruit bunches and the two components, mean annual bunch number and single bunch weight, among different populations derived from the NIFOR breeding programme by intercrossing as follows:

(i) Four full-sib descendants of the Serdang Avenue Deli *dura* selections, representing breeding within a restricted Deli sub-population;

(ii) Five Deli *dura* selections, from different sources representing introgression among Deli sub-populations; and

(iii) Five unrelated African *dura* selections, representing a genetically diverse population.

The value of introgressing Delis from different sources as a means of building up heritable variation for bunch yield and its two components is examined.

MATERIALS AND METHODS

Three populations from the NIFOR breeding programme have been evaluated in this study.

Population I consists of six progenies derived from a complete diallel of four Deli parents, excluding reciprocals and selfs. The four Deli parents are full-sib selections from first generation Serdang Avenue (19 x 65) Delis introduced into NIFOR.

Population II consists of eight progenies derived using the Design I mating scheme of Comstock and Robinson (1952) by intercrossing Deli selections from the five different sources outlined below:

(i) NIFOR ex Serdang Avenue Malaysia selection

(ii) NIFOR ex AVROS[a] selection

(iii) Pamol Nigeria Limited, Cowan Estate Selection

(iv) IRHO[b] Dabou (ex Sucfindo) selection

(v) IRHO Pobe selection

Four palms used as male were each separately mated to two different palms used as females, to produce eight progenies.

Population III consists of 10 progenies derived from a complete diallel (excluding reciprocals and selfs) among five unrelated African *dura* palms selected from the NIFOR breeding programme whose parentages are (i) 3.361(Calabar 256 selfed); (ii) 3.3164 (103.148 selfed (Calabar 703 selfed)); (iii) 1.53 (Aba 931 x Aba 864); (iv) 2.3570 (Aba 731 selfed) and (v) 1.2209 (Angola 263 selfed). A summary of these three populations is presented in *Table 1*.

The three populations were field planted between 1959 and 1963 on the NIFOR Main Station in randomized complete blocks of four replicated with 10 palms per plot at 8.8 metre triangular spacing. The recording of bunch yield started in the fourth year of field

a) *Algemene Vereeniging Rubberondermingen ter Oestikust van Sumatra (now RISPA).*

b) *Institut de Recherches pour les Huiles et Oleagineux.*

TABLE 1. SUMMARY OF THE THREE OIL PALM POPULATIONS

Population	Type of population	Mating design	Number of parents	Number of crosses	Level of inbreeding	Year planted
Intra-Deli	Deli x Deli among fullsibs from Serdang Avenue	4 x 4 Diallel excluding reciprocals and self (19x16)	4	6	0.322	1959
Inter-Deli	Deli x Deli among parents from 5 different selection programmes	Comstock and Robinson Design 1	12:4 males 8 females	8	0.29	1962
Inter-*dura*	*dura* x *dura* among unrelated parents	5 x 5 Diallel excluding reciprocal and selfs	5	10	0	1962-1963

planting. Harvesting was at weekly intervals and recording was on an individual palm basis. The mean annual bunch number (BN) and the total yield of fresh fruit bunch (FFB) were calculated on a per palm per year basis using plot means of eight palms. The mean single bunch weight (SBW) was derived from each year's yield average. Four years' mature yield (1973 - 1976) were analysed.

Statistical analysis of populations I and III, derived by diallel, followed Griffin's approach of analysing F1 crosses excluding reciprocals and selfs as outlined by Singh and Chaudhary (1979). The analysis of Comstock and Robinson's (1952) Design I (population II) was as described by Kempthorne *et al.* (1961). All analyses were based on plot means of eight palms. The analysis of variance showing the expectations of mean squares of the two mating schemes is given in *Table 2*.

Estimation of variance components and their genetic interpretation:

$$M_1 - M_2 = p\text{-}2\ \sigma^2_g \quad \text{(population I and III)}$$

$$M_1 - M_2 = rf\ \sigma^2_g \quad \text{(population II)}$$

$$\sigma^2_g = \frac{1 + Fx}{4}\ \sigma^2_A$$

$$h^2 = \frac{\sigma^2_A}{V_T}$$

$$\sigma^2_{h^2} = \frac{16h^2}{T} \quad \text{(Fullsib families)}$$

$$V_G = \frac{C^2}{V_T}$$

where: σ^2_A = Additive genetic variance

$\sigma^2_{h^2}$ = Variance of heritability estimate

h^2 = Narrow sense heritability

F_X = Inbreeding among parents

V_G = Total genetic variance

V_T = Total phenotypic variance

T = Nn = number of fullsib families (N) x number of palms per family(n).

All other notations have the same meaning as in *Table 2*.

