GENETIC PERFORMANCE OF 40 DELI *DURA* x AVROS *PISIFERA* FULL-SIB FAMILIES

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ABSTRACT

A total of 40 oil palm dura *x* pisifera *progenies were planted on inland soil of the Serdang Series in Malaysia. They were evaluated for fresh fruit bunch (FFB), fruit components and agronomic traits. FFB production for the majority of the progenies was reasonably good for inland soil, ranging from 77.99 to 162.37 kg palm^{-1} yr^{-1}. Analysis of variance showed no significant difference among the progenies, indicating lack of genetic variability for FFB and its components except average bunch weight (ABW). This was further supported by the low genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and broad-sense heritability (h_B^2). However, greater genetic control was observed in the fruit components and agronomic traits. For example, the genetic variation for mesocarp to fruit (M/F) and shell to fruit (S/F) ratios contributed more than 40% to the phenotypic variation of the characters. Among the vegetative traits, leaflet length (LL) and rachis length (RL) exhibited similar magnitude in their GCV to PCV contribution. The lack of variability in some of the characters in these materials may be an obstacle to future breeding and selection. Introgression with new materials from the germplasm collection will likely broaden their genetic base for future breeding and improvement.*

Keywords: oil palm, Deli *dura*, AVROS *pisifera*, heritability.

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INTRODUCTION

The progress of oil palm breeding and selection in Malaysia is partly due to the joint research programmes between research centres in Malaysia and Africa since the 1950s (Hardon *et al*., 1976). One of the programmes was the Sabah Breeding Programme (SBP). In 1964, C W S Hartley, then a consultant to the Sabah government, initiated SBP with the aim of producing high-yielding planting materials suitable for the Sabah agroclimatic conditions (Rajanaidu *et al*., 1985). Quoting Kushairi and Rajanaidu (2000), the breeding materials for the programme were acquired through exchange among four Malaysian and three African participating agencies. The Malaysian participants were Chemara, Harrison Malaysia Plantations Sdn Bhd (HMPB), Socfin and the Federal Department of Agriculture (DOA) while the African participants were the West African Institute for Oil Palm Research (WAIFOR), Unilever Nigeria and Unilever Cameroon. The exchanged materials in the programme included African *tenera* selections crossed with selected Malaysian Deli *dura*, and African *dura* selfs and crosses. Similarly, the African *tenera*s were also selfed and crossed. A cross-section of the SBP materials was distributed to the participating agencies for their own use (Rajanaidu *et al*., 1985). The male parents used in this study were the Algemeene Vereniging van Rubberplanters ter Oostkust van Sumatra (AVROS) *pisifera*, derived from the progeny Sungai Pancur 540 (SP540) crossed to materials from Bangun Bandar

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Experimental Station, Sumatra, Indonesia (Kushairi and Rajanaidu, 2000).

The Oil Palm Research Station (OPRS) HMPB and DOA imported oil palm materials into Malaysia from Sumatra in 1959 (Lee and Yeow, 1985). The Malaysian Agricultural Research and Development Institute (MARDI) later managed DOA's oil palm breeding materials. In 1979 when the Palm Oil Research Institute of Malaysia (PORIM) (now Malaysian Palm Oil Board, MPOB) was formed, this management was transferred to PORIM (Kushairi and Rajanaidu, 2000). Oil palm breeding and selection programmes in MPOB have been geared towards prospecting for new materials and utilizing the traditional collections of Deli *dura* and AVROS *pisifera*. Extensive studies on the performance of their DxP progenies have been carried out to identify outstanding progenies to increase oil production. In this study, 40 Deli *dura* x AVROS *pisifera* progenies were evaluated for bunch yield, bunch quality components and vegetative traits.

MATERIALS AND METHODS

A total of 40 full-sib progenies from Deli *dura* x AVROS *pisifera* (DxP) with a standard cross (SC) were planted in Trial 0.314 at MPOB Keratong Station Malaysia in 1994 on inland soil predominantly of the Serdang Series. These DxP progenies were laid down in a randomized complete block design (RCBD) in three replications with 16 palms per progeny per replicate. The trial was planted at 148 palms ha^{-1}. Individual progenies were identified by the progeny code, prefixed PK (PORIM Kluang). The different *dura* sources were denoted as 'DS' (DS1-DS5) and the *pisifera* as 'P' (P1-P11). Mean annual rainfall (from 1993-2004) was 2051.44 mm per year, ranging from 984 to 3314 mm per year. Data collection of the *tenera* progenies was carried out for fresh fruit bunch (FFB) yield (1998-2004), bunch quality components (1999-2004) and one round of vegetative measurements in 2003. The phenotypic (PCV) and genotypic (GCV) coefficients of variation for the agronomic characters were calculated using the method introduced by Singh and Chaudhary (1977). Data collection was based on individual palms and analysed using the Statistical Analysis System (SAS).

RESULTS AND DISCUSSION

Yield and Yield Components

Analysis of variance (ANOVA) of the 40 progenies (*Table 1*) showed no significant difference for FFB and bunch number (BNO) between progenies. However, a highly significant difference was detected for average bunch weight (ABW), indicating that a significant amount of genetic variability existed. The replicate × progeny (R×P) item was also highly significant for all the traits, implying

TABLE 1. MEAN SQUARES AND VARIANCE COMPONENTS FOR YIELD AND YIELD COMPONENTS IN 40 DxP FULL-SIB FAMILIES

Source	df	FFB (kg palm^{-1} yr^{-1})	BNO (bunches palm^{-1} yr^{-1})	ABW (kg palm^{-1} yr^{-1})
Replications (R)	2	55 290.29**	300.01**	138.96*
Progenies (P)	39	6 199.08^{ns}	29.26^{ns}	72.58**
R x P	78	4 952.03**	21.93**	38.94**
Within palms	1 224	898.36	4.88	9.89
σ^2g	-	13.65	0.30	0.88
		(1.01)	(4.34)	(6.52)
σ^2gr	-	434.86	1.62	2.56
		(32.21)	(23.67)	(18.85)
σ^2w	-	901.59	4.92	10.12
		(66.78)	(71.99)	(74.63)
Total		1 350.10	6.83	13.56

Note: *, **, ns: significant at P<0.05, P<0.01 and non-significant, respectively. Values in brackets are percentages of the corresponding values of the phenotypic variances.

FFB = fresh fruit bunch, BNO = bunch number, ABW = average bunch weight.

inconsistencies in performance of the traits across replicates.

