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Bunch Component Variations of Inbred Progenies in Third Cycle of Limited Breeding Programme of *Dura* Materials Planted in Peninsular Malaysia and Sabah

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A total of 7163 bunches were analysed from progenies with identical genotype derived from the third cycle of limited breeding programme (LBP) of dura *materials from 2016 to 2020 in Bayok Estate of Pamol Sabah and Gomali Estate in Batu Anam, Peninsular Malaysia. The bunch components of the identical* dura *inbred progenies showed significant differences in traits when planted in geographically distant locations. The mean square (variance) analysed through ANOVA between the two locations showed that the bunch components of fruit to bunch, oil to dry mesocarp and wet mesocarp to fruits were statistically significant at probability (p)=<5 per cent to result in a significantly low oil to bunch in Sabah when compared to Peninsular Malaysia. Difference in kernel to fruit percent between the two locations was marginally significant at p=<5 per cent, while shell to fruit percent was marginally significant at p=<0.1 per cent. Although the progenies from Sabah showed heavier fruit weight (in grammes), statistically the difference in weights of the fruit in both locations were not significant. Correlation coefficient matrix analysis indicates that the two major bunch analysis components that affected the low oil to bunch were low fruit to bunch and low oil to dry mesocarp percent which were highly significant at p=<0.1 per cent. The differences in bunch phenotypic components on fruit to bunch ratio could be the result of the seasonal high rainfall in Sabah as compared to Peninsular Malaysia. The high soil water table from Typic Endoaquept soil in Sabah during flood and tidal water could be the reason for low oil in dry mesocarp. The low seasonal fruit to bunch percent is a common annual natural phenomenon in Sabah.*

Keywords*:* *Oil to bunch percent, parthenocarpy, environmental variations, inbred progenies and oil palm breeding.*

Considerable phenotypic variations should be anticipated in the progenies when an open pollinated and broad-based *dura* population is bred for a new generation. However, in Deli *dura* population, the phenotypic variations could have been tapered through continuous selection for many generations from a narrow base population (Hardon & Thomas, 1968). There were several *tenera* (*dura* x *pisifera*) progeny trials conducted to study the genotype and environmental interactions. Rajanaidu *et al*. (1992), Lee and Toh (1992), Chin (1992)

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and Yong and Chan (1992) analysed the genotype and environmental interactions of fresh fruit bunch and the components yield in oil palm progenies of Deli *dura*/Ulu Remis x *pisiferas* of various origins. Rao *et al*. (1992) studied palm progenies for palm density effects on oil palm yields of fresh fruit bunch, average bunch weight, bunch number and bunch components for oil to bunch percent. Rajanaidu *et al*. (1998), presented the variations of oil and kernel in the bunches of *tenera* planting materials of PORIM Nigerian germplasm and Deli *dura* crossed with *pisifera* progenies of six seed producers. Yong and Chan (1998) studied the *tenera* materials developed from URT, URT introgressed with AVROS and URT introgressed with Cameroon *pisiferas* for fresh fruit bunch production, and bunch components in their progeny testing. However, most of the above work was conducted on the variance study of the fresh fruit bunch performances of various *tenera* materials that originated from several *pisiferas* and Deli *duras* or Ulu Remis *duras* under different environments.

IOI Group's entry into oil palm breeding programme was initiated in 1974 through the selection of Ulu Remis planting materials from Oil Palm Genetic Laboratory (OPGL) (Dunlop Research Report, 1974; Rosenquist, 1984; Corley & Tinker, 2003). These were later called Limited Breeding Programme (LBP) materials which were inherited by IOI group following the acquisition of Dunlop and Pamol companies in 1990 and 2003, respectively (Donough & Chia, 2005; Mathews *et al*., 2007). In any oil palm breeding programme, the bunch interrelated components such as fruit to bunch, wet mesocarp to fruit, oil to dry mesocarp, oil to bunch, kernel to fruit and shell to fruit are routinely analysed and quantified in terms of percentage in the *dura* mother palms or in progeny testing to meet the selection criteria of materials for the SIRIM (Standard and Industrial Research Institute of Malaysia) standard (Malaysian standard MS157: 2017). There are environmental variations within Malaysia, especially for the oil palm planted in the belt of Sabah and Sarawak, where the annual rainfall is higher than that of Peninsular Malaysia which may affect the bunch components. The *dura* palms or any progenies derived from the breeding programmes struggle to meet the SIRIM standard under such high rainfall. IOI Group had developed the third cycle of *dura* from the LBP programme and identical progenies derived from the third cycle were planted at geographically distant locations with different environments. One of the locations was in Gomali, Batu Anam in Johore with low to moderately low rainfall and the other was in Bayok Estate, Pamol Sabah, Beluran District, a region with relatively high rainfall. This paper presents the observations on bunch samples collected at the two environments and the variations observed in the components of bunch and how it affects the selection of inbred *dura* mother palms according to the SIRIM standards.

