



## Variability and performance evaluation of introgressed Nigerian *dura* x Deli *dura* oil palm progenies

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**ABSTRACT.** Twelve introgressed oil palm (*Elaeis guineensis*) progenies of Nigerian *dura* x Deli *dura* were evaluated for bunch yield, yield attributes, bunch quality components and vegetative characters at the Malaysian Palm Oil Board Research Station, in Keratong, Pahang, Malaysia. Analysis of variance revealed significant to highly significant genotypic differences, indicating sufficient genetic variability among the progenies for bunch yield and its attributes, vegetative characters and bunch quality components, except fruit to bunch ratio. Fresh fruit bunch yield ranged from 167 kg·palm<sup>-1</sup>·year<sup>-1</sup> in PK1330 to 212 kg·palm<sup>-1</sup>·year<sup>-1</sup> in PK1351, with a mean yield of 192 kg·palm<sup>-1</sup>·year<sup>-1</sup>. Among the progeny, PK1313 had the highest oil to bunch ratio (19.36%), due

to its high mesocarp to fruit ratio, fruit to bunch ratio and low shell to fruit ratio. Among the progenies, PK1313 produced the highest oil yield of 31.4 kg·palm<sup>-1</sup>·year<sup>-1</sup>, due to a high mesocarp to fruit ratio (61.2%) and a low shell to fruit ratio (30.7%), coupled with high fruit to bunch ratio (65.6%). PK1330 was found promising for selection, as it had desirable vegetative characters, including smaller petiole cross section (27.15 cm<sup>2</sup>), short rachis length (4.83 m), short palm height (1.85 m), and the lowest leaf number (164.6), as these vegetative characters are prerequisites for selecting palms for high density planting and high yield per hectare. The genetic variability among the progenies was found to be high, indicating ample scope for further breeding, followed by selection.

**Key words:** Oil palm; Heritability; Introgressed progenies; Nigerian *dura*; Deli *dura*

## INTRODUCTION

Palm oil is one of the world's healthiest oils and a major crop that ranks second in the world market as a producer of vegetable fats and oils. As a natural vegetable oil, it contains no trans fatty acids or cholesterol. It is currently being used by doctors and government agencies to treat specific illnesses and improve nutritional status. Recent medical studies have shown that palm oil, particularly virgin (red) palm oil, can protect against many common health problems (Bruce, 2007). To achieve sustainable agricultural production and food security, current research efforts have been directed to systematic varietal improvement programs to generate a superior population with improved productivity. As the leader of oil palm industry in Malaysia, the Malaysian Palm Oil Board (MPOB) has assembled a large collection of oil palm germplasm from Africa and South/Central America for the development of elite planting materials for growers to achieve sustainable production. These collections were systematically planted and evaluated in a field genebank at MPOB Kluang, Johor in 1975/76. The first collection was from Nigeria in 1973 (Rajanaidu et al., 2008). Due to the narrow genetic base of the existing native oil palm materials, it was essential to introgress genes from new germplasm sources into existing populations, to broaden their genetic base. To achieve this new germplasm, sources were introduced from abroad to enrich the genetic base of the current native breeding materials. The first generation of the Nigerian Material was utilized by MPOB to produce value added planting material and released to the industry in 1994 (Rajanaidu et al., 2008). These materials were also distributed to the industry and have been utilized in their breeding programs to produce new generations of planting materials for the future. In Federal Land Development Authority (FELDA), the materials were extensively used in their *dura* x *tenera* (D x T), *tenera* x *tenera* (T x T), *dura* x *dura* (D x D) and *dura* x *pisifera* (D x P) crossing program (Junaidah et al., 2008; 2011). Their Deli *dura* x Nigerian *dura* progenies produced high fresh fruit bunch (FFB) yield (26.47 t/ha), oil to bunch ratio (O/B) ranging from 19.4 to 23.8% and height increment from 0.38 to 0.46 m/year (Junaidah et al., 2008). The D x D Nigerian population was also reported to produce high FFB yield (180.6 to 231.3 kg·palm<sup>-1</sup>·year<sup>-1</sup>) and O/B ranging from 15.49 to 19.19% (Veriappan et al., 2008).

