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PERFORMANCE OF SELFED AND INTERCROSSED OIL PALM DELI ULU REMIS PROGENIES BASED ON SELECTED AGRONOMIC TRAITS

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ABSTRACT

Deli is considered the best dura material for breeding and seed production. The Deli dura *is predominantly utilised as the maternal parent in all commercial* dura *x* pisifera *(DxP) hybrid seed production programmes. This study evaluated the selfed and intercrossed Deli Ulu Remis oil palm progenies at the Malaysian Palm Oil Board (MPOB) Research Station in Kluang, Johor, Malaysia. Performance of the selfed and intercrossed progenies in the bunch yield and bunch quality components were assessed. We also estimated the variance components and heritability for selected agronomic traits, based on the parental types. Intercrossed progenies produced significantly higher yields compared to selfed progenies. Broad-sense heritability estimates were higher in selfed compared to intercrossed progenies for most of the agronomic characters. In summary, this study identified the most promising* dura *progeny and individual palms as the female parents for commercial oil palm seed production, as well as a source for further genetic improvement via ongoing breeding programmes.*

Keywords: breeding, deli *dura*, heritability, yield.

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INTRODUCTION

The oil palm (*Elaeis guineensis* Jacq.) is the most productive oil crop in terms of oil yield per hectare compared to other vegetable oils (Kome *et al.*, 2020). Although the maximum theoretical oil yield has been predicted to be 18.2 t/ha/yr (Corley, 1998), stagnation in the oil yields of between 3.5 to 3.9 t/ha has been observed for more than two decades (Kushairi *et al.*, 2010). Therefore, increasing productivity through high-yielding planting materials is a feasible approach as such materials are available in the industry. In 2020, the Malaysian oil palm industry produced 19.14 million tonnes of crude palm oil (CPO), where the average fresh fruit bunch (FFB) yield was 16.73 t/ha with an oil extraction rate (OER) of 19.92% (MPOB, 2021). This performance was slightly lower, compared to the previous year due to the outbreak of the global COVID-19 pandemic.

Commercial seed production programmes in Malaysia currently use the Deli *dura*s as the female parents (Kushairi *et al.*, 2011; Kushairi and Mohd Din, 2020). The Deli type is still considered the best *dura* for breeding and seed production which originated from the four palms planted at the Botanical Garden in Bogor (1848) (Hartley 1988; Rajanaidu *et al.*, 2000). Compared to the *tenera* fruit form and the African *dura*s, Deli *dura*s produce fewer but heavier bunches. The fruit colour is darker, larger, and have a high mesocarp content, with higher oil to bunch ratio compared to African *dura*s. Despite their

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narrow genetic base, Sparnaaij and van der Vossen (1980) in their review, provided justifications for the continuous exploitation of Deli populations in breeding programmes.

Oil palm has a long breeding cycle of 10 to 12 years. It is therefore of utmost importance to understand the variability, inheritance and genetic pattern of the materials studied. This information would be useful in designing breeding programmes for selection and improvement. Oil palm breeding programmes and selection in the Malaysian Palm Oil Board (MPOB) adopt a two-pronged approach, which includes prospecting new germplasm apart from fully utilising the traditional Deli *dura* and AVROS *pisifera* collections (Marhalil *et al*., 2016; Noh *et al*., 2012). Studies on the performance of (Deli x Deli) and (Deli x AVROS) progenies have been carried out extensively to identify the outstanding progenies to increase oil production.

In this study, the performance of 28 intercrossed and 35 selfed progenies from Deli Ulu Remis *dura*s were evaluated in terms of bunch yield and bunch quality components. Analyses were conducted to estimate the genetic components and heritability of these agronomic traits and to identify the potential progenies and individual palms for breeding and seed production.

MATERIALS AND METHODS

The materials used in this study comprise two groups, *i.e.,* Deli *dura* (Ulu Remis) progenies: intercrossed (28 progenies) and selfed (35 progenies). The intercrossed and selfed progenies were field planted on inland soil in trials 0.484 and 0.488 respectively, at MPOB Kluang Research Station, Johor, Malaysia. Both trials (0.484 and 0.488) were initiated in August 2008, in a Randomised Complete Block Design (RCBD) with four and three replications for intercrossed and selfed progenies respectively, and at 16 palms per progeny per replication. The total number of palms evaluated in this study was 2553.

Data Collection

Harvesting and FFB yield recording were initiated by MPOB in August 2011. FFB yield data were recorded for each individual palm, at each harvesting round (2 to 3 rounds per month), starting from 36 months after field planting. The yield record was summarised over twelve months, between January and December for each year until December 2020. Summarised bunch yields for the four best consecutive years (*i.e.,* 2016 to 2019 or 7.5 to 10.5 years old) were used for data analysis. Meanwhile, bunch and fruit quality components were analysed for nine years (2012-2020). Bunch quality components were estimated using the bunch analysis method (Rao *et al*., 1983), to determine the oil extraction and fruit quality components. For this purpose, three bunches were sampled from each palm. To avoid seasonal variation, ripe bunches with one to 10 loose fruits were randomly sampled at intervals of at least three months (Rao, 1987).

Data Analysis

Data on bunch yield and bunch quality characters was based on individual palms and computed using the Statistical Analysis System (SAS) program. Analysis of variance (ANOVA) and comparison between progeny means was carried out using Fisher's Least Significant Difference (LSD) procedure at the minimum 5% level of probability. Broad-sense heritability statistics were estimated for each character using variance components. Variance analysis for the estimation of broad-sense heritability was processed from the variance component procedure (PROC VARCOMP) of SAS version 9.2 using Equation (1):

$$h_{\mathrm{B}}^{2} = \frac{a^{2}f}{a^{2}f + a^{2}wf} \qquad (1)$$

where α^2f = variance between progenies, α^2wf = variance within progenies. In full-sib progenies, $2h^2_B$ equals broad sense heritability (Falconer and Mackay, 1996).