The performance of the 40 DxP progenies and one standard cross in the trial is presented in *Table 2*. The best performer was progeny PK1396 [0.212/268 (DS3) × 0.174/247 (P1)] at 162.37 kg FFB palm^{-1} yr^{-1}. The high FFB yield was due to high BNO of 10.62 bunches palm^{-1} yr^{-1} and moderate ABW of 15.75 kg bunch^{-1}. This BNO was highest among the progenies. On the other hand, PK1241 [0.212/598 (DS5) × 0.182/297 (P9)] recorded the lowest FFB yield with only 77.99 kg palm^{-1} yr^{-1}, far below the trial mean of 131.62 kg palm^{-1} yr^{-1}. The low FFB yield in this progeny was due to its lowest ABW of 9.77 kg bunch^{-1} and low BNO of 7.50 bunches palm^{-1} yr^{-1}. PK1188 [0.212/439 (DS1) × 0.182/30 (P6)] recorded the highest ABW at 18.12 kg bunch^{-1}. However, the FFB yield of PK1188 was low (129.41 kg palm^{-1} yr^{-1}) due to low BNO (7.31 bunches palm^{-1} yr^{-1}). It is therefore important in the selection of high-yielding palms to choose those with a medium ABW and high BNO. The test for least significant difference (LSD α = 0.05) indicated significant differences between progeny PK1396 and all the other progenies except PK1399 and PK1400. Progenies PK1399 and PK1400 had FFB yields of 150.24 kg palm^{-1} yr^{-1} and 155.92 kg palm^{-1} yr^{-1}, respectively.

In oil palm breeding and selection, the emphasis is on FFB and oil yields. However, yield is greatly influenced by environmental factors. This trial was laid down on inland soil of predominantly Serdang Series. Inland soils have lower fertility compared to coastal soils. Besides, the annual rainfall (in 1993-2004) of the area ranged from 984.55 to 3314.14 mm, making it marginal for oil palm growth and production in certain years. Due to these constraints, the trial mean FFB yield was relatively low (131.62 kg palm^{-1} yr^{-1}). Ideally, oil palm requires about 2000 mm rainfall annually evenly distributed throughout the year. Rafii *et al*. (2001), in their study on a different set of 40 oil palm DxP progenies evaluated over six locations, reported that higher FFB yields were obtained at Carey Island (184.63 kg palm^{-1} yr^{-1}) and Teluk Intan (177.86 kg palm^{-1} yr^{-1}) due to the very fertile soils and good rainfall amounting to 150 mm month^{-1} in these two locations compared to Kluang (96.22 kg palm^{-1} yr^{-1}), which had poor soil texture (laterite soils) and Kudat (86.06 kg palm^{-1} yr^{-1}) due to the dry season (lasting about two months in a year).

Bunch Quality Components

ANOVA showed highly significant differences among the progenies for all the traits: the ratios of mesocarp to fruit (M/F), kernel to fruit (K/F), shell to fruit (S/F), oil to dry mesocarp (O/DM), fruit to bunch (F/B), oil to bunch (O/B) and of kernel to bunch (K/B), as well as oil yield (OY) and kernel yield (KY), but not for oil to wet mesocarp (O/WM) (*Table 3*). The results indicated substantial genetic variations existed in the progenies for these traits and the parents may be utilized for further selection and improvement. The replicate x progeny interaction was also highly significant, implying differences in the performance of the traits across the three replicates.

Data on the performance of the 40 DxP progenies and one standard cross are presented in *Table 4*. M/F of the progenies was excellent for the DxP progenies with a trial mean of 80.44%. The highest (85.41%) M/F was from progeny PK1436 and lowest (72.82%) from PK1241 [0.212/598 (DS5) × 0.182/297 (P9)]. The latter progeny had the lowest M/F due to high S/F of more than 18%.

The oil palm kernel is also an oil-bearing component of the fruit. Oil extracted from the kernel is rich in lauric acid, the raw material for the oleochemical industries. K/F of the progenies varied from 6.49% to 10.84% while that of K/B from 4.08% to 7.15%. Progeny PK1272 [0.212/442 (DS1) × 0.182/308 (P11)] recorded the highest K/F (10.84%) and K/B (7.15%), while progeny PK1436 had the lowest K/F of 6.49% and progeny PK2436 the lowest K/B. Besides, PK1436, as mentioned earlier, also showed highest M/F among the progenies.

The amounts of shell and kernel in an oil palm fruit directly affect the mesocarp content. The strategy is therefore to reduce S/F and K/F in order to get a higher content of mesocarp, the oil-bearing portion of the fruit. Overall, S/F of the progenies was low with an average of 10.82%, and ranged from PK1388 [0.212/515 (DS2) × 0.174/348 (P2)] with 7.57% to PK1241 with 18.38% (*Table 4*).

The trial means for O/DM and O/WM were 78.76% and 48.04%, respectively. PK1196 [0.212/438 (DS1) × 0.182/30 (P6)] had the highest O/DM, while PK1241 [0.212/598 (DS5) × 0.182/297 (P9)] had the lowest. Likewise, for O/WM, PK1382 [0.212/70 (DS5) × 0.174/663 (P4)] was the highest and PK1414 [0.212/435 (DS1) × 0.182/297 (P9)] was the lowest, respectively. O/WM is a component in the calculation of O/B (*Table 4*).

F/B is an estimate of the fruit set of an oil palm bunch. Among the progenies, PK1279 had the best F/B at 69.47%, while PK1321 [0.212/271 (DS3) × 0.182/305 (P10)] had the lowest F/B of 51.43%. High F/B is a prerequisite for high O/B. O/B is a derived character consisting of F/B, M/F and O/WM. The trial mean for O/B was 24.91%, reasonably good for DxP progenies. PK1436 showed the highest (27.20%) and PK 1241 the lowest (21.23%) O/B. PK1436 and PK1241 also showed the highest and the lowest M/F, respectively (*Table 4*).

Among the progenies, PK1396 [0.212/268 (DS3) × 0.174/247 (P1)] had the highest OY of 38.32 kg