MATERIALS AND METHODS

The lineage of *dura* material derived from limited breeding programme 1 (LBP1) to LBP 3 is given in *Figure 1.* Total progenies of eight crosses were taken for the study.

Palms selected from six inbred lines of LBP2 were used to develop LBP3 material through various mating designs. The LBP3 progenies derived from full-sib mating were IDD62, IDD67, IDD69 and IDD72. IDD63 and IDD71 were derived through half-sib mating. Two crosses, IDD61 and IDD73, were

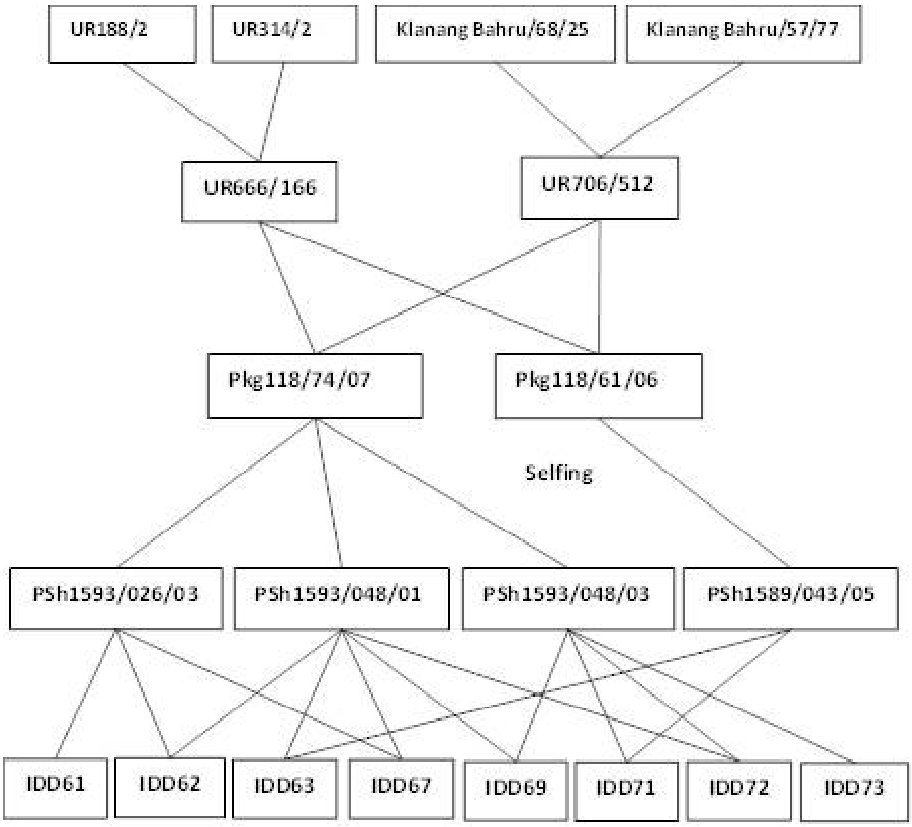

Figure 1 Ancestry of dura *from limited breeding material*

made by selfing of same dura mother palm, and considered as the second generation of aggressive inbred lines. These palms of LBP3 were planted in Gomali Estate, Batu Anam in December 2012, and in Bayok Estate, Pamol Sabah in March 2013. The soil in Gomali Estate is sub recent alluvium of Typic Kandiudox and in Bayok Estate is recent riverine alluvium of Typic Endoaquept and generally the water table is high during wet months. The annual rainfall and rain days of Gomali Estate, Batu Anam and Bayok Estate, Pamol Sabah are given in *Tables 1* and *2*. In both locations, the rainfall and number of rain days varied, Gomali has lower rainfall when compared to Bayok, Pamol Sabah. As given in *Tables 1* and *2*, the mean of 5 years (2016 to 2020) annual rainfall in Gomali Estate, Batu Anam, Johore, was 1 884 mm per year with 125 rain days, whereas in Bayok Estate, Pamol Sabah, the mean rainfall was 2 886 mm in 166 rain days. The rainfall in Sabah could reach over 3 500 mm as measured in 2017, whereas during the same period, rainfall in Peninsular Malaysia was only 2 384 mm. In general, the rainfall in Sabah was exceedingly higher than in Peninsular Malaysia.