RESULTS AND DISCUSSION

Yield Performance of DxD Intercrossed and Selfed Progenies

The progeny factor in both intercrossed and selfed progenies was highly significant for all yield traits (*Table 1*). It is widely known that many factors affect oil palm yield components including uncontrollable aspects, such as its growing environment and the genetic background of the planting materials. High heritability values were observed for the bunch number (BNO), with a higher value of 0.34 for selfed progenies compared to 0.22 for intercrossed progenies. Our results further revealed that genetic variation contributed to 0.16-0.34 of the phenotypic variation in yield, *i.e.,* FFB, BNO and average bunch weight (ABW), suggesting stronger uncontrolled factors that include environmental influence on the expression of these characters.

Moreover, heritability estimates for yield characters vary depending on location, suggesting that the environment may exert a stronger influence on yield (Mohd Din *et al*., 2015).

The best performing progeny among the intercrossed progenies is PK4687, producing FFB of 218.77 kg/p/yr (*Table 2*), *i.e.*, ~25% above the trial mean of 175.59 kg/p/yr. This high FFB yield was likely contributed by its high BNO (13.91 bunches/p/yr). Selecting for high BNO may also lead to a high sex ratio. In comparison, PK4669 produced the lowest FFB yield of only 146.28 kg/p/yr, *i.e.*, 16.7% below the trial mean. PK4654 recorded the highest ABW of 18.0 kg/bunch, with a moderate FFB yield of 155.91 kg/p/yr, likely resulting from its low BNO (8.80 bunches/p/yr). On the other hand, evaluation of the DxD selfed progenies revealed that PK4587 produced the highest FFB yield with 182.67 kg/p/yr but this was not significantly different from the yields of seven other progenies, PK4341, PK4378, PK4386, PK4440, PK4452, PK4497 and PK4554. The lowest FFB yield in PK4677 progeny was likely due to its lower BNO of 7.56 bunches/p/yr and producing a modest ABW (14.49 kg/bunch/yr). Improvements on various *dura* lines such as Banting, Elmina and Ulu Remis have shown that Elmina *dura*s provide the best FFB yield with oil to bunch (O/B) of 24.09% (Marhalil *et al*., 2016). However, only a small improvement was observed from the F4 to F5 Elmina *dura* generations, which may be due to several factors including inbreeding. Selection improvement for FFB yield in the second and subsequent generations has been estimated to be 10%-15% per generation (Hardon *et al*., 1987).

TABLE 1. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITIES FOR YIELD AND YIELD COMPONENTS IN 28 DxD INTERCROSSED AND 35 DxD SELFED PROGENIES

Source	df	Mean squares		
		FFB (kg/p/yr)	BNO (bunches/p/yr)	ABW (kg/p/yr)
		DxD intercrossed progenies		
Replication (R)	3	57 015.91**	171.25**	61.13**
Progenies (P)	27	13 933.44**	63.65**	39.20**
RxP	77	4 395.53**	13.84**	19.72**
Within palms	1 192	1 765.89	7.20	6.16
Progeny variance (σ^2_p)		167.66	0.92	0.72
RxP variance (σ^2_{gr})		162.76	0.41	0.84
Within palms variance (σ^2_w)		1 765.90	7.20	6.16
Broad-sense heritability, h^2_B		**0.16**	**0.22**	**0.19**
		DxD selfed progenies		
Replication (R)	2	3 831.09*	2.45^{ns}	23.41**
Progenies (P)	34	15 299.72**	95.44**	50.00**
RxP	65	4 019.88**	23.21**	18.97**
Within palms	1 151	1 369.20	6.25	4.95
Progeny variance (σ^2_p)		246.09	1.58	0.67
RxP variance (σ^2_{gr})		214.69	1.37	1.14
Within palms variance (σ^2_w)		1 369.20	6.25	4.95
Broad-sense heritability, h^2_B		**0.27**	**0.34**	**0.20**

Note: FFB - Fresh fruit bunch; BNO - Bunch number; ABW - Average bunch weight; *, ** Significant at $P\leq0.05$ and $P\leq0.01$ respectively, otherwise not significant.

TABLE 2. PROGENY MEANS OF 28 DxD INTERCROSSED AND 35 DxD SELFED DELI ULU REMIS PROGENIES FOR YIELD AND YIELD COMPONENTS

No.	Progeny	Pedigree	N	FFB (kg/p/yr)	BNO (bunches/p/yr)	ABW (kg/p/yr)
			DxD intercrossed progenies			
1.	PK4419	0.332/451 x 0.332/83	49	186.16b-e	11.32e-i	16.48c-e
2.	PK4494	0.332/83 x 0.332/215	44	159.31j-n	10.95g-i	14.75g-k

TABLE 2. PROGENY MEANS OF 28 DxD INTERCROSSED AND 35 DxD SELFED DELI ULU REMIS PROGENIES FOR YIELD AND YIELD COMPONENTS (continued)