Nigerian materials were also distributed to the Eastern Plantation Agency (EPA) in 1991 and field planted in 1992. The FFB production of their D x T and T x D progenies planted in Pasak Estate, Kota Tinggi, Johor was the highest with 149 kg·palm<sup>-1</sup>·year<sup>-1</sup> compared to the commercial D x P (145.64 kg·palm<sup>-1</sup>·year<sup>-1</sup>) and standard cross (140.92 kg·palm<sup>-1</sup>·year<sup>-1</sup>) (Isa et al., 2008). The high FFB yield was due to high bunch number (BN) but low bunch weight (BWT). Their bunch characteristics were generally not attractive as compared to the commercial *dura* x *pisifera* (D x P) (Isa et al., 2008). In the United Plantation Berhad (UPB), the Nigerian materials were introgressed with their breeding materials (Musa and Gurmit, 2008). The performance of their UPB *dura* x Nigerian PS2 *dura* progenies were good with FFB production ranging from 229 to 270 kg·palm<sup>-1</sup>·year<sup>-1</sup>. O/B was also satisfactory with all progenies exceeding 18% (Musa and Gurmit, 2008). MPOB also utilized the MPOB-Nigerian materials in a number of varietal development programs. Genetic variation has been previously estimated for the different oil yield components of this crop (Okwuagwu and Tai, 1995; Rafii et al., 2002; Musa et al., 2004; Okwuagwu, 2008) and also in another industrial oil crop physic nut, *Jatropha curcus* L. (Shabanimofrad et al., 2011; Rafii et al., 2012a). There is, however, a need to estimate genetic variability for the fresh fruit bunch yield traits, bunch quality components and vegetative characters among the different breeding populations for future utilization. This paper outlines the variability study and performance evaluation of 12 introgressed progenies of Nigerian *dura* x Deli *dura* planted in MPOB Keratong, Pahang.

## MATERIAL AND METHODS

Twelve introgressed palm progenies (Table 1) were planted in a field trial in April, 1994 on inland soils (Serdang Series) at MPOB Keratong Research Station, Pahang. Performances of the female and male parental lines of the introgressed progenies are shown in [Table S1](#) (Nigerian *dura*) and [Table S2](#) (Deli *dura*), respectively.

**Table 1.** List of twelve introgressed progenies of Nigerian *dura* x Deli *dura* along with pedigree.

No.	Progenies	Pedigree ♀ x ♂	Grand parent of male (♂) parent		Cross type
			Female	Male	
1	PK1190	0.152/46 x 0.212/642	0.82/2054	0.102/8544	D x D
2	PK1210	0.149/13051 x 0.212/515	0.85/4338	0.85/4338	D x D
3	PK1231	0.149/3951 x 0.212/637	0.102/8428	0.102/8539	D x D
4	PK1236	0.149/6710 x 0.212/179	0.82/2360	0.82/2360	D x D
5	PK1296	0.150/1780 x 0.212/564	0.82/2054	0.102/8544	D x D
6	PK1301	0.150/1780 x 0.212/41	0.82/2360	0.82/2360	D x D
7	PK1313	0.149/14483 x 0.212/612	0.102/8539	0.82/2231	D x D
8	PK1316	0.149/14483 x 0.212/637	0.102/8428	0.102/8539	D x D
9	PK1330	0.151/629 x 0.212/331	0.82/2258	0.82/2200	D x D
10	PK1339	0.150/2221 x 0.212/529	0.82/1876	0.82/1876	D x D
11	PK1351	0.149/3985 x 0.212/515	0.85/4338	0.85/4338	D x D
12	PK1441	0.149/13051 x 0.212/648	0.102/8428	0.102/8539	D x D

The progenies were laid down in a triangular planting system at 9 m apart in a randomized complete block design with 16 palm plants per plot in four replications.