TABLE 2. PROGENY MEANS FOR BUNCH YIELDS AND ITS COMPONENTS IN 40 DxP FULL-SIB FAMILIES

No.	Progeny	Pedigree	*Dura* origin x *Pisifera* origin	*Dura* source	*Pisifera* code	N	FFB (kg palm^{-1} yr^{-1})	BNO (bunches palm^{-1} yr^{-1})	ABW (kg palm^{-1} yr^{-1})
1	PK1179	0.212/41 x 0.174/498	(Banting x Banting) x AVROS	DS1	P3	36	146.72	8.98	17.07
2	PK1188	0.212/439 x 0.182/30	(Banting x Banting) x AVROS	DS1	P6	44	129.41	7.31	18.12
3	PK1196	0.212/438 x 0.182/30	(Banting x Banting) x AVROS	DS1	P6	39	143.50	9.04	16.46
4	PK1253	0.212/108 x 0.182/297	(Banting x Banting) x AVROS	DS1	P9	36	142.93	9.68	15.17
5	PK1272	0.212/442 x 0.182/308	(Banting x Banting) x AVROS	DS1	P11	31	132.36	8.07	16.78
6	PK1400	0.212/438 x 0.174/498	(Banting x Banting) x AVROS	DS1	P3	20	155.92	9.33	16.99
7	PK1414	0.212/435 x 0.182/297	(Banting x Banting) x AVROS	DS1	P9	32	109.40	8.84	12.43
8	PK1269	0.212/515 x 0.174/498	(Elmina x Elmina) x AVROS	DS2	P3	44	131.41	8.55	15.58
9	PK1280	0.212/546 x 0.182/7	(Elmina x Elmina) x AVROS	DS2	P5	43	131.80	8.47	16.13
10	PK1348	0.212/482 x 0.182/305	(Elmina x Elmina) x AVROS	DS2	P10	37	138.88	9.64	14.75
11	PK1381	0.212/482 x 0.174/663	(Elmina x Elmina) x AVROS	DS2	P4	34	137.91	8.51	16.80
12	PK1388	0.212/515 x 0.174/348	(Elmina x Elmina) x AVROS	DS2	P2	20	140.36	9.43	15.66
13	PK1097	0.212/374 x 0.182/230	(H.Est x Elmina) x AVROS	DS3	P8	35	132.00	8.35	16.06
14	PK1241	0.212/598 x 0.182/297	(H.Est x Elmina) x AVROS	DS3	P9	23	77.99	7.50	9.77
15	PK1250	0.212/292 x 0.182/297	(H.Est x Elmina) x AVROS	DS3	P9	40	104.30	6.35	16.38
16	PK1266	0.212/361 x 0.182/308	(H.Est x Elmina) x AVROS	DS3	P11	41	130.17	8.08	16.75
17	PK1270	0.212/278 x 0.182/77	(H.Est x Elmina) x AVROS	DS3	P7	38	146.45	10.62	13.90
18	PK1273	0.212/628 x 0.182/77	(H.Est x Elmina) x AVROS	DS3	P7	45	143.73	8.93	17.05
19	PK1275	0.212/627 x 0.182/297	(H.Est x Elmina) x AVROS	DS3	P9	37	147.35	9.75	15.21
20	PK1278	0.212/270 x 0.182/7	(H.Est x Elmina) x AVROS	DS3	P5	38	132.09	8.18	16.73
21	PK1279	0.212/364 x 0.182/7	(H.Est x Elmina) x AVROS	DS3	P5	42	135.96	9.84	14.13
22	PK1321	0.212/271 x 0.182/305	(H.Est x Elmina) x AVROS	DS3	P10	40	120.46	8.35	14.67
23	PK1358	0.212/730 x 0.182/305	(H.Est x Elmina) x AVROS	DS3	P10	24	104.71	6.32	16.74
24	PK1379	0.212/369 x 0.174/663	(H.Est x Elmina) x AVROS	DS3	P4	25	87.37	6.29	13.62
25	PK1380	0.212/424 x 0.174/663	(H.Est x Elmina) x AVROS	DS3	P4	42	128.61	9.18	14.36
26	PK1384	0.212/272 x 0.174/348	(H.Est x Elmina) x AVROS	DS3	P2	29	135.98	9.68	14.16

TABLE 2. PROGENY MEANS FOR BUNCH YIELDS AND ITS COMPONENTS IN 40 DxP FULL-SIB FAMILIES (continued)

No.	Progeny	Pedigree	*Dura* origin x *Pisifera* origin	*Dura* source	*Pisifera* code	N	FFB (kg palm^{-1} yr^{-1})	BNO (bunches palm^{-1} yr^{-1})	ABW (kg palm^{-1} yr^{-1})
27	PK1389	0.212/265 x 0.174/247	(H.Est x Elmina) x AVROS	DS3	P1	23	128.67	7.93	16.51
28	PK1396	0.212/268 x 0.174/247	(H.Est x Elmina) x AVROS	DS3	P1	33	162.37	10.62	15.75
29	PK1397	0.212/ 26 x 0.174/247	(H.Est x Elmina) x AVROS	DS3	P1	36	136.70	8.35	16.53
30	PK1405	0.212/694 x 0.182/297	(H.Est x Elmina) x AVROS	DS3	P9	21	141.92	9.20	15.89
31	PK1421	0.212/730 x 0.182/230	(H.Est x Elmina) x AVROS	DS3	P9	34	128.33	7.94	16.72
32	PK1424	0.212/271 x 0.182/230	(H.Est x Elmina) x AVROS	DS3	P8	37	126.89	8.44	14.95
33	PK1436	0.212/623 x 0.182/230	(H.Est x Elmina) x AVROS	DS3	P8	35	113.04	8.03	13.74
34	PK1106	0.212/646 x 0.174/348	(H.Est x H.Est) x AVROS	DS4	P2	43	135.83	10.10	13.65
35	PK1274	0.212/637 x 0.182/77	(H.Est x H.Est) x AVROS	DS4	P7	25	138.03	8.56	16.55
36	PK1387	0.212/648 x 0.174/348	(H.Est x H.Est) x AVROS	DS4	P2	27	137.46	8.23	17.25
37	PK1399	0.212/645 x 0.174/498	(H.Est x H.Est) x AVROS	DS4	P3	25	150.24	9.68	15.94
38	PK1182	0.212/738 x 0.182/30	(U.Remis x H.Est) x AVROS	DS5	P6	29	121.18	7.66	17.05
39	PK1382	0.212/70 x 0.174/663	(U.Remis x H.Est) x AVROS	DS5	P4	38	126.41	8.10	15.90
40	PK1418	0.212/738 x 0.182/230	(U.Remis x H.Est) x AVROS	DS5	P8	23	133.36	9.22	15.10
41	*SC3*	*0.175/964 x 0.151/2626*	*Elmina x Nigerian*			*40*	*92.43*	*7.42*	*12.61*
Mean						1 344	131.62	8.66	15.6
Std Dev							38.03	2.7	3.69
LSD ($P \leq 0.05$)							ns	ns	1.55

Note: SC ~ Standard Cross, DxP.

FFB = fresh fruit bunch, BNO = bunch number, ABW = average bunch weight.

TABLE 3. MEAN SQUARES AND VARIANCE COMPONENTS FOR BUNCH QUALITY IN 40 DxP FULL-SIB FAMILIES

Source	df	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)	F/B (%)	O/B (%)	K/B (%)	OY (kg palm^{-1} yr^{-1})	KY (kg palm^{-1} yr^{-1})
Replications (R)	2	158.08**	79.32**	21.67ns	29.04*	12.30ns	263.08**	63.99*	41.73**	1788.04**	315.63**
Progenies (P)	39	159.22**	22.93**	80.77**	14.97**	40.36ns	129.29**	44.64**	10.79**	295.53**	27.48**
R x P	78	44.44**	9.10**	20.08**	13.49**	36.46ns	74.84**	24.94**	4.17**	236.04**	15.50**
Within palms	835	18.08	4.25	8.01	7.48	29.36	50.86	15.71	2.33	67.75	5.21
σ^2g		*4.63*	*0.59*	*2.52*	*0.00*	*0.23*	*2.01*	*0.84*	*0.29*	*5.29*	*0.76*
		(17.58)	(10.79)	(20.71)	(0.00)	(0.75)	(3.58)	(4.73)	(10.06)	(5.51)	(10.35)
σ^2gr		3.61	0.67	1.65	0.82	0.97	3.29	1.26	0.25	23.07	1.41
		(13.73)	(12.07)	(13.58)	(9.93)	(3.19)	(5.85)	(7.10)	(8.81)	(24.00)	(19.08)
σ^2w		18.08	4.25	8.01	7.48	29.36	50.86	15.71	2.33	67.75	5.21
		(68.69)	(77.14)	(65.72)	(90.07)	(96.06)	(90.57)	(88.17)	(81.13)	(70.49)	(70.57)
Total		26.3245	5.5113	12.1886	8.2995	30.5601	56.1617	17.8214	2.8683	96.1176	7.3887