No.	Progeny	Pedigree	N	FFB (kg/p/yr)	BNO (bunches/p/yr)	ABW (kg/p/yr)
3.	PK4515	0.332/83 x 0.332/451	37	173.81e-l	11.99b-g	14.41i-k
4.	PK4520	0.332/190 x 0.332/451	47	203.18ab	13.04ab	15.71d-g
5.	PK4536	0.332/190 x 0.332/157	46	165.43g-m	11.41e-i	14.61h-k
6.	PK4566	0.332/382 x 0.332/451	48	179.09d-n	11.04g-i	16.36c-f
7.	PK4567	0.332/451 x 0.332/382	50	156.82 l-n	10.45i-k	15.08g-i
8.	PK4571	0.332/382 x 0.332/83	45	167.14f-m	12.20b-f	13.81jk
9.	PK4572	0.332/157 x 0.332/83	43	178.08d-i	11.73c-h	15.39f-i
10.	PK4588	0.332/360 x 0.332/83	50	186.87b-e	12.71bc	14.84g-j
11.	PK4597	0.332/330 x 0.332/83	49	192.11b-d	11.72c-h	16.86bc
12.	PK4602	0.332/360 x 0.332/157	48	156.36l-n	11.52d-i	13.78k
13.	PK4603	0.332/83 x 0.332/190	49	175.24d-k	11.46d-i	15.56e-h
14.	PK4612	0.332/360 x 0.332/45	48	178.13d-i	11.38e-i	15.68e-g
15.	PK4615	0.332/190 x 0.332/83	50	185.25c-e	12.54b-d	14.85g-j
16.	PK4618	0.332/157 x 0.332/382	49	163.22h-n	11.23f-i	14.70g-k
17.	PK4619	0.332/83 x 0.332/45	12	160.69i-n	11.88c-h	13.74k
18.	PK4628	0.332/446 x 0.332/83	55	186.81b-e	12.04b-g	15.62e-h
19.	PK4634	0.332/190 x 0.332/382	54	182.95c-g	12.39b-e	14.84g-j
20.	PK4641	0.332/360 x 0.332/215	50	151.13mn	9.21 l	16.52c-e
21.	PK4642	0.332/215 x 0.332/45	39	158.26k-n	9.59kl	16.75b-d
22.	PK4654	0.332/451 x 0.332/215	44	155.91mn	8.80l	18.00a
23.	PK4665	0.332/360 x 0.332/330	44	175.76d-k	11.71c-h	15.57e-h
24.	PK4669	0.332/330 x 0.332/215	44	146.28n	9.79j-l	15.25g-i
25.	PK4680	0.332/360 x 0.332/451	47	199.21bc	11.37e-i	17.68ab
26.	PK4687	0.332/45 x 0.332/83	44	218.77a	13.91a	15.68e-g
27.	PK4688	0.332/330 x 0.332/382	54	183.90c-f	10.78h-j	17.31a-c
28.	PK4718	0.332/382 x 0.332/45	58	176.37d-j	12.19b-f	14.72g-k
	Mean			**175.59**	**11.46**	**15.53**
	LSD			17.88	1.12	1.05
			DxD selfed progenies			
1.	PK4232	0.332/382 x 0.332/382	40	138.10jk	11.40f-j	11.99p
2.	PK4244	0.332/214 x 0.332/214	47	119.75l	9.45mn	12.68n-p
3.	PK4260	0.332/203 x 0.332/203	41	143.31h-k	10.32j-n	13.95d-j
4.	PK4289	0.332/19 x 0.332/19	38	169.42a-e	11.39f-j	15.01bc
5.	PK4291	0.332/370 x 0.332/370	31	168.99a-e	12.55b-e	13.89e-k
6.	PK4297	0.332/277 x 0.332/277	41	141.73i-k	10.83h-l	13.21h-o
7.	PK4309	0.332/100 x 0.332/100	31	172.31a-c	12.68b-d	14.32c-g
8.	PK4336	0.332/363 x 0.332/363	40	148.56f-k	10.58i-m	14.19c-h
9.	PK4337	0.332/133 x 0.332/133	45	165.24b-f	10.07l-n	16.60a
10.	PK4341	0.332/224 x 0.332/224	22	176.16ab	14.22a	12.42op
11.	PK4342	0.332/285 x 0.332/285	42	159.70b-h	11.26g-k	14.25c-g
12.	PK4343	0.332/275 x 0.332/275	43	144.88g-k	10.68i-l	13.67g-n
13.	PK4378	0.332/247 x 0.332/247	31	171.61a-c	11.65d-i	14.76c-f
14.	PK4385	0.332/2 x 0.332/2	41	111.213l	8.18o	13.63g-n
15.	PK4386	0.332/329 x 0.332/329	37	171.21a-d	11.40e-j	14.97b-d

TABLE 2. PROGENY MEANS OF 28 DxD INTERCROSSED AND 35 DxD SELFED DELI ULU REMIS PROGENIES FOR YIELD AND YIELD COMPONENTS (continued)

No.	Progeny	Pedigree	N	FFB (kg/p/yr)	BNO (bunches/p/yr)	ABW (kg/p/yr)
16.	PK4395	0.332/330 x 0.332/330	42	144.54g-k	10.01l-n	14.65c-g
17.	PK4435	0.332/317 x 0.332/317	34	147.83g-k	9.34n	15.88ab
18.	PK4440	0.332/413 x 0.332/413	34	171.08a-e	13.39a-c	12.95j-p
19.	PK4443	0.332/124 x 0.332/124	44	159.72b-h	11.84d-h	13.73g-m
20.	PK4447	0.332/153 x 0.332/153	39	141.54i-k	10.13k-n	14.09c-i
21.	PK4448	0.332/47 x 0.332/47	40	154.69d-j	10.69h-l	14.59c-g
22.	PK4452	0.332/369 x 0.332/369	31	172.84a-c	12.44c-f	14.14c-h
23.	PK4487	0.332/222 x 0.332/222	26	138.38jk	10.11k-n	13.80f-l
24.	PK4497	0.332/144 x 0.332/144	37	173.18a-c	13.62ab	12.84l-p
25.	PK4514	0.332/451 x 0.332/451	17	150.62f-k	10.13k-n	15.00bc
26.	PK4544	0.332/107 x 0.332/107	39	154.36e-j	11.32f-j	13.79f-l
27.	PK4554	0.332/83 x 0.332/83	37	175.67ab	13.48a-c	13.10i-o
28.	PK4559	0.332/416 x 0.332/416	35	137.08k	11.38f-j	12.04p
29.	PK4585	0.332/215 x 0.332/215	41	136.91k	9.43mn	14.61c-g
30.	PK4587	0.332/114 x 0.332/114	31	182.67a	11.56d-i	16.38a
31.	PK4633	0.332/9 x 0.332/9	28	156.36c-i	12.37c-g	12.70m-p
32.	PK4649	0.332/135 x 0.332/135	38	157.84c-i	11.05h-l	14.37c-g
33.	PK4676	0.332/394 x 0.332/394	22	158.75c-h	10.68i-l	14.85b-e
34.	PK4677	0.332/378 x 0.332/378	41	108.38l	7.56o	14.49c-g
35.	PK4678	0.332/45 0.332/45	27	160.25b-g	12.56b-d	12.90k-p
	Mean			**152.60**	**11.04**	**14.00**
	LSD			16.83	1.16	1.04
		Parent Mean (0.332)		**160.86**	**14.42**	**11.21**

Note: FFB - Fresh fruit bunch; BNO - Bunch number; ABW - Average bunch weight; N – Number of individual palms. Means with the same letter in superscript are not significantly different at *p*≤0.05 based on the Least Significant Difference (LSD) test.