Yield recording of the materials was initiated in 1997 at 37 months after planting at fifteen-day intervals or two rounds per month for a period of seven consecutive years. The fresh fruit bunch FFB yield and its components, namely BN and average bunch weight (ABW) data, were then summarized annually. Analysis of the bunch quality components mesocarp to fruit ratio (M/F), kernel to fruit ratio (K/F), shell to fruit ratio (S/F), oil to dry mesocarp ratio (O/DM), fruit to bunch ratio (F/B), oil to bunch ratio (O/B), kernel to bunch ratio (K/B), oil yield (OY) and kernel yield (KY) was commenced a year later following the method of Rao et al. (1983) applied by Rafii et al. (2012b). Vegetative measurements including frond production (FP), petiol cross-section (PCS), rachis length (RL), leaflet length (LL), LW leaflet width (LW), leaflet number (LN), palm height (HT), leaflet area (LA), leaf area index (LAI), and trunk diameter (DIAM) were taken at eight years (2002) after field planting, adopting the one-shot method (Breure and Powell, 1987). Palm height was measured from the ground level to the base of frond number 41. Height increment was calculated according to Breure and Powell (1987) using the formula: height increment/year = (height at year t) / (t - 2), where t is the age of the palm. All the traits studied were computed for analysis of variance (ANOVA). The data were analyzed by ANOVA and least significant difference (LSD) using the Statistical Analysis System program (SAS Institute, 1992).

Heritability values for each trait were calculated on the basis of the intra-class correlation coefficient ( $t_g$ ) as follows:

$$t_g = \frac{\sigma_g^2}{\sigma_w^2 + \sigma_{gr}^2 + \sigma_g^2}$$

where:

$\sigma_g^2$  = progeny variance

$\sigma_{gr}^2$  = G x R variance

$\sigma_w^2$  = within palm variance

According to Falconer and Mackay (1996), in full-sib families,  $2t_g$  equals broad sense heritability ( $h_B^2$ ).

## RESULTS AND DISCUSSION

### *Yield components and yield*

ANOVA for FFB, BN, and ABW revealed the presence of significant genotypic differences, indicating sufficient variability among the introgressed progenies studied for these three traits (Table 2). The results also indicated that there was ample scope for breeding and selection for these traits. Thus, wide variability was exhibited for all three bunch yield traits. Similar findings were reported for yield and related characters by Rafii et al. (2002) and Okoye et al. (2009) in introgressed oil palm. The replicate item was not significant, implying the uniformity of experimental plots. However, the ranking of the progenies for FFB and BN was not consistent except for ABW as shown in the replicates x progenies item in

ANOVA. FFB recorded the lowest  $h^2_B$  of only 6.47% as compared to BN and ABW with  $h^2_B$  values of 68.04 and 66.38%, respectively. Low estimate of broad sense heritability in FFB yield indicates a significant role of environment in the expression of this trait. High broad sense heritability was reported for BN and ABW by Musa et al. (2004) and Okwuagwu et al. (2008) from their study on D x P and Deli/*dura* x *tenera* breeding populations, respectively, which supports the present result.

**Table 2.** Mean squares, variance components and heritability for FFB yield and its components of 12 introgressed progenies.

Source	d.f.	FFB (kg·palm <sup>-1</sup> ·year <sup>-1</sup> )	BN (bunches·palm <sup>-1</sup> ·year <sup>-1</sup> )	ABW (kg/bunch)
Replications (R)	3	3465.67 <sup>ns</sup>	10.09 <sup>ns</sup>	15.50 <sup>ns</sup>
Progenies (G)	11	7550.49*	94.70**	392.86**
G x R	33	3557.00**	8.68**	21.90 <sup>ns</sup>
Within palms	461	1951.79	4.29	18.9
Progeny variance ( $\sigma^2_g$ )		70 (3.23%)	2.48 (34.08%)	10.04 (33.19%)
G x R variance ( $\sigma^2_{gr}$ )		71 (3.28%)	0.44 (5.98%)	0.89 (2.95%)
Within palms variance ( $\sigma^2_w$ )		2022 (93.48%)	4.37 (59.94%)	19.32 (63.86%)
Broad sense heritability ( $h^2_B$ , %)		6.47	68.04	66.38

\*, \*\*, and <sup>ns</sup> indicate significant at  $P \leq 0.05$ ,  $P \leq 0.01$  and not significant, respectively; Values in brackets are percentages of the corresponding values of the phenotypic variances; FFB = fresh fruit bunch; BN = bunch number; ABW = average bunch weight.