TABLE 2. ANALYSIS OF VARIANCE AND EXPECTED MEAN SQUARES

Populations I and III: Diallel (Griffin's Method 4[a])

Sources of Variation	df	Mean Square	Expected Mean Square
Replication	(r-1)		
Cross	[p(p-1)/2]-1		$\sigma_e^2 + r\sigma_c^2$
GCA	(p-1)	M_1	$\sigma_e^2 + \sigma_s^2 + (p-2)\ \sigma_g^2$
SCA	p(p-3)/2	M_2	$\sigma_e^2 + \sigma_s^2$
e'		1/r M_3	
Error	(r-1)[p(-1)/2-1]	M_3	σ_e^2

[a]) In Singh and Chandhar (1979).

r = number of replications

p = number of parents

σ_g^2 = General Combing Ability (GCA) Variance

σ_s^2 = Specific Combing Ability (SCA) Variance

σ_e^2 = Variance among plots within replications

σ_c^2 = Variance among crosses

e' = Error for GCA and SCA

RESULTS

The mean annual mature bunch yields of the three oil palm populations over a four-year period is presented in *Table 3*. The inter-*dura* population gave the highest mean annual yield of fresh fruit bunch (FFB) of 80.298 kg per palm per year. The high yield was due to both high mean annual bunch number (BN) and high single bunch weight (SBW). The FFB yield of the intra-Deli population was higher than that of the inter-Deli population. This higher yield was due to the higher BN in spite of the inter-Deli's higher mean SBW (14.096 kg and 11.396 kg respectively).

The analysis of variance with the estimates of mean squares for the three bunch

Populations II: Constock and Robinson's Design 1 (1952)

Sources of Variation	df	Mean Square	Expected Mean Square
Replication	(r-1)		
Cross	(mf-1)		$\sigma^2_e + r\sigma^2_c$
Male	(m-1)	M_1	$\sigma^2_e + r\sigma^2_{f/m} + rf\sigma^2_g$
Female in Males	m(f-1)	M_2	$\sigma^2_e + r\sigma^2_{f/m}$
Error	(r-1)(mf-1)	M_3	σ^2_e

σ^2_g = Variance among males

$\sigma^2_{f/m}$ = Variance among females within males

σ^2_e = Variance among plots within replication

m = number of male parents

f = number of females mated to each male = 2.
Other notations have the same meaning as indicated for populations I and III above.

TABLE 3. MEAN ANNUAL YIELDS (FFB), BUNCH NUMBERS (BN) AND SINGLE BUNCH WEIGHTS (SBW) FOR THREE POPULATIONS FROM 1973 TO 1976.

Population	Bunch Yield Trait	1973 Mean	1973 CV%	1974 Mean	1974 CV%	1975 Mean	1975 CV%	1976 Mean	1976 CV%	1973-1976 Mean	1973-1976 CV%
Intra-Deli	FFB (kg/palm/yr)	52.213	23.78	55.400	17.27	34.412	26.63	68.713	23.23	52.714	16.07
	BN	5.325	18.65	5.592	14.55	3.054	23.15	4.450	23.04	4.617	12.00
	SBW (kg)	9.804	12.56	10.000	13.71	11.296	15.24	15.529	12.34	11.396	8.52
Inter-Deli	FFB (kg/palm/yr)	42.938	19.74	48.742	15.51	32.303	27.22	46.397	34.65	42.319	15.37
	BN	4.909	17.74	4.559	18.43	2.544	25.93	2.672	30.22	3.612	12.73
	SBW((kg)	9.216	15.42	10.822	13.21	13.100	10.40	17.969	15.75	12.787	9.98
Inter-*dura*	FFB (kg/palm/yr)	63.615	12.73	86.415	18.24	65.897	16.23	104.082	13.29	80.298	10.63
	BN	6.228	12.28	7.007	19.63	4.422	20.27	5.473	16.16	5.783	11.73
	SBW(kg)	10.333	15.92	12.535	17.27	15.378	16.05	19.813	16.18	14.095	6.91

yield traits of the three populations is presented in *Table 4.* The intra-Deli population gave no significant difference among crosses for the three bunch yield traits. For the inter-Deli and inter-*dura* populations highly significant differences among crosses were obtained for all the 'three bunch yield traits. The main (male) effect was highly significant for the two components of yield (BN and SBW) in the inter-Deli while in the inter-*dura* population the main (GCA) effect was highly significant for all the three yield traits. The interaction (female/male) effect was highly significant for SBW and FFB yield but not for BN in the inter-Deli population. Interaction (SCA) effect was only significant for SBW in the inter-*dura* population. The estimates of total genetic (V_G) and heritable (h^2) variances are presented in *Table 5.* Total (V_G) and heritable (h^2) genetic variations were absent in the intra-Deli population for all three bunch field traits. The estimate of (V_G) was very high for the two yield components BN and SBW in inter-Deli and inter-*dura* populations. The estimate for V_G for FFB yield was higher for the inter-*dura* population than the inter-Deli population. The estimate for h^2 for FFB was also higher in the inter-*dura* population.