Performance of DxD Intercrossed and Selfed Progenies on Bunch Quality Components

Bunch quality components for the oil palm are related to the oil content and variability in bunch composition. Substantial genetic variations on these traits were observed (*Table 3*), which may be exploited for further selection and improvements. There was a statistically significant interaction between the replicates and progeny factors (R×P) on all the evaluated traits except kernel to fruit ratio (K/F) in selfed progenies. This suggested that there may be irregularities in the performance of these traits across the replicates. The results contrasted with Noh *et al.* (2014) where these five traits showed no significant difference in R×P interaction among twelve introgressed progenies of Nigerian *dura* x Deli *dura*. It is not usual to observe R×P interactions for bunch components. Many reasons can be investigated. The main suggestion should be to verify the identity of the crossings in each replicate, to eliminate the risk of mistakes.

Alvarado and Escobar (2016) reported that a mesocarp to fruit ratio (M/F) of 60.7% to 67.8% was observed in 33 DxD progenies planted in Costa Rica. They also observed that the percentage of O/B varied from 23% to 26% which was higher than the industry standard for *dura* palms. In DxD intercrossed progenies, PK4619 provided the highest M/F (67.71%) while PK4232 from the selfed progenies produced the highest M/F (68.07%), likely due to its lowest S/F among the selfed progenies (*Table 4*). The M/F for the intercrossed progenies ranged from 59.46%-67.71% while a slightly wider range was observed for selfed progenies (57.27%-68.07%). The O/B varied from 18.84%-23.57% for the intercrossed progenies and 15.21%-22.26% for the selfed progenies, which is lower than the O/B range reported for the DxD progenies in Costa Rica (Alvarado and Escobar, 2016). O/B is a derived character comprising of fruit to bunch, mesocarp to fruit and oil to wet mesocarp ratios. Thus, the O/B differences observed between the DxD progenies in Alvarado and Escobar (2016) and this study may be due to the other contributing parameters to the O/B, such as the oil to wet mesocarp and fruit to bunch values, in addition to environmental and genotypic differences.

O/B is a significant character used for oil palm breeding and selection (Noh *et al*., 2010). In this study, the highest achieving intercrossed progeny in terms of O/B was PK4612 (0.332/360 x 0.332/45) (23.57%) and may thus be selected for oil improvement through breeding. Among the selfed progenies, PK4678 (0.332/45 x 0.332/45) recorded the highest O/B (22.26%) which was slightly lower than PK4612's O/B of 23.57%. Based on these results, the parent palm of PK4612 and PK4678 (palm no. 0.332/45) may possess a good genetic control for the O/B character. A previous evaluation of 10 DxD progenies means of 22.19% O/B and 62.73% M/F (Burhanuddin *et al*., 2017), suggested that the O/B and M/F means of the selfed and intercrossed DxD progenies obtained in this study are comparable.

Based on several parameters, most of the material evaluated displayed mean values higher than the commercial minimum standard requirement. The main objective in establishing these trials was to select potential palms for use as female parents for commercial seed production. To ensure production authenticity for desired productivity and sustainability of the oil palm industry, a Malaysian Standard (MS) was developed for DxP hybrid seeds. Based on this Malaysian standard, the *dura* to be used as a female parent must meet certain criteria and be differentiated based on the pedigree and performance (SIRIM, 2017). Malaysian Standard (MS 157) issued by the Department of Standards Malaysia (STANDARDS MALAYSIA) is developed by a committee which consists of a representative from oil palm breeders, producers and planters. The standard, *Oil Palm Seeds for Commercial Planting -Specification, was* first published in 1973 and has been reviewed periodically and the latest (fourth) edition (MS 157:2017) was published in 2017. The standard includes a minimum fresh fruit bunch yield of 150 kg per palm per year, a minimum mesocarp to fruit ratio of 57%, a maximum shell to the fruit of 33%, a minimum kernel to fruit ratio of 5%, a minimum oil to dry mesocarp of 75% and a minimum oil to a bunch of 19%. However, Kandha *et al*. (2017) reported that many commercial oil palm seed producers have progressed from simple two-way crosses to more complicated multi-way crosses, with the expectation of increasing the hybrid vigour and hence developing a higher yield potential.

TABLE 3. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITIES FOR BUNCH QUALITY COMPONENTS IN 28 DxD INTERCROSSED PROGENIES AND 35 DxD SELFED PROGENIES

Source	df	Mean squares				
		M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/B (%)
		DxD intercrossed progenies				
Replication (R)	3	146.62**	4.91^{ns}	193.51**	13.71^{ns}	12.08^{ns}
Progenies (P)	27	167.85**	31.24**	133.58**	44.39**	67.39**
RxP	77	24.57*	4.88**	20.17**	1.86**	17.25**
Within palms	1 192	16.28	2.05	11.56	4.60	9.50
Progeny variance (σ^2_p)	-	2.92	0.53	2.30	0.72	0.99
RxP variance (σ^2_{gr})	-	0.56	0.19	0.58	0.26	0.52
Within palms variance (σ^2_w)	-	16.28	2.05	11.56	4.60	9.50
Broad-sense heritability		**0.30**	**0.38**	**0.32**	**0.26**	**0.18**
		DxD selfed progenies				
Replication (R)	2	68.10**	27.03**	10.71^{ns}	6.76^{ns}	14.86^{ns}
Progenies (P)	34	283.65**	41.08**	185.33**	62.79**	93.95**
RxP	65	42.33**	6.85	31.98**	11.92**	14.41**
Within palms	1 151					
Progeny variance (σ^2_p)		5.94	0.84	3.77	1.25	1.96
RxP variance (σ^2_{gr})		2.47	0.43	1.80	0.69	0.60
Within palms variance (σ^2_w)		15.61	2.16	12.49	4.45	7.88
Broad-sense heritability		**0.49**	**0.49**	**0.42**	**0.39**	**0.38**

Note: M/F - Mesocarp to fruit; K/F - Kernel to fruit; S/F - Shell to fruit; O/DM - Oil to dry mesocarp; O/B - Oil to bunch. *, ** Significant at $P \leq 0.05$ and $P \leq 0.01$, respectively. Otherwise, non-significant.