The bunches were sampled and the bunch components were measured concurrently in both locations from 2016 to 2020. Bunch analysis was conducted as per the procedure laid out by Mathews *et al*. (2009), except for the extraction of oil where only the fertile fruits

TABLE 1
RAIN DAYS AND RAINFALL IN GOMALI ESTATE, BATU ANAM

Months	*2016*		*2017*		*2018*		*2019*		*2020*		*Mean*	
	Rain days	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*
January	8	33	12	443	19	387	7	87	8	99	11	210
February	7	259	13	174	5	53	2	186	8	74	7	149
March	2	25	12	341	12	89	5	75	4	37	7	113
April	7	63	13	211	8	136	9	175	14	204	10	158
May	10	220	12	210	13	127	9	131	14	260	12	190
June	5	31	12	365	8	111	7	59	14	193	9	152
July	9	197	4	33	10	132	8	111	19	248	10	144
August	7	86	14	165	6	64	8	116	9	126	9	111
September	7	68	9	77	11	161	9	83	12	118	10	101
October	7	75	8	92	19	321	17	230	12	90	13	162
November	18	203	16	128	14	244	13	97	18	284	16	191
December	15	255	10	145	12	89	11	315	12	209	12	203
Total	102	1515	135	2384	137	1914	105	1665	144	1942	125	1884

TABLE 2
RAIN DAYS AND RAINFALL IN BAYOK ESTATE, PAMOL SABAH

Months	*2016*		*2017*		*2018*		*2019*		*2020*		*Mean*	
	Rain days	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*	*Rain days*	*Rainfall (mm)*
January	12	124	18	645	18	442	19	710	20	245	17	433
February	12	230	14	228	9	338	4	44	15	101	11	188
March	6	120	15	334	16	336	5	130	8	52	10	194
April	5	36	12	310	15	139	17	38	8	66	11	118
May	10	161	19	285	10	102	12	161	12	134	13	169
June	12	162	16	262	14	300	16	288	13	97	14	222
July	8	124	15	249	17	160	14	339	15	123	14	199
August	11	274	17	154	13	251	16	195	12	206	14	216
September	13	478	13	457	14	318	8	74	16	243	13	314
October	20	354	12	251	10	235	14	214	24	275	16	266
November	15	145	14	121	15	217	13	289	20	485	15	251
December	15	181	18	265	18	380	20	372	18	379	18	315
Total	139	2 389	183	3 561	169	3 218	158	2 854	181	2 406	166	2 886

from *dura* bunches were sampled. The mesocarp oil was extracted by the Soxhlet method. The total number of bunches analysed for each progeny for both locations are given in *Table 3*. The total number of bunches analysed in Pamol Sabah were 4 628 and in Batu Anam, Peninsular Malaysia were 2 535. The analysis of variance (ANOVA) on the bunch variation due to the environment was analysed according to the Hand Book of Agricultural Statistics (Chandel, 1984). The current study and observations made were not meant to study the genotypic variations for each progeny planted at the two locations, but to study the variations of bunch components between the environmentally different locations, which influence the oil to bunch percent for *dura* palm selection as per the SIRIM standard.

RESULTS

Each component of bunch was subjected to one way ANOVA test as given in *Tables 4* to *11*. The coefficient of correlation and regression matrix of bunch analysis component are shown in *Table 12*.

The fruit to bunch ratio between the two locations is shown in *Table 4*. The general mean of fruit to bunch of 42.7 per cent in eight progenies in Pamol Sabah was significantly low as compared to 55.1 per cent observed in Peninsular Malaysia. Regression of bunch analysis in both locations indicate that fruit bunch percent and oil to bunch percent were positively correlated (+0.9) and highly significant at probability (p) p = < 0.1 per cent as shown in *Table 12*. The fruit to bunch percent is the first and major component in the bunch analysis of the present study that determines oil to bunch percent of identical *dura* progenies planted at two different locations.