The performances of the progenies regarding yield and its components are shown in Table 3. Among the progenies, PK1351 (0.149/3985 x 0.212/515) produced the highest FFB yield of 212 kg·palm<sup>-1</sup>·year<sup>-1</sup> which was due to its high ABW (22.4 kg/bunch) and moderate BN (9.7 bunches palm<sup>-1</sup> year<sup>-1</sup>). This result is in contrast to MPOB Nigerian material, characterized by high BN and low ABW (Isa et al., 2008). On the other hand, PK1330 had the lowest FFB yield among the progenies due to its low BN (5.94 bunches palm<sup>-1</sup> year<sup>-1</sup>) but recorded the highest ABW (28.1 kg bunch<sup>-1</sup>), which implies that average ABW and moderate BN were prerequisites for high FFB yield.

**Table 3.** Mean performance of the progenies for FFB yield and its components.

No	Progeny	Pedigree	FFB (kg·palm <sup>-1</sup> ·year <sup>-1</sup> )	BN (bunches·palm <sup>-1</sup> ·year <sup>-1</sup> )	ABW (kg/bunch)
1	PK1190	0.152/46 x 0.212/642	199	11.0	18.0
2	PK1210	0.149/3985 x 0.212/515	186	7.7	24.2
3	PK1231	0.149/3951 x 0.212/637	185	7.5	25.0
4	PK1236	0.149/6710 x 0.212/179	185	7.4	25.5
5	PK1296	0.150/1780 x 0.212/564	179	7.0	25.8
6	PK1301	0.150/1780 x 0.212/41	196	7.2	27.7
7	PK1313	0.149/14483 x 0.212/612	198	10.8	18.7
8	PK1316	0.149/14483 x 0.212/637	207	10.4	20.0
9	PK1330	0.151/629 x 0.212/331	167	5.9	28.1
10	PK1339	0.150/2221 x 0.212/529	195	9.3	21.2
11	PK1351	0.149/3985 x 0.212/515	212	9.7	22.4
12	PK1441	0.149/13051 x 0.212/648	198	8.7	23.4
Standard deviation			46.4	2.65	5.35
LSD ( $P \leq 0.05$ )			20.2	0.95	1.95
CV (%)			24.1	30.7	23.1

FFB = fresh fruit bunch; BN = bunch number; ABW = average bunch weight; LSD = least significant difference; CV = coefficient variation.

### Bunch quality components

ANOVA for bunch quality components revealed the presence of significant to highly genotypic differences indicating sufficient genetic variability exists among the progenies for the component characters, i.e., M/F, K/F, S/F, O/DM, O/B, K/B, KY, and OY but not F/B (Table 4). This was anticipated as the Nigerian material used in this study was from the oil palm germplasm collected from Nigeria in 1973. In oil palm, as in many other crops, a number of generations of selection are required for the material to be genetically stable. Among the traits, M/F and S/F exhibited moderate heritability values of 55.85 and 49.24%, respectively. The rest of the component traits had low heritability values, which ranged from 6.51% in OY to 33.04% in K/F. Low estimate of broad sense heritability indicates a significant role of environment in the expression of these traits. In oil palm breeding, traits with low heritability are normally selected based on the best family and individual selection, while traits with high heritability values may be selected through mass selection.

The performances of the progenies regarding bunch quality components are shown in Table 5. Most of the progenies had moderate mean fruit weight (MFW) with a mean of 10.48 g. O/B is an important character in oil palm breeding and selection. It has been reported that Nigerian materials are normally characterized by having small fruit with an MFW of 7.98 g (Rajanaidu et al., 1999; 2000). The results showed that O/B of the progenies studied was high for *dura* with all progenies attaining more than 16%. Among the progenies, five (PK1210, PK1301, PK1313, PK1316 and PK1339) were identified with higher O/B, i.e., more than 18%, and among them PK1313 had the highest, 19.4%. The high O/B of PK1313 might have been due to its high M/F (61.15%) and low S/F (30.72%) coupled with high F/B (65.56%). As a result, among the progenies, PK1313 produced the highest oil yield, 31.40 kg·palm<sup>-1</sup>·year<sup>-1</sup>.

### Vegetative traits

All the vegetative traits, i.e., FP, PCS, RL, LL, LW, LN, HT, LA, LAI, and DIAM, showed highly significant differences, indicating the high genetic variability of these traits (Table 6). Heritability estimates for the vegetative traits ranged from 20.69% in LW to 82.45% in LL. Among the characters, high estimate of heritability was observed only in RL and LL, with 82.45 and 81.08%, respectively. Characters with lower estimates of broad sense heritability indicate a significant role of environment in the expression of those traits. On the other hand, high broad sense heritability in RL and LL indicates little influence of the environment on the expression of these two traits. Traits with high heritability estimates are generally more amenable for future breeding and selection.