Note: *, **, ns: significant at $P<0.05$, $P<0.01$ and non-significant, respectively. Values in brackets are percentages of the corresponding values of the phenotypic variances.
M/F = mesocarp to fruit, K/F = kernel to fruit, S/F = shell to fruit, O/DM = oil to dry mesocarp, O/WM = oil to wet mesocarp, F/B = fruit to bunch, O/B = oil to bunch, K/B = kernel to bunch, OY = oil yield, KY = kernel yield.

TABLE 4. PROGENY MEANS FOR BUNCH QUALITY COMPONENTS IN 40 DxP FULL-SIB FAMILIES

No.	Progeny	Pedigree	*Dura* source	*Pisifera* code	N	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)	F/B (%)	O/B (%)	K/B (%)	OY (kg palm^{-1} yr^{-1})	KY (kg palm^{-1} yr^{-1})
1	PK1179	0.212/ 41 x 0.174/498	DS1	P3	26	80.75	9.03	10.22	78.64	48.11	64.95	25.20	5.86	34.02	8.01
2	PK1400	0.212/438 x 0.174/498	DS1	P3	12	81.61	8.90	9.49	77.82	47.10	65.16	24.89	5.95	35.47	7.94
3	PK1253	0.212/108 x 0.182/297	DS1	P9	30	81.86	8.50	9.64	78.47	47.77	66.04	25.82	5.63	34.40	7.55
4	PK1414	0.212/435 x 0.182/297	DS1	P9	19	83.02	8.53	8.46	77.68	43.89	66.39	24.19	5.65	24.20	5.72
5	PK1188	0.212/439 x 0.182/30	DS1	P6	28	76.83	9.81	13.36	79.41	47.08	63.57	23.02	6.21	27.60	7.36
6	PK1196	0.212/438 x 0.182/30	DS1	P6	24	80.00	8.79	11.21	80.22	48.90	66.08	25.82	5.81	34.83	8.08
7	PK1272	0.212/442 x 0.182/308	DS1	P11	25	76.87	10.84	12.29	78.85	47.47	66.00	23.97	7.15	28.78	8.51
8	PK1388	0.212/515 x 0.174/348	DS2	P2	15	84.67	7.76	7.57	78.32	46.08	61.71	23.85	4.86	31.22	6.27
9	PK1269	0.212/515 x 0.174/498	DS2	P3	27	78.13	9.82	12.06	78.19	47.58	64.77	24.05	6.42	31.18	8.31
10	PK1381	0.212/482 x 0.174/663	DS2	P4	21	76.91	9.83	13.26	78.50	48.58	66.91	24.98	6.58	33.75	8.97
11	PK1348	0.212/482 x 0.182/305	DS2	P10	33	82.57	8.93	8.50	78.49	48.30	61.61	24.62	5.47	31.09	6.90
12	PK1280	0.212/546 x 0.182/7	DS2	P5	32	83.06	7.22	9.72	78.91	49.58	65.55	26.93	4.74	33.71	5.96
13	PK1389	0.212/265 x 0.174/247	DS3	P1	18	80.08	8.67	11.26	77.33	46.73	64.23	23.90	5.58	30.39	6.89
14	PK1396	0.212/268 x 0.174/247	DS3	P1	29	78.79	9.79	11.42	79.00	48.18	67.07	25.51	6.55	38.32	9.77
15	PK1397	0.212/26 x 0.174/247	DS3	P1	29	78.73	9.67	11.60	79.36	49.60	65.47	25.50	6.34	32.46	8.11
16	PK1384	0.212/272 x 0.174/348	DS3	P2	24	79.65	9.23	11.13	78.69	48.15	63.23	24.21	5.88	30.56	7.18
17	PK1379	0.212/369 x 0.174/663	DS3	P4	15	76.41	9.07	14.52	78.98	48.57	62.20	22.90	5.76	18.83	5.05
18	PK1380	0.212/424 x 0.174/663	DS3	P4	32	77.83	8.89	13.28	78.86	48.20	67.24	25.32	5.93	28.78	6.85
19	PK1097	0.212/374 x 0.182/230	DS3	P8	25	78.65	9.65	11.71	77.11	45.59	62.43	22.35	6.07	26.58	7.18
20	PK1421	0.212/730 x 0.182/230	DS3	P8	24	81.62	7.48	10.90	77.98	46.64	62.85	23.87	4.68	28.22	5.44
21	PK1424	0.212/271 x 0.182/230	DS3	P8	26	85.17	6.54	8.29	79.79	48.21	65.24	26.69	4.29	32.09	5.21
22	PK1436	0.212/623 x 0.182/230	DS3	P8	25	85.41	6.49	8.11	80.11	51.20	62.61	27.20	4.08	27.53	3.92
23	PK1241	0.212/598 x 0.182/297	DS3	P9	11	72.82	8.81	18.38	77.00	46.42	62.67	21.23	5.55	18.62	4.82
24	PK1250	0.212/292 x 0.182/297	DS3	P9	28	80.07	9.94	9.99	79.00	48.70	64.21	25.01	6.41	28.26	7.05
25	PK1275	0.212/627 x 0.182/297	DS3	P9	33	78.47	9.00	12.53	79.18	49.33	65.35	25.41	5.91	36.21	8.49
26	PK1405	0.212/694 x 0.182/297	DS3	P9	12	80.98	9.97	9.05	78.12	49.02	64.05	25.44	6.43	33.29	8.41
27	PK1321	0.212/271 x 0.182/305	DS3	P10	27	81.06	8.60	10.35	77.55	46.27	57.86	21.56	5.04	25.38	5.99
28	PK1358	0.212/730 x 0.182/305	DS3	P10	19	81.52	8.46	10.02	78.53	47.80	60.84	23.61	5.28	22.19	4.91
29	PK1266	0.212/361 x 0.182/308	DS3	P11	31	80.48	8.26	11.26	79.07	48.83	62.01	24.25	5.20	30.27	6.19
30	PK1278	0.212/270 x 0.182/7	DS3	P5	34	79.94	8.41	11.65	79.75	49.25	64.71	25.54	5.45	30.67	6.59

TABLE 4. PROGENY MEANS FOR BUNCH QUALITY COMPONENTS IN 40 DxP FULL-SIB FAMILIES (continued)