TABLE 4. PROGENY MEANS OF 28 DxD INTERCROSSED AND 35 DxD SELFED PROGENIES FOR BUNCH QUALITY COMPONENTS

No.	Progeny	Pedigree	N	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/B (%)
		DxD intercrossed progenies						
1.	PK4419	0.332/451 x 0.332/83	49	63.59e-i	6.41d-f	30.00f-k	79.81a	22.98ab
2.	PK4494	0.332/83 x 0.332/215	44	62.29hi	5.87f-j	31.85cd	76.66j	18.84m
3.	PK4515	0.332/83 x 0.332/451	37	62.36g-i	5.79g-j	31.85cd	78.53d-f	20.38h-l
4.	PK4520	0.332/190 x 0.332/451	47	60.37jk	6.82b-d	32.81bc	79.32a-d	20.92g-k
5.	PK4536	0.332/190 x 0.332/157	46	60.35jk	5.26j-l	34.40a	77.00ij	19.55lm
6.	PK4566	0.332/382 x 0.332/451	48	65.31b-e	5.98e-i	28.71k-n	78.78c-f	21.64c-h
7.	PK4567	0.332/451 x 0.332/382	50	64.31c-f	6.42d-f	29.27h-m	79.75ab	22.35a-e
8.	PK4571	0.332/382 x 0.332/83	45	66.87ab	4.75lm	28.38l-n	77.91f-i	20.96g-k
9.	PK4572	0.332/157 x 0.332/83	43	64.01d-h	4.76lm	31.24d-f	78.55d-f	21.14e-k
10.	PK4588	0.332/360 x 0.332/83	50	66.72ab	5.12kl	28.16mn	78.01fg	21.59c-h
11.	PK4597	0.332/330 x 0.332/83	49	59.46k	7.19a-c	33.36ab	78.84b-f	20.21i-l
12.	PK4602	0.332/360 x 0.332/157	48	65.83bc	4.77lm	29.41h-m	76.97j	20.39h-l
13.	PK4603	0.332/83 x 0.332/190	49	62.62f-i	5.87f-j	31.52c-e	77.97f-h	21.11e-k
14.	PK4612	0.332/360 x 0.332/45	48	65.31b-e	6.08e-i	28.61k-n	79.66a-c	23.57a
15.	PK4615	0.332/190 x 0.332/83	50	63.99d-h	5.30j-l	30.72d-h	78.07fg	21.10e-k
16.	PK4618	0.332/157 x 0.332/382	49	64.67c-e	4.38m	30.95d-g	77.51g-j	19.99j-m
17.	PK4619	0.332/83 x 0.332/45	12	67.71a	4.72lm	27.57n	79.59a-c	22.79a-c
18.	PK4628	0.332/446 x 0.332/83	55	64.77c-e	6.59c-e	28.64k-n	79.61a-c	22.14b-g
19.	PK4634	0.332/190 x 0.332/382	54	63.98d-h	5.50i-k	30.52d-i	78.49d-f	21.01f-k
20.	PK4641	0.332/360 x 0.332/215	50	65.21b-e	5.66h-k	29.13i-m	78.19fg	21.33d-i
21.	PK4642	0.332/215 x 0.332/45	39	63.69d-i	7.32ab	29.00j-n	79.27a-d	23.46ab
22.	PK4654	0.332/451 x 0.332/215	44	65.05ij	7.59a	30.36e-j	79.17a-e	20.67h-l
23.	PK4665	0.332/360 x 0.332/330	44	65.31b-e	5.51i-k	29.19i-m	78.07fg	21.26d-j
24.	PK4669	0.332/330 x 0.332/215	44	62.92f-i	5.59h-k	31.50c-e	77.06h-j	19.86k-m
25.	PK4680	0.332/360 x 0.332/451	47	64.02d-g	6.44d-f	29.54g-m	79.50a-c	22.31a-f
26.	PK4687	0.332/45 x 0.332/83	44	64.17c-f	6.14e-h	29.70g-l	79.94a	23.56a
27.	PK4688	0.332/330 x 0.332/382	54	64.10c-f	6.12e-i	29.78f-l	78.26e-g	20.43h-l
28.	PK4718	0.332/382 x 0.332/45	58	65.41b-d	6.38d-g	28.21mn	79.66a-c	22.55a-d
	Mean			**63.98**	**5.86**	**30.16**	**78.53**	**21.32**
	LSD			1.74	0.62	1.48	0.93	1.33
		DxD selfed progenies						
1.	PK4232	0.332/382 x 0.332/382	40	68.07a	4.77l-o	27.16m	77.00d-j	19.35f-i
2.	PK4244	0.332/214 x 0.332/214	47	65.64bc	5.22j-n	29.15j-l	77.70d-f	19.31f-i
3.	PK4260	0.332/203 x 0.332/203	41	63.36e-h	5.21j-n	31.43e-h	76.66g-l	19.19g-j
4.	PK4289	0.332/19 x 0.332/19	38	58.83n-q	6.80c-f	34.3ab	75.70lm	16.75o-q
5.	PK4291	0.332/370 x 0.332/370	31	63.07f-i	5.48i-l	31.45e-h	75.86k-m	19.39e-i
6.	PK4297	0.332/277 x 0.332/277	41	59.24l-p	6.84c-f	33.92a-c	76.59g-l	17.49l-o
7.	PK4309	0.332/100 x 0.332/100	31	63.08f-i	7.32a-d	29.61i-l	79.34ab	22.08ab
8.	PK4336	0.332/363 x 0.332/363	40	61.13j-l	6.93b-e	31.94e-g	76.96d-j	18.26i-n