The mean performances of the introgressed progenies regarding vegetative traits are presented in Table 7. The results indicate that the variations observed among the progenies for the vegetative traits were found to be comparable to the progenies of Deli *dura* x AVROS *pisifera* (D x P) reported by Noh et al. (2010; 2012). Among the progenies, PK1330 was found to have the smallest PCS (27.2 cm<sup>2</sup>), RL (4.8 m) and HT (1.85 m) and the lowest LN (165 leaflets/frond) as compared to other progenies under trial. Short LL, HT, and small PCS are the prerequisite characters in selecting palms for compactness. Compact palms can be utilized for high density planting and are capable of producing higher yield per hectare.

**Table 4.** Mean squares, variance components and heritability estimates for bunch quality components of the progenies.

Source	d.f.	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	F/B (%)	O/B (%)	K/B (%)	OY (kg palm <sup>-1</sup> .year <sup>-1</sup> )	KY (kg palm <sup>-1</sup> .year <sup>-1</sup> )
Replications (R)	3	2.03 <sup>ns</sup>	1.93 <sup>ns</sup>	0.80 <sup>ns</sup>	13.41 <sup>ns</sup>	23.90 <sup>ns</sup>	10.80 <sup>ns</sup>	0.55 <sup>ns</sup>	7.24 <sup>ns</sup>	18.29 <sup>ns</sup>
Progenies (G)	11	224.32 <sup>**</sup>	18.37 <sup>**</sup>	145.25 <sup>**</sup>	18.80 <sup>*</sup>	42.75 <sup>ns</sup>	35.59 <sup>**</sup>	9.05 <sup>**</sup>	167.50 <sup>**</sup>	20.78 <sup>*</sup>
G x R	33	14.69 <sup>ns</sup>	1.48 <sup>ns</sup>	14.49 <sup>ns</sup>	6.44 <sup>ns</sup>	33.40 <sup>ns</sup>	8.19 <sup>ns</sup>	0.58 <sup>ns</sup>	88.71 <sup>**</sup>	9.25 <sup>ns</sup>
Within palms	461	17.13	2.86	12.18	6.12	23.09	5.71	1.4	40.11	6.09
Progeny variance ( $\sigma_g^2$ )		6.68 (27.91%)	0.57 (16.53%)	4.05 (24.60%)	0.57 (8.67%)	0.77 (3.26%)	0.83 (12.50%)	0.27 (16.27%)	1.40 (3.41%)	0.29 (4.23%)
G x R variance ( $\sigma_{gr}^2$ )		0.00 (0.00%)	0.06 (1.77%)	0.00 (0.00%)	0.01 (0.10%)	0.03 (0.13%)	0.08 (1.22%)	0.01 (0.80%)	0.11 (0.27%)	0.30 (4.46%)
Within palms variance ( $\sigma_p^2$ )		17.24 (72.09%)	2.82 (81.70%)	12.40 (75.40%)	6.05 (91.23%)	22.84 (96.62%)	5.71 (86.29%)	1.39 (82.93%)	39.55 (96.32%)	6.24 (91.32%)
Broad sense heritability ( $h^2_{bp}$ , %)		55.85	33.04	49.24	17.20	6.51	25.08	32.34	6.82	8.49

\*, \*\*, and <sup>ns</sup> indicate significant at  $P \leq 0.05$ ,  $P \leq 0.01$  and not significant, respectively; Values in brackets are percentages of the corresponding values of the phenotypic variances; M/F = mesocarp to fruit ratio; K/F = kernel to fruit ratio; S/F = shell to fruit ratio; O/DM = oil to dry mesocarp ratio; F/B = fruit to bunch ratio; O/B = oil to bunch ratio; K/B = kernel to bunch ratio; OY = oil yield; KY = kernel yield.