No.	Progeny	Pedigree	*Dura* source	*Pisifera* code	N	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/WM (%)	F/B (%)	O/B (%)	K/B (%)	OY (kg palm^{-1} yr^{-1})	KY (kg palm^{-1} yr^{-1})
31	PK1279	0.212/364 x 0.182/7	DS3	P5	32	82.13	7.82	10.06	77.90	47.55	69.47	27.10	5.43	34.47	6.92
32	PK1270	0.212/278 x 0.182/77	DS3	P7	28	83.48	7.16	9.36	79.66	47.89	67.24	26.93	4.78	37.82	6.78
33	PK1273	0.212/628 x 0.182/77	DS3	P7	32	79.70	9.33	10.97	79.03	49.07	66.24	25.91	6.22	34.26	8.24
34	PK1106	0.212/646 x 0.174/348	DS4	P2	38	83.39	8.19	8.72	79.00	47.44	64.71	25.56	5.32	32.19	6.74
35	PK1387	0.212/648 x 0.174/348	DS4	P2	18	82.66	8.18	9.17	79.55	49.27	62.39	25.41	5.08	34.76	6.81
36	PK1399	0.212/645 x 0.174/498	DS4	P3	16	75.73	10.35	13.93	78.55	46.73	65.94	23.25	6.83	32.68	9.55
37	PK1274	0.212/637 x 0.182/77	DS4	P7	14	82.59	7.64	9.77	77.77	46.72	67.06	25.56	5.10	34.08	6.82
38	PK1382	0.212/ 70 x 0.174/663	DS5	P4	15	81.60	8.42	9.99	79.64	51.43	62.13	25.69	5.45	32.71	6.92
39	PK1418	0.212/738 x 0.182/230	DS5	P8	11	81.79	9.07	9.14	78.42	46.51	62.33	23.91	5.64	33.28	7.70
40	PK1182	0.212/738 x 0.182/30	DS5	P6	17	75.68	10.55	13.77	78.52	46.90	64.94	23.14	6.85	26.37	7.51
41	*SC*				*18*	*82.53*	*7.97*	*9.50*	*78.97*	*49.15*	*60.09*	*24.28*	*4.90*	*24.28*	*4.85*
Mean				955	80.44	8.75	10.82	78.76	48.04	64.55	24.91	5.67	31.15	7.07	
Std Dev					5.14	2.39	3.48	2.87	5.52	7.50	4.22	1.72	10.01	2.85	
LSD (P≤0.05)					2.56	1.24	1.71	1.65	3.26	4.30	2.39	0.92	4.96	1.38	

Note: SC ~ Standard Cross (DxP).
M/F = mesocarp to fruit, K/F = kernel to fruit, S/F = shell to fruit, O/DM = oil to dry mesocarp, O/WM = oil to wet mesocarp, F/B = fruit to bunch, O/B = oil to bunch, K/B = kernel to bunch, OY = oil yield, KY = kernel yield.

palm^{-1} yr^{-1}, equivalent to 5.7 t ha^{-1} yr^{-1}. This is due to its above average MFW, O/WM, F/B and O/B, even though the M/F value was slightly below the trial mean. PK1241 had the lowest OY among the progenies at only 18.62 kg palm^{-1} yr^{-1}, equivalent to 2.8 t ha^{-1} yr^{-1}. This was due to its lowest values of M/F, O/DM and O/B but highest for S/F (*Table 4*).

Progeny PK1396 also recorded the highest KY of 9.77 kg palm^{-1} yr^{-1}, or 1.4 t ha^{-1} yr^{-1}, far above the trial mean of 7.07 kg palm^{-1} yr^{-1}. At the other extreme, PK1436 recorded the lowest KY at 3.92 kg palm^{-1} yr^{-1}or 0.6 t ha^{-1} yr^{-1}. This was due to its low K/F and K/B. This progeny was however excellent for M/F and O/B (*Table 4*).

Vegetative Traits

ANOVA for the vegetative traits is presented in *Table 5*. The results indicated that all the vegetative traits were significantly different among the progenies, implying high genetic variation in these traits. The replicate x progeny item was also highly significant, again implying the inconsistent performance of the traits across the replicates.

Data on performance of the progenies for vegetative characters are shown in *Table 6*. Among the progenies, PK1418 [0.212/738 (DS5) × 0.182/230 (P8)] scored the highest frond production (FP) at 28.48 fronds palm^{-1} yr^{-1}. As bunches are produced at the frond axils, the higher the number of fronds produced, the higher would be the potential for higher yield. At the other extreme, PK1358 [0.212/730 (DS3) × 0.182/305 (P10)] had the lowest FP with 24.79 fronds palm^{-1} yr^{-1}. The trial mean for FP was 26.64 fronds palm^{-1} yr^{-1}. Significant difference ($LSD_{0.05}$ = 1.28) was detected between PK1418 and the other progenies.

The petiole cross-section (PCS) of the progenies varied from 22.41 to 37.84 cm^2. PK1280 [0.212/546 (DS2) × 0.182/7 (P5)] and PK1321 [0.212/271 (DS3) × 0.182/305 (P10)] had the highest and lowest PCS, respectively. Significant differences ($LSD_{0.05}$ = 3.03) were detected between PK 1280 and PK 1381 and also with the other progenies (*Table 6*).

Rachis length (RL) may be used as a guide for the determination of planting density. With shorter RL, more palms can be planted in a unit area. PK1348 [0.212/482 (DS2) × 0.182/305 (P10)] had the longest (6.20 m) and PK 1358 [0.212/730 (DS3) × 0.182/305 (P10)], the shortest (4.85 m) RL. The trial mean for the character was 5.56 m (*Table 6*). No significant difference ($LSD\alpha = 0.20$) was found between PK1358 and all the other progenies, except PK1279, PK1321 and PK1379.

Leaflet length (LL) and leaflet width (LW) are used in the determination of leaf area. The ranges for LL and LW were 84.56 to 105.69 cm and 5.04 to 6.34 cm, respectively (*Table 6*). PK1278 [0.212/270 (DS3) × 0.182/7 (P5)] had the longest LL (105.69 cm). PK 1321, besides having the smallest PCS, had also the shortest LL (84.56 cm) among the progenies. The progeny PK1280 had the widest LW (6.34 cm) besides being the largest in PCS. On the other hand, PK1358 which was identified as having the shortest LW (5.04 cm) was also the lowest in FP and RL (*Table 6*).

Trunk height (HT) is an important factor in determining the economic life of an oil palm plantation due to the difficulties in harvesting tall palms. Trunk heights of the progenies at 9 years varied from 1.88 to 2.87 m. PK1179 [0.212/41 (DS1) × 0.174/498(P3)] had the highest HT with a height increment of 0.5 m yr^{-1}. PK1097 [0.212/ 374 (DS3) × 0.182/230 (P8)] was identified as the shortest among the progenies (1.88 m) with a height increment of 0.3 m yr^{-1}. Significant differences (LSD0.05 = 0.19) for HT were detected among the progenies (*Table 6*).