DISCUSSION

The higher yield of fresh fruit bunch (FFB) and the higher mean annual bunch number (BN) of the African *dura* compared with the two Deli populations is consistent with earlier results of Toovey and Brockmans (1955) in which poor yield was obtained for Deli populations under the Nigerian growing conditions. The higher bunch yield of the partially inbred intra-Deli progenies compared with inter-Deli progenies was due to the higher mean annual bunch number of the later whose parents have undergone one generation of effective selection for high bunch number in the NIFOR breeding programme (Sparnaaij, 1972; West, 1976). The importance of high bunch number in the determination of total yield of FFB under seasonal environmental variation that characterizes Nigerian growing conditions is thus exemplified. The high single bunch weight which characterizes the Delis does not compensate for its very low bunch number hence its characteristically lower yield of fresh fruit bunches.

Estimates of heritable genetic variation obtained from breeding populations despite their known limitations, continue to provide a reliable basis for determining the progress expected from breeding within such populations (Gardener, 1963). The intra-Deli progenies represent an extreme case in narrow genetic base of a breeding population. Consequently it was not surprising that the levels of both total and heritable genetic variation for the three yield traits in this population were negligible. This result is comparable to the estimates obtained for the four Deli breeding populations in Malaysia (Ooi *et al.*, 1973) Thus the common conclusion that most Deli breeding sub-populations have become considerably inbred is further confirmed. The continued breeding within these various sub-populations cannot be effective in attaining future genetic improvement in yield and its two components. Among the inter-Deli population, genetic improvement can only be effective for increasing bunch number. The improvement for single bunch weight and total bunch yield are limited, as they are determined, mainly by non-additive genetic variation. In the inter-*dura* population, the determination for yield and the two components are mainly by heritable genetic variation. Genetic improvement for these three traits in this population will be effective.

It is obvious from the foregoing analysis that inter-mating Deli selections from different breeding programmes has resulted in the build-up for heritable genetic variation of the two yield components , but not for the total bunch yield, when compared with the restricted intra-Deli population. This however was not accompanied by increase in yield. The exploitation of the high heritable genetic variation for the two components of bunch yield in the improvement of total yield is limited by the high negative genetic

TABLE 4. ANALYSIS OF VARIANCE FOR THE THREE YIELD COMPONENTS IN THE THREE OIL PALM POPULATIONS

Population	Source of Variation	df	MEAN SQUARE		
			Average Bunch number	Average bunch weight	Fresh fruit bunch yield
Intra-Deli	Rep	3	0.040	5.085	75.667
	Cross	5	0.190 NS	1.340 NS	36.905 NS
	Error	15	0.307	0.942	71.770
Inter-Deli	Rep	3	0.323	4.228	59.761
	Cross	7	1.884***	33.059***	222.349***
	Male	3	3.868***	59.312***	140.875 NS
	Female/Male	4	0.395 NS	13.370***	283.455***
	Error	21	0.211	1.630	50.383
Inter-*dura*	Rep	3	0.530	3.263	281.118
	Cross	9	3.616***	13.671***	245.646***
	GCA	4	1.692***	7.084***	84.208**
	SCA	5	0.281*	0.516 NS	42.908 NS
	e'		0.115	0.244	18.352
	Error	27	0.460	0.949	72.878

TABLE 5. ESTIMATES OF TOTAL GENETIC VARIANCE (V_G) AND NARROW SENSE HERITABILITY (h^2) FOR THE THREE BUNCH YIELD COMPONENTS IN THE THREE OIL PALM POPULATIONS

Population	Average bunch number		Average bunch weight		Fresh fruit bunch yield	
	V_G	h^2	V_G	h^2	V_G	h^2
Intra-Deli	0	0	0	0	0	0
Inter-Deli	1.98	2.24 + 0.75	0.87	1.98 + 0.70	0.48	0
Inter-*dura*	1.08	0.79 + 0.43	1.20	1.07 + 0.46	0.79	0.43 + 0.29

correlation between the two yield traits. Further yield increases among Deli *dura* populations will have to rely on introgression with African *dura*. This can result in the selection of a new population which combines the high yield of the African *dura* with the excellent fruit quality of the Delis. The continual exploitation of the Deli population as parents in the production of high yielding *tenera* hybrids can only be short lived. Sustained progress in yield increases between Deli x *tenera/pisifera* hybrids would require higher yielding Deli genotypes than are now available in most breeding programmes.

Variability among African *dura* and *tenera* populations abounds in natural and seminatural groves and gene pool collections all over the world. Evaluations of the NIFOR-MARDI collection reveal the enormous potential of this and other collections (Rajanaidu *et al.*, 1990). Their exploitation and their introgression into the present breeding populations provide the most practical and promising option for the future improvement of genetically-determined yield in the oil palm.

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