**Table 5.** Progeny means for bunch quality components of the progenies.

No.	Progeny	Pedigree	MFW (g)	M/F (%)	K/F (%)	S/F (%)	ODM (%)	F/B (%)	O/B (%)	K/B (%)	OY (kg palm <sup>-1</sup> .year <sup>-1</sup> )	KY (kg palm <sup>-1</sup> .year <sup>-1</sup> )
1	PK1190	0.152/46 x 0.212/642	10.2	55.5	8.85	35.6	76.4	64.8	16.8	5.73	26.4	9.03
2	PK1210	0.149/3985 x 0.212/515	11.6	54.7	10.14	35.2	78.0	65.5	18.3	6.63	27.5	10.02
3	PK1231	0.149/3951 x 0.212/657	10.4	53.8	9.17	37.0	77.9	66.7	17.6	6.12	26.1	9.16
4	PK1236	0.149/6710 x 0.212/179	10.4	54.5	9.58	35.8	76.9	63.8	16.4	6.10	25.1	9.38
5	PK1296	0.150/1780 x 0.212/564	9.4	57.1	10.42	32.5	75.6	61.7	16.3	6.43	24.5	9.67
6	PK1301	0.150/1780 x 0.212/41	7.8	58.8	9.74	31.4	76.4	62.5	18.0	6.05	25.1	8.38
7	PK1313	0.149/14483 x 0.212/612	10.8	61.2	8.14	30.7	78.1	65.6	19.4	5.36	31.4	8.75
8	PK1316	0.149/14483 x 0.212/637	10.3	60.1	6.99	32.9	78.4	62.9	19.1	4.42	30.0	7.00
9	PK1330	0.151/629 x 0.212/331	10.2	57.1	9.75	33.1	77.3	64.0	16.9	6.25	21.9	7.89
10	PK1339	0.150/2221 x 0.212/529	9.7	57.0	9.56	33.4	76.9	65.1	18.5	6.23	29.6	10.02
11	PK1351	0.149/3985 x 0.212/515	11.8	56.3	8.81	34.9	77.3	63.4	17.5	5.59	29.8	9.40
12	PK1441	0.149/13051 x 0.212/648	11.1	52.5	10.03	37.4	78.9	66.2	17.9	6.62	28.1	10.37
	Standard deviation		2.25	4.85	1.88	4.11	2.70	5.23	2.67	1.28	6.94	2.63
	LSD (P ≤ 0.05)		0.95	2.30	1.02	2.15	1.97	ns	0.97	0.53	2.61	1.20
	CV (%)		21.5	8.6	20.28	11.9	3.5	8.1	15.1	21.4	25.3	28.5

MFW = mean fruit weight; M/F = mesocarp to fruit ratio; K/F = kernel to fruit ratio; S/F = shell to fruit ratio; O/DM = oil to dry mesocarp ratio; F/B = fruit to bunch ratio; O/B = oil to bunch ratio; K/B = kernel to bunch ratio; OY = oil yield; KY = kernel yield; LSD = least significant difference; CV = coefficient variation.



**Table 6.** Mean squares, variance components and heritability for vegetative measurements of the progenies.

Source	d.f.	FP (No.)	PCS (cm <sup>2</sup> )	RL (m)	LL (cm)	LW (cm)	LN (No.)	HT (m)	LA (m <sup>2</sup> )	LAI	DIAM (m)
Replications (R)	3	52.6**	33.6 <sup>ns</sup>	2.0*	41.93 <sup>ns</sup>	0.81 <sup>ns</sup>	1111**	0.45 <sup>ns</sup>	12.9 <sup>ns</sup>	4.5 <sup>ns</sup>	0.02 <sup>ns</sup>
Progenies (G)	11	319**	4057**	56.0**	15679**	15.9**	14905**	32.5**	410**	144**	0.6**
G x R	33	373**	2268**	16.2**	2896**	11.9*	10715**	14.8**	180**	63**	0.1 <sup>ns</sup>
Within palms	461	4.5	36.6	0.19	45.9	0.26	94.1	0.14	2.3	0.8	0.11
Progeny variance ( $\sigma^2_p$ )		0.65 (11.2%)	7.59 (16.0%)	0.15 (40.9%)	35.05 (41.2%)	0.03 (8.8%)	33.21 (22.3%)	0.06 (25.9%)	0.83 (24.8%)	0.29 (24.7%)	0.05 (31.3%)
G x K variance ( $\sigma^2_{gp}$ )		0.48 (8.4%)	2.69 (5.7%)	0.02 (4.4%)	1.26 (1.5%)	0.00 (0.8%)	22.03 (14.8%)	0.02 (7.2%)	0.17 (5.0%)	0.06 (5.1%)	0.00 (0.0%)
Within palms variance ( $\sigma^2_e$ )		4.63 (80.4%)	37.06 (78.3%)	0.20 (54.7%)	48.71 (57.3%)	0.26 (90.4%)	93.39 (62.8%)	0.15 (66.9%)	2.37 (70.2%)	0.83 (70.2%)	0.11 (68.7%)
Broad sense heritability ( $h^2_{bp}$ , %)		22.57	32.07	81.08	82.45	20.69	44.69	52.17	49.26	49.15	62.50