Leaf area (LA) and leaf area index (LAI) of the progenies varied from 8.20 to 12.29 cm^2 and from 4.85 to 7.28, respectively. The progeny PK1280 [212/546 (DS2) × 0.182/7 (P5)] had the biggest LA (12.29 cm^2) and LAI (7.28), while PK1358 [0.212/730 (DS3) × 0.182/305 (P10)] had the lowest LA and LAI at 8.20 cm^2 and 4.85, respectively (*Table 6*).

For trunk diameter (DIA), the smallest was recorded in PK1414 [0.212/435 (DS1) × 0.182/297 (P9)] at 0.56 m (*Table 6*). The progeny PK1097 [0.212/374 (DS3) × 0.182/297 (P9)] had the biggest DIA at 0.75 m, a character that is not selected for in oil palm breeding. However, genotypes with large DIA may be a good source of timber for the future.

Phenotypic and Genotypic Coefficients of Variation and Heritability Estimates

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV) and heritability estimates are the basic tools for selection in breeding programmes. For rapid progress in breeding, the character selected must have a substantial amount of variation and heritability to provide ample scope for response to selection.

The values of PCV, GCV and broad sense heritability of the full-sib families for all the characters studied are presented in *Table 7*. The results show that genetic variation for yield and yield components, namely, FFB, BNO and ABW, contributed about 10.0% to 25.5% to the phenotypic variation, indicating a large environmental influence in the expression of these characters. The overall GCV for these characters was low (less than 10%), implying a limited level of genetic variation. Broad-sense heritability (h^2_B) estimates for FFB and ABW were also low (<10%), except ABW (13.0%).

Unlike bunch yield and its components, the genetic variation for M/F contributed more than 40% to the phenotypic variation (*Table 7*). A moderate

TABLE 5. MEAN SQUARES AND VARIANCE COMPONENTS FOR VEGETATIVE TRAITS IN 40 DxP FULL-SIB FAMILIES

Source	df	FP (No. palm^{-1} yr^{-1})	PCS (cm^2)	RL (cm)	LL (cm)	LW (cm)	LN (No. palm^{-1} yr^{-1})	HT (m)	LA (m^2)	LAI	DIA (cm)
Replications (R)	2	21.34*	1 178.99**	4.86**	448.72**	16.16**	4016.63**	1.63**	121.02**	42.40**	0.01ns
Progenies (P)	39	28.66**	354.99**	3.01**	653.56**	2.14**	774.41**	1.76**	24.44**	8.56**	0.05**
R x P	78	15.68**	199.44**	1.40**	178.49**	1.79**	453.33**	1.39**	15.02**	5.26**	0.01**
Within palms	1 223	6.77	37.79	0.17	45.96**	0.25	118.04	0.16	2.33	0.82	0.003
σ^2g		0.63	4.87	0.07	16.21	0.02	13.21	0.01	0.44	0.16	0.00
		(7.59)	(8.40)	(20.20)	(21.68)	(4.61)	(8.10)	(4.56)	(11.17)	(11.16)	(0.21)
σ^2gr		0.85	15.33	0.12	12.57	0.15	31.81	0.12	1.20	0.42	0.0007
		(10.26)	(26.44)	(32.89)	(16.82)	(35.31)	(19.51)	(41.01)	(30.21)	(30.22)	(0.12)
σ^2w		6.77	37.79	0.17	45.96	0.25	118.04	0.16	2.33	0.82	0.003
		(82.15)	(65.16)	(46.91)	(61.50)	(60.07)	(72.39)	(54.43)	(58.62)	(58.62)	(0.49)
Total		8.24	57.99	0.36	74.74	0.41	163.05	0.29	3.98	1.40	1.395

Note: *, **, ns: significant at $P<0.05$, $P<0.01$ and non-significant, respectively. Values in brackets are percentages of the corresponding values of the phenotypic variances.
FP = frond production, PCS = petiole cross-section, RL = rachis length, LL = leaflet length, LW = leaflet width, LN = leaflet number, HT = palm height, LA = leaflet area, LAI = leaf area index, DIA= diameter.

TABLE 6. PROGENY MEANS FOR VEGETATIVE TRAITS IN 40 DxP FULL-SIB FAMILIES

No.	Progeny	Pedigree	*Dura* source	*Pisifera* code	N	FP (No. palm^{-1} yr^{-1})	PCS (cm^2)	RL (cm)	LL (cm)	LW (cm)	LN (No. palm^{-1} yr^{-1})	HT (m)	LA (m^2)	LAI	DIA (cm)
1	PK1179	0.212/ 41 x 0.174/498	DS1	P3	36	26.61	33.10	6.02	94.81	6.03	170.44	2.87	11.10	6.57	0.62
2	PK1188	0.212/439 x 0.182/30	DS1	P6	44	25.32	28.31	5.61	98.39	5.69	169.68	2.30	10.87	6.44	0.64
3	PK1196	0.212/438 x 0.182/30	DS1	P6	39	26.79	32.20	5.75	97.68	5.79	169.46	2.43	11.01	6.52	0.64
4	PK1253	0.212/108 x 0.182/297	DS1	P9	36	25.58	28.62	6.03	91.31	6.02	165.56	2.56	10.32	6.11	0.61
5	PK1272	0.212/442 x 0.182/308	DS1	P11	31	26.84	28.27	5.79	95.67	5.79	170.65	2.35	10.79	6.39	0.67
6	PK1400	0.212/438 x 0.174/498	DS1	P3	20	27.90	30.69	6.11	103.88	5.73	175.25	2.35	11.98	7.09	0.71
7	PK1414	0.212/435 x 0.182/297	DS1	P9	32	27.81	24.67	5.09	87.04	5.19	159.91	2.11	8.31	4.92	0.56
8	PK1269	0.212/515 x 0.174/498	DS2	P3	44	25.41	32.70	5.81	102.94	5.22	171.55	2.33	10.51	6.22	0.67
9	PK1280	0.212/546 x 0.182/7	DS2	P5	43	25.58	37.84	6.03	99.76	6.34	169.47	2.66	12.29	7.28	0.64
10	PK1348	0.212/482 x 0.182/305	DS2	P10	37	25.38	32.67	6.20	94.23	5.78	171.97	2.65	10.68	6.32	0.63
11	PK1381	0.212/482 x 0.174/663	DS2	P4	34	27.91	32.71	5.85	96.94	5.54	173.62	2.43	10.65	6.31	0.68
12	PK1388	0.212/515 x 0.174/348	DS2	P2	20	27.20	28.18	5.75	100.55	5.39	166.75	2.37	10.31	6.10	0.60
13	PK1097	0.212/374 x 0.182/230	DS3	P8	35	25.37	28.61	5.63	94.97	5.37	169.17	1.88	9.91	5.87	0.75
14	PK1241	0.212/598 x 0.182/297	DS3	P9	23	28.17	25.27	5.08	101.08	5.77	150.87	1.90	10.03	5.94	0.69
15	PK1250	0.212/292 x 0.182/297	DS3	P9	39	25.38	25.85	5.23	90.98	5.25	155.00	1.96	8.63	5.11	0.64
16	PK1266	0.212/361 x 0.182/308	DS3	P11	41	25.54	25.72	5.57	96.23	5.24	172.63	2.28	9.98	5.91	0.58
17	PK1270	0.212/278 x 0.182/77	DS3	P7	38	26.76	31.07	5.51	91.60	5.47	171.16	2.81	9.94	5.88	0.58
18	PK1273	0.212/628 x 0.182/77	DS3	P7	45	25.67	30.38	6.04	96.08	5.87	173.91	2.57	11.23	6.65	0.64
19	PK1275	0.212/627 x 0.182/297	DS3	P9	37	25.97	29.45	5.62	97.77	5.33	175.76	2.57	10.50	6.22	0.61
20	PK1278	0.212/270 x 0.182/7	DS3	P5	38	25.05	32.87	5.79	105.69	5.81	171.71	2.51	12.05	7.13	0.64
21	PK1279	0.212/364 x 0.182/7	DS3	P5	42	27.88	27.67	5.10	98.23	5.53	162.41	2.82	10.13	6.00	0.61
22	PK1321	0.212/271 x 0.182/305	DS3	P10	40	27.10	22.41	4.87	84.56	5.19	162.05	2.34	8.22	4.87	0.60
23	PK1358	0.212/730 x 0.182/305	DS3	P10	24	24.79	24.25	4.85	86.19	5.04	163.83	1.93	8.20	4.85	0.59
24	PK1379	0.212/369 x 0.174/663	DS3	P4	25	26.48	23.24	5.10	94.9	5.07	166.16	1.97	9.25	5.48	0.62
25	PK1380	0.212/424 x 0.174/663	DS3	P4	42	27.60	25.09	5.39	93.74	5.29	167.76	2.46	9.53	5.64	0.61
26	PK1384	0.212/272 x 0.174/348	DS3	P2	29	27.76	24.56	5.39	97.67	5.38	164.83	2.35	9.98	5.91	0.64