TABLE 4. PROGENY MEANS OF 28 DxD INTERCROSSED AND 35 DxD SELFED PROGENIES FOR BUNCH QUALITY COMPONENTS (continued)

No.	Progeny	Pedigree	N	M/F (%)	K/F (%)	S/F (%)	O/DM (%)	O/B (%)
9.	PK4337	0.332/133 x 0.332/133	45	63.97c-f	4.65m-o	31.39e-h	76.12j-l	18.18i-n
10.	PK4341	0.332/224 x 0.332/224	22	64.37c-f	4.82l-o	30.82g-j	76.84f-k	18.35h-n
11.	PK4342	0.332/285 x 0.332/285	42	59.75k-p	4.97k-n	35.29a	73.18o	16.15p-r
12.	PK4343	0.332/275 x 0.332/275	43	60.89j-m	7.60ab	31.51e-g	77.78c-f	19.61d-h
13.	PK4378	0.332/247 x 0.332/247	31	60.00j-o	7.04b-e	32.96b-e	77.15d-i	18.38h-m
14.	PK4385	0.332/2 x 0.332/2	41	60.70j-n	5.60i-k	33.70a-d	77.70d-f	15.21r
15.	PK4386	0.332/329 x 0.332/329	37	58.70o-q	6.60d-g	34.70a	76.53h-l	17.97j-o
16.	PK4395	0.332/330 x 0.332/330	42	61.33i-k	6.33e-h	32.35c-g	76.44h-l	19.02g-j
17.	PK4435	0.332/317 x 0.332/317	34	63.42d-h	5.89g-j	30.70g-k	78.73bc	20.51c-f
18.	PK4440	0.332/413 x 0.332/413	34	61.54h-k	5.76h-j	32.71b-f	76.19i-l	18.83h-k
19.	PK4443	0.332/124 x 0.332/124	44	57.99pq	7.65ab	34.37ab	77.03d-j	17.24m-p
20.	PK4447	0.332/153 x 0.332/153	39	64.77b-f	5.91g-j	29.32j-l	77.68d-f	18.13i-n
21.	PK4448	0.332/47 x 0.332/47	40	64.02c-f	6.55e-g	29.43j-l	75.06mn	17.05n-p
22.	PK4452	0.332/369 x 0.332/369	31	64.49c-f	5.93g-j	29.58i-l	77.38d-h	18.35h-n
23.	PK4487	0.332/222 x 0.332/222	26	60.48j-o	7.57ab	31.95e-g	77.93cd	19.12g-j
24.	PK4497	0.332/144 x 0.332/144	37	61.72g-j	6.19f-i	32.09d-g	77.87c-e	18.70h-l
25.	PK4514	0.332/451 x 0.332/451	17	65.00b-e	6.36e-h	28.64lm	79.75a	21.67a-c
26.	PK4544	0.332/107 x 0.332/107	39	63.06f-i	5.76h-j	31.19f-i	76.88e-j	19.28f-j
27.	PK4554	0.332/83 x 0.332/83	37	65.57bc	4.62no	29.82h-l	77.43d-h	20.69c-e
28.	PK4559	0.332/416 x 0.332/416	35	66.42ab	4.67m-o	28.92l	77.57d-g	20.82b-d
29.	PK4585	0.332/215 x 0.332/215	41	65.31b-d	5.54i-k	29.14j-l	77.12d-j	18.67h-l
30.	PK4587	0.332/114 x 0.332/114	31	65.15b-e	5.35j-m	29.51i-l	77.33d-h	20.23d-g
31.	PK4633	0.332/9 x 0.332/9	28	59.14m-q	7.86a	33.00b-e	76.61g-l	15.70qr
32.	PK4649	0.332/135 x 0.332/135	38	63.28e-h	5.34j-m	31.38e-h	76.50h-l	18.19i-n
33.	PK4676	0.332/394 x 0.332/394	22	60.45j-o	4.22o	35.34a	74.06no	17.55k-o
34.	PK4677	0.332/378 x 0.332/378	41	57.27q	7.59ab	35.14a	77.86c-e	18.43h-m
35.	PK4678	0.332/45 0.332/45	27	63.60d-g	7.33a-c	29.07kl	79.36ab	22.26a
	Mean			**62.31**	**6.10**	**31.60**	**76.92**	**18.58**
	LSD			1.90	0.72	1.69	1.01	1.32
		Parent Mean (0.332)		**62.07**	**6.53**	**31.40**	**77.39**	**19.38**

Note: M/F - Mesocarp to fruit; K/F - Kernel to fruit; S/F - Shell to fruit; O/DM - Oil to dry mesocarp, O/B - Oil to bunch. N – Number of individual palms. Means with the same letter are not significantly different at $p \leq 0.05$ based on Least Significant Difference (LSD).

Yield Performance of Selected DxD Selfed and Their Intercrossed Reciprocal Progenies

Yield performance from three sets of selected selfed and reciprocal intercrossed oil palm Deli Ulu Remis progenies was evaluated in detail (*Table 5*). Mean FFB values for set A indicated that PK4687 (0.332/45 x 0.332/83) with 218.77 kg/p/yr was the best performer, compared to its reciprocal cross and selfed progenies. The high FFB yield was contributed by its BNO (13.91 bunches/p/yr) and ABW (15.68 kg/bunch), which were also the highest among the progenies. For set B, the highest FFB yield was recorded by PK4419 (0.332/451 x 0.332/83) which was significantly higher than the FFB of its selfed progeny PK4514 (selfed 0.332/451). For the third set (C), the intercrossed progeny PK4566 (0.332/382 x 0.332/451) had achieved the best FFB yield, likely contributed by its high ABW, the highest among the progenies in the set. These effects from selfings and intercrossings are in agreement with Fadila *et al*. (2015) who suggested that intercrosses of MPOB Deli *dura*s may broaden the genetic base of Deli *dura* in Malaysia. The highest FFB-producing progeny from each set (*Table 5*) are indeed intercrosses, which were higher yielding than their selfings. The narrow genetic diversity coupled with intensive selection has reduced the variability of yield components of oil palm breeding populations (Maizura *et al*., 2022). Selfing may have led to inbreeding depression among the evaluated traits as can be seen from the inferior FFB yield performance among the selfed progenies. Furthermore, intercrossed Deli *dura* progenies were also more tolerant to *Ganoderma* infection than selfed Deli *dura* progenies in Kluang, Malaysia (Norziha *et al*., 2012). Meanwhile, a lower incidence was reported among Deli x Yangambi crosses than pure Deli *dura* (Durand-Gasselin *et al*., 2005). The introduction of new genetic resources into the *dura* populations is therefore highly recommended. Such efforts could help breeders to strategise crossing schemes to avoid inbreeding and preserve sufficient variability in their effort to produce more resilient progenies against diseases and climate change.