\*, \*\*, and <sup>ns</sup> indicate significant at  $P \leq 0.05$ ,  $P \leq 0.01$  and not-significant, respectively. Values in brackets are percentages of the corresponding values of the phenotypic variances; FP = frond production, PCS = petiol cross-section, RL = rachis length, LL = leaflet length, LW = leaflet width, LN = leaflet number, HT = palm height, LA = leaflet area, LAI = leaf area index, DIAM = trunk diameter.

**Table 7.** Means of twelve introgressed progenies for vegetative characters.

No.	Progeny	Pedigree	FP (No.)	PCS (cm <sup>2</sup> )	RL (m)	LL (cm)	LW (cm)	LN (No.)	HT (m)	LA (m <sup>2</sup> )	LAI	DIAM (m)
1	PK1190	0.152/46 x 0.212/642	27.1	27.3	5.1	84.4	5.4	171	2.16	9.0	5.3	0.69
2	PK1210	0.149/3985 x 0.212/515	25.6	33.7	6.05	97.8	5.6	181	2.71	11.3	6.7	0.68
3	PK1231	0.149/3951 x 0.212/637	25.8	36.6	6.08	98.6	5.8	178	2.20	11.6	6.9	0.71
4	PK1236	0.149/6710 x 0.212/179	25.1	34.2	6.0	96.1	5.7	184	2.29	11.5	6.8	0.69
5	PK1296	0.150/1780 x 0.212/564	25.4	31.5	5.8	88.4	5.5	179	2.46	10.1	6.0	0.63
6	PK1301	0.150/1780 x 0.212/41	25.6	27.6	5.7	83.1	5.2	174	2.05	9.0	5.3	0.60
7	PK1313	0.149/14483 x 0.212/612	24.2	30.9	5.7	98.5	5.2	175	2.22	10.3	6.1	0.59
8	PK1316	0.149/14483 x 0.212/637	27.0	30.2	5.5	89.4	5.5	173	2.01	9.7	5.7	0.61
9	PK1330	0.151/629 x 0.212/331	24.8	27.2	4.8	96.9	5.3	165	1.85	9.8	5.8	0.69
10	PK1339	0.150/2221 x 0.212/529	24.6	30.0	6.1	96.8	5.5	181	2.57	11.0	6.5	0.66
11	PK1351	0.149/3985 x 0.212/515	25.6	32.4	5.6	102.9	5.3	172	2.59	10.7	6.3	0.61
12	PK1441	0.149/13051 x 0.212/648	26.8	29.8	5.4	91.5	5.6	166	2.37	9.8	5.8	0.66
	Standard deviation		2.31	7.59	0.48	8.73	0.48	9.52	0.47	1.52	0.90	0.07
	LSD (P ≤ 0.05)		1.00	2.80	0.21	3.14	0.23	4.71	0.18	0.71	0.42	0.03
	CV (%)		9.0	24.3	8.5	9.3	8.7	5.4	20.3	14.6	14.6	10.6

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; DIAM = trunk diameter; LSD = least significant difference; CV = coefficient variation.

## CONCLUSION

These crossing programs were aimed to broaden *dura* population genetic base. The genetic variability of the crosses was high for most of the characters, giving ample scope for further selection. A total of 87 palm progenies were selected from this trial based on SIRIM oil palm seed quality production specifications, MS157:2005 (SIRIM, 2005) as *dura* mother palms for D x P seeds production. In addition, the outstanding *dura* palm progenies from these programs could be cloned and utilized for the production of commercial semi-clonal or clonal D x P planting materials.

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## [Supplementary material](#)

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