TABLE 6. PROGENY MEANS FOR VEGETATIVE TRAITS IN 40 DxP FULL-SIB FAMILIES (continued)

No.	Progeny	Pedigree	*Dura* source	*Pisifera* code	N	FP (No. palm^{-1} yr^{-1})	PCS (cm^2)	RL (cm)	LL (cm)	LW (cm)	LN (No. palm^{-1} yr^{-1})	HT (m)	LA (m^2)	LAI	DIA (cm)
27	PK1389	0.212/265 x 0.174/247	DS3	P1	23	27.91	29.92	5.31	92.28	5.63	168.65	2.62	9.97	5.90	0.58
28	PK1396	0.212/268 x 0.174/247	DS3	P1	33	26.82	28.31	5.58	93.73	5.50	169.46	2.65	9.96	5.90	0.60
29	PK1397	0.212/26 x 0.174/247	DS3	P1	36	26.81	27.60	5.73	94.92	5.57	167.39	2.54	10.11	5.98	0.64
30	PK1405	0.212/694 x 0.182/297	DS3	P9	21	25.71	27.57	5.80	101.41	5.81	174.95	2.56	11.75	6.95	0.62
31	PK1421	0.212/730 x 0.182/230	DS3	P8	34	27.79	29.64	5.38	91.15	5.75	162.41	2.50	9.72	5.75	0.59
32	PK1424	0.212/271 x 0.182/230	DS3	P8	37	27.51	28.07	5.06	90.26	5.38	164.68	2.66	9.13	5.41	0.65
33	PK1436	0.212/623 x 0.182/230	DS3	P8	35	25.60	30.91	5.46	86.56	5.54	164.77	2.56	9.10	5.39	0.56
34	PK1106	0.212/646 x 0.174/348	DS4	P2	43	26.60	28.56	5.53	90.77	5.67	165.12	2.43	9.70	5.74	0.64
35	PK1274	0.212/637 x 0.182/77	DS4	P7	25	27.48	37.09	5.88	92.04	5.90	177.16	2.50	11.09	6.56	0.63
36	PK1387	0.212/648 x 0.174/348	DS4	P2	27	26.37	31.36	5.56	92.75	5.63	171.44	2.53	10.23	6.06	0.63
37	PK1399	0.212/645 x 0.174/498	DS4	P3	25	28.28	27.20	5.74	98.83	5.59	167.48	2.23	10.52	6.23	0.70
38	PK1182	0.212/738 x 0.182/30	DS5	P6	29	27.83	24.69	5.37	93.00	5.36	166.17	2.64	9.50	5.62	0.60
39	PK1382	0.212/70 x 0.174/663	DS5	P4	38	28.16	29.14	5.33	95.77	5.51	163.11	2.20	9.87	5.85	0.70
40	PK1418	0.212/738 x 0.182/230	DS5	P8	23	28.48	28.49	5.30	92.16	5.63	161.44	2.64	9.59	5.68	0.60
41	*SC3*	0.175/964 x 0.151/2626			*40*	*24.43*	*28.29*	*5.55*	*92.02*	*5.27*	*160.75*	*1.68*	*8.93*	*5.29*	*0.76*
Mean					1 343	26.64	29.01	5.56	94.89	5.57	167.71	2.44	10.17	6.02	0.63
Std. Dev						2.87	7.75	0.6	8.71	0.66	12.96	0.53	2.04	1.21	0.07
LSD (P≤0.05)						1.28	3.03	0.2	3.34	0.25	5.35	0.19	0.40	0.23	0.01

Note: SC ~ Standard Cross, DxP.
FP = frond production, PCS = petiole cross-section, RL = rachis length, LL = leaflet length, LW = leaflet width, LN = leaflet number, HT = palm height, LA = leaflet area, LAI = leaf area index, DIA= diameter.

heritability estimate (h^2_B = 41.9%) was obtained for M/F, indicating that the character was more heritable than bunch yield and its components.

For S/F, genetic variation contributed more than 45% to the phenotypic variation, implying high genetic control of the character. This was further supported by its h^2_B value of more than 41%. It will therefore be an advantage to select for mother palms with thinner shelled fruit, to obtain higher M/F and better O/B in the progenies.

With respect to K/F and K/B, substantial genetic contribution was also recorded to the phenotypic variation, *i.e.* 32.7% and 31.8%, respectively (*Table 7*). The h^2_B for both traits were more than 20%, indicating moderate genetic control of the characters.