For bunch quality components, the highest M/F (67.71%) reported in set A was from progeny PK4619 (0.332/83 x 0.332/45) (*Table 6*). The progeny had the highest M/F, due to its lowest S/F of less than 28%. Similar findings had been observed by Schmole (1930), whereby Deli *dura* fruit has on average, 62%-63% mesocarp, 30% shell, and 7%-8% kernel. Selfed progeny, PK4554 (0.332/83 x 0.332/83) had reported the highest S/F (29.82%) and the lowest K/F (4.62%), O/DM (77.43%) and O/B (20.69%). Among the set B progenies, the lowest M/F was obtained by intercrossed progeny, PK4515 (0.332/83 x 0.332/451), and also had the lowest O/B (20.38%), and the highest S/F (31.85%). On the other hand, PK4554 (0.332/83 x 0.332/83) was found significantly different from intercrossed progenies (PK4419 and PK4515). The selfed progeny recorded the lowest K/F (4.62%) and O/DM (77.43%). Based on set C, a significant difference was observed between selfed progeny, PK4232 (0.332/382 x 0.332/382) and selfed progeny, PK4514 (0.332/451 x 0.332/451). However, PK4514 was not significantly different from their reciprocal crosses. PK4232 obtained the lowest K/F (4.77%), S/F (27.16%), O/DM (77.0%) and O/B (19.35%). The best O/B was reported in intercrossed progeny, PK 4567 (0.332/451 x 0.332/382) which also had the highest K/F (6.42%), S/F (29.27%) and O/DM (79.75%). The findings from these results could serve as supplementary information for breeders during their crossing designs, assisting in a more precise decision on the selection of parental materials for seed production and inbred line development.

The mean values observed for each bunch quality component within each set were not significantly different from one another. This suggested that selfings and intercrossing do not affect these components. The highest O/B obtained was generally not significantly different from the other selfings or intercrossing in the same set though it was generally exhibited by an intercrossed progeny. Therefore, the reciprocal intercrosses and selfings appear to significantly influence the yield components and not the bunch quality components. Some studies were reported on maternal effects evaluated in oil palm progenies. Rajanaidu and Jalani (1994) mentioned that the kernel to bunch ratio is highly heritable and maternally inherited. Norziha *et al*., 2012 reported that the yield components may have a strong maternal influence on the production of oil palm progenies. The information on the genetic contribution of each parent is important and this type of analysis may serve as a guide for the breeders on the use of a *dura* palm as the male or female parent in intercrossing programmes to obtain higher yields from their progenies.

Identifying good and promising *dura* combinations is one of the measures taken to improve current DxD planting materials. This improvement can only be realised if breeders have the knowledge and access to quality breeding materials. The breeding strategy carried out by MPOB went through more generations of improvement either through selfing of Deli *dura* or intercrossing of Deli *dura* from different sub-populations (Tey *et al*., 2018). Progress was made in using the remaining variability available in Deli populations which resulted in a new *dura* which is now used for seed production. The selected *dura*s may subsequently be progeny tested with *pisifera*s from the advanced breeding population such as AVROS, Yangambi, La Me and Nigeria. The AVROS *pisifera* progenies, for example, produce more BNO which is the most heritable trait and exhibits a high M/F ratio. Besides, a high M/F implied a high O/B. Swaray *et al.* (2020) reported that Deli Ulu Remis × AVROS was the most outstanding progeny, producing mean values above the trial means in all bunch fruit quality components, except in kernel-related components. Deli Ulu Remis was found to be a good associate with AVROS *pisifera* due to its overall performance in bunch quality components.

TABLE 5. MEAN PERFORMANCE FOR SELFED AND INTERCROSSED RECIPROCAL PROGENIES FOR YIELD AND ITS COMPONENTS

Set	No.	Progeny	Pedigree	Type	N	FFB (kg/p/yr)		BNO (bunches/p/yr)		ABW(kg/p/yr)	
						Mean	CV	Mean	CV	Mean	CV
A	1	PK4554	0.332/83 x 0.332/83	self	37	175.67b	25.87	13.48ab	21.34	13.10b	18.70
	2	PK4678	0.332/45 x 0.332/45	self	31	160.25b	28.28	12.56ab	26.67	12.90b	20.64
	3	PK4619	0.332/83 x 0.332/45	intercross	12	160.69b	19.71	11.88b	18.43	13.74b	19.92
	4	PK4687	0.332/45 x 0.332/83	intercross	44	218.77a	23.69	13.91a	18.50	15.68a	12.94
				Mean		**185.66**	**25.18**	**13.25**	**21.49**	**14.03**	**17.07**
				LSD		**26.62**		**1.62**		**1.36**	

Set	No.	Progeny	Pedigree	Type	N	FFB (kg/p/yr)		BNO (bunches/p/yr)		ABW (kg/p/yr)	
						Mean	CV	Mean	CV	Mean	CV
B	1	PK4514	0.332/451 x 0.332/451	self	15	153.34b	20.10	10.37c	14.38	14.87b	16.98
	2	PK4554	0.332/83 x 0.332/83	self	37	175.67ab	25.87	13.48a	21.34	13.10c	18.70
	3	PK4419	0.332/451 x 0.332/83	intercross	53	186.16a	27.16	11.32bc	24.68	16.48a	13.41
	4	PK4515	0.332/83 x 0.332/451	intercross	39	173.81ab	31.21	11.99b	25.56	14.41b	15.23
				Mean		**176.70**	**27.58**	**11.96**	**23.36**	**14.88**	**15.47**
				LSD		**25.32**		**1.45**		**1.20**	

Set	No.	Progeny	Pedigree	Type	N	FFB (kg/p/yr)		BNO (bunches/p/yr)		ABW (kg/p/yr)	
						Mean	CV	Mean	CV	Mean	CV
C	1	PK4232	0.332/382 x 0.332/382	self	48	138.10b	31.38	11.40a	24.72	11.99c	13.76
	2	PK4514	0.332/451 x 0.332/451	self	15	153.34b	20.10	10.37a	14.38	14.87b	16.98
	3	PK4566	0.332/382 x 0.332/451	intercross	48	179.09a	25.75	11.04a	23.53	16.36a	16.82
	4	PK4567	0.332/451 x 0.332/382	intercross	50	156.82b	32.18	10.45a	29.6	15.08b	15.29
				Mean		**160.04**	**28.52**	**10.91**	**25.06**	**14.73**	**16.03**
				LSD		**22.25**		**1.33**		**1.15**	

Note: FFB - Fresh fruit bunch; BNO - Bunch number; ABW - Average bunch weight; N – Number of individual palms. Means with the same letter are not significantly different at $p \leq 0.05$ based on Least Significant Difference (LSD).

TABLE 6. MEAN PERFORMANCE FOR SELFED AND INTERCROSSED RECIPROCAL PROGENIES FOR BUNCH QUALITY COMPONENTS

Set	No.	Progeny	Pedigree	Type	N	M/F (%)		K/F (%)		S/F (%)		O/DM (%)		O/B (%)	
						Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
A	1	PK4554	0.332/83 x 0.332/83	self	34	65.57ab	7.85	4.62c	28.46	29.82a	14.49	77.43b	2.76	20.69b	12.89
	2	PK4678	0.332/45 x 0.332/45	self	27	63.60b	8.64	7.33a	22.26	29.07a	19.21	79.36a	2.38	22.26a	14.59
	3	PK4619	0.332/83 x 0.332/45	intercross	11	67.71a	4.62	4.72c	15.57	27.58a	11.40	79.59a	1.63	22.79a	11.34
	4	PK4687	0.332/45 x 0.332/83	intercross	40	64.17b	4.31	6.14b	18.16	29.70a	8.30	79.94a	1.51	23.56a	7.76
				Mean		**64.80**	**6.73**	**5.82**	**22.17**	**29.38**	**13.75**	**79.01**	**2.17**	**22.30**	**11.47**
				LSD		**2.61**		**0.77**		**2.42**		**1.03**		**1.53**	
Set	**No.**	**Progeny**	**Pedigree**	**Type**	**N**	**M/F (%)**		**K/F (%)**		**S/F (%)**		**O/DM (%)**		**O/B (%)**	
						Mean	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
B	1	PK4514	0.332/451 x 0.332/451	self	15	65.10a	6.26	6.36a	29.01	28.54b	10.68	79.71a	1.58	21.92ab	14.25
	2	PK4554	0.332/83 x 0.332/83	self	34	65.57a	7.85	4.62b	28.46	29.82b	14.89	77.43c	2.76	20.69b	12.89
	3	PK4419	0.332/451 x 0.332/83	intercross	50	63.59ab	5.41	6.41a	18.97	30.00ab	10.22	79.81a	1.93	22.98a	10.32
	4	PK4515	0.332/83 x 0.332/451	intercross	35	62.36b	7.49	5.79a	41.52	31.85a	13.26	78.53b	2.85	20.38b	20.81
				Mean		**63.94**	**6.76**	**5.79**	**29.29**	**30.28**	**12.33**	**78.86**	**2.39**	**21.6**	**14.4**
				LSD		**1.98**		**0.9**		**1.99**		**1.00**		**1.66**	
Set	**No.**	**Progeny**	**Pedigree**	**Type**	**N**	**M/F (%)**		**K/F (%)**		**S/F (%)**		**O/DM (%)**		**O/B (%)**	
						Mean	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
C	1	PK4232	0.332/382 x 0.332/382	self	48	68.07a	7.10	4.77b	44.20	27.16b	15.79	77.00b	3.33	19.35b	17.02
	2	PK4514	0.332/451 x 0.332/451	self	15	65.10b	6.26	6.36a	29.01	28.54ab	10.68	79.71a	1.58	21.92a	14.25
	3	PK4566	0.332/382 x 0.332/451	intercross	48	65.31b	6.55	5.98a	24.57	28.71ab	12.09	78.78a	2.79	21.64a	13.78
	4	PK4567	0.332/451 x 0.332/382	intercross	41	64.31b	6.74	6.42a	23.08	29.27a	11.43	79.75a	2.62	22.35a	12.45
				Mean		**65.84**	**6.75**	**5.78**	**29.66**	**28.39**	**12.91**	**78.59**	**2.83**	**21.18**	**14.36**
				LSD		**2.22**		**0.86**		**1.83**		**1.11**		**1.52**	

Note: M/F - Mesocarp to fruit; K/F - Kernel to fruit; S/F - Shell to fruit; O/DM - Oil to dry mesocarp; O/B - Oil to bunch; N – Number of individual palms. Means with the same letter are not significantly different at $p \leq 0.05$ based on Least Significant Difference (LSD).

CONCLUSION

In this study, intercrossed *dura* progenies were found to produce higher yields compared to selfed progenies. Parental lines of advanced breeding materials are continuously being improved at MPOB, where crossing programmes involving palms with different economic characters, are being routinely conducted. The best materials obtained from the new combinations are further evaluated to develop the next generation of parental lines for commercial seed production which is necessary for the sustainable development of the Malaysian oil palm industry.

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