TABLE 7. PHENOTYPIC (PCV) AND GENETIC (GCV) COEFFICIENTS OF VARIATION AND BROAD-SENSE HERITABILITY ESTIMATES ($h^2_B = 2t_g$) FOR YIELD AND YIELD COMPONENTS, BUNCH QUALITY AND VEGETATIVE TRAITS

Character	PCV (%)	GCV (%)	GCV/PCV (%)	$h^2_B = 2t_g$
Fresh fruit bunch (FFB)	27.9	2.8	10.0	2.0
Bunch number (BNO)	30.2	6.3	21.0	8.7
Average bunch weight (ABW)	23.6	6.0	25.5	13.0
Mesocarp to fruit (M/F)	6.4	2.7	41.9	35.2
Shell to fruit (S/F)	32.3	14.7	45.5	41.4
Kernel to fruit (K/F)	26.8	8.8	32.7	21.6
Kernel to bunch (K/B)	29.9	9.5	31.8	20.1
Fruit to bunch (F/B)	11.6	2.2	18.9	7.1
Oil to bunch (O/B)	17.0	3.7	21.7	9.5
Oil to dry mesocarp (O/DM)	3.7	0.0*	0.0*	0.0*
Oil to wet mesocarp (O/WM)	11.5	1.0	8.7	1.5
Oil yield (OY)	31.5	7.4	23.5	11.0
Kernel yield (KY)	38.5	12.3	32.1	20.7
Height (HT)	22.1	4.1	18.6	9.1
Frond production (FP)	10.8	3.0	27.7	15.2
Petiole cross-section (PCS)	26.3	7.6	29.0	16.8
Rachis length (RL)	10.8	4.8	44.1	40.4
Leaflet length (LL)	9.1	4.2	46.6	43.4
Leaflet width (LW)	11.5	2.5	22.1	9.2
Leaflet number (LN)	7.6	2.2	28.5	16.2
Leaflet area (LA)	19.6	6.5	33.2	22.3
Leaf area index (LAI)	19.7	6.6	33.8	22.3
Total economic product (TEP)	30.2	7.3	24.3	11.8

Note: *Negative estimate for which the most reasonable value is zero.

There was a marked influence of the environment on the magnitude of the PCV and h^2_B values for F/B and O/B (*Table 7*). This was indicated by the lower values of GCV. The h^2_B for both characters were lower than 10%.

For O/DM and O/WM, the characters were highly influenced by the environment with GCV values of 0% and 1%, respectively (*Table 7*). This was further supported by the h^2_B of 0% for O/DM and 1.5% for O/WM.

With respect to OY and KY of the progenies, GCV contribution to PCV was 23.5% and 32.1%, respectively, indicating moderate genetic control of the characters. The heritability estimates indicated similar trends, with h^2_B for KY being 11.0% and OY being 20.7%.

In general, GCV for most of the vegetative traits contributed about 19% to 47% towards the phenotypic variation (*Table 7*). Some of the characters had higher genetic control compared to the yield components as indicated by the higher GCV. The h^2_B for vegetative traits varied from 9.1% to 43.4%.

The highest GCV to PCV ratio was for LL (46.6%), while the lowest was for HT (18.6%) (*Table 7*). Among the vegetative traits, LL and RL had fairly good genetic control to the phenotypic variation at 46.6% and 44.1% contribution, respectively. This was further supported by h^2_B estimates of more than 40% for both these traits. The rest of the characters, LAI, LA, PCS, LN, FP, LW and HT, had moderate to low GCV contribution to the phenotypic variation.

PCV and GCV for bunch yield in the full-sib families were low. Genetic variation contributed 10% to 26% to the phenotypic variance, with FFB ranked lowest. The h^2_B was also low, below 10% except ABW with 12.9%. The low genetic variation and heritability estimates in FFB and BNO may hinder further breeding and selection for the traits in these materials. However, further improvement can still be achieved for ABW because there was sufficient genetic variation, contributing more than 25% to the phenotypic variation and having h^2_B of 12.9%. Musa (2004) in his studies on Deli-AVROS populations found low PCV and GCV for bunch yields. In his Population 1, the PCV and GCV values were less than 10%. However, slightly higher values were obtained in Population 2 with some values reaching 14%. Rafii (1996) who studied 40 oil palm DxP progenies reported PCV values between 21.97% and 31.75%, and GCV of less than 10% for bunch yield. His results also indicated low h^2_B for all the characters studied except BNO (14.39%).

Unlike bunch yield, the *dura* sources showed higher genetic variation for fruit quality characters such as M/F, S/F, K/F, KY and OY. Variability in these characters can be exploited for the production of higher yielding oil palm materials. OY is economically important. The trait is derived and dependent on FFB and O/B. Beirnaert and Vanderweyen (1941) discovered a single gene that controls shell thickness. Exploitation of the inheritance of shell thickness has led to the commercialization of the DxP or *tenera* fruit form with high proportion of mesocarp and reduced shell content of the fruit.

Among the 40 progenies in the full-sib families in this study, PCV and GCV indicated low genetic variability for bunch quality components. Low GCV of less than 10% was recorded for F/B, O/B, O/WM, O/DM, OY, K/F and K/B. However, their PCVs were reasonably good with the majority being more than 10%. Musa (2004) also reported low GCV for F/B, O/B and O/WM. Rafii (1996) found low GCV for M/F, F/B, O/B, O/WM, O/DM and OY, but obtained reasonably good PCV values (>10%) for these traits. Yong and Chan (1990) in their studies on Deli *dura* populations obtained low PCV for F/B, O/B and M/F. The low GCV values may be due to repeated selection in the previous cycles. However, in their studies M/F, S/F and KY had better GCV and PCV values. The heritability estimates for these characters were also reasonably good at more than 20%. Therefore, ample genetic variation for future breeding and selection.

Besides bunch yield, and bunch and fruit qualities, vegetative traits are gaining importance in oil palm breeding and selection. Palms with small PCS and short RL are preferred for high density planting that may increase yield per unit area. In this study, the *dura* sources 3 and 5 had the lowest PCS and RL. HT is also an important vegetative character. In oil palm, as in many other crops, height is given negative emphasis in selection. Palms with slower height increment are preferred because this may prolong the economic life of the crop and reduce the cost of harvesting. For trial 0.314, the shortest full-sib family was PK1097, derived from DS3 (H.Estate x Elmina) with the Dumpy E206 gene. The tallest progeny, PK1179 was from DS1 (Banting x Banting). Mean trunk height of PK1097 was 1.88 m, or a height increment of 31 cm yr^{-1}, which is slower than that of the current DxP planting materials of 40-75 cm yr^{-1} (Rajanaidu *et al*., 2000).

CONCLUSION

Performance of the 40 oil palm progenies for FFB was reasonably good for materials planted on inland soil. The range in FFB yield of the full-sib DxP progenies was 77.99 to 162.37 kg $palm^{-1}$ yr^{-1}. ANOVA showed the lack of variability in FFB and its components except ABW. This was supported by the low GCV, PCV and h^2_B. The best progeny PK1396 (0.212/268 × 0.174/247) from DS3 (H.Estate x Elmina *dura*) had an FFB yield of 162 kg $palm^{-1}$ yr^{-1}

and OY of 38.32 kg palm^{-1} yr^{-1}, equivalent to 5.67 t ha^{-1} yr^{-1}. Best FFB yield was attributed to highest BNO (10.62 bunches palm^{-1} yr^{-1}) and moderate ABW (15.75 kg bunch^{-1}), and further augmented by O/B of 25%. Overall, fruit components and vegetative traits showed higher variability compared to bunch yields. There is ample room for breeding and selection for these traits.

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