The extent of wet mesocarp to fruit percent in both locations is depicted in *Table 5*. The mean of wet mesocarp of 74.0 per cent in the fruits of Sabah was greater than the 70.5 per cent of similar progenies planted in Peninsular Malaysia. Although, the overall mean value of wet mesocarp size of individual progeny in Sabah was larger than that of Peninsular Malaysia, the least significance difference (p=<5%) of IDD61 and IDD69 planted in Sabah was not significant when compared to Peninsular Malaysia. Due to low fruit to bunch, there is a possibility of the bunches in Sabah to have better spacing and hence, allowing the remaining fertile fruits to grow larger in size.

TABLE 3
TOTAL NUMBER OF BUNCHES ANALYSED

Progeny code	*Pamol Sabah*	*Batu Anam*
IDD61	1 204	319
IDD62	662	636
IDD63	760	341
IDD67	558	194
IDD69	445	456
IDD71	125	259
IDD72	738	217
IDD73	136	113
Total	4 628	2 535

TABLE 4

ONE WAY ANOVA OF FRUIT TO BUNCH PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

	Fruit to bunch percent										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	38.8	41.9	49.1	40.8	40.6	46.3	40.3	43.9	42.7	5.5	7.5
Batu Anam	49.5	53.4	60.3	54.1	58.0	56.6	58.2	50.7	55.1		
General mean									48.9		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	616.8	616.8	46.2**	4.6	8.9					
Within progenies (Error) N-n	14	187.0	13.4								
Total	15	803.8									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, **Statistically the variance is highly significant at p=< 5%.

TABLE 5

ONE WAY ANOVA OF WET MESOCARP TO FRUIT PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

	Wet mesocarp to fruit percent										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	73.5	74.8	70.9	73.8	75.8	71.7	76.0	75.2	74.0	3.2	2.9
Batu Anam	71.0	71.3	67.9	71.6	71.2	66.0	71.9	72.8	70.5		
General mean									72.2		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	49.0	49.0	11.1**	4.6	8.9					
Within progenies (Error) N-n	14	61.9	4.4								
Total	15	110.9									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, **Statistically the variance is highly significant at p=< 5%.

TABLE 6
ONE WAY ANOVA OF OIL TO DRY MESOCARP PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

	Oil to dry mesocarp percent										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	72.9	73.2	73.7	74.6	73.4	72.6	75.1	74.5	73.7	1.1	1.0
Batu Anam	77.3	76.9	76.8	77.2	76.6	75.7	76.8	77.2	76.8		
General mean									75.3		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	38.1	38.1	73.1**	4.6	8.9					
Within progenies (Error) N-n	14	7.3	0.5								
Total	15	45.4									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, **Statistically the variance is highly significant at p=< 5%.

TABLE 7
ONE WAY ANOVA OF OIL TO WET MESOCARP PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

	Oil to wet mesocarp percent										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	48.7	49.2	48.6	49.9	47.9	47.8	48.6	47.9	48.6	2.3	3.2
Batu Anam	50.5	48.8	45.8	49.0	45.3	46.1	45.1	46.1	47.1		
General mean									47.8		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	8.8	8.8	3.8 ns	4.6	8.9					
Within progenies (Error) N-n	14	32.7	2.3								
Total	15	41.5									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, ns=Statistically the variance is not significant at p=< 5%.

TABLE 8
ONE WAY ANOVA OF OIL TO BUNCH PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

						Oil to bunch percent					
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	13.6	15.2	16.7	14.7	14.6	15.6	14.7	15.7	15.1	1.3	5.3
Batu Anam	17.4	18.2	18.5	18.8	18.5	17.0	18.7	16.7	18.0		
General mean									16.5		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	33.3	33.3	43.8**	4.6	8.9					
Within progenies (Error) N-n	14	10.7	0.8								
Total	15	44.0									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, **Statistically the variance is highly significant at p=< 5%.

TABLE 9
ONE WAY ANOVA OF KERNEL TO FRUIT PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

						Kernel to fruit percent					
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	3.9	3.5	4.0	3.7	2.9	3.6	2.9	3.2	3.4	0.7	12.9
Batu Anam	4.4	3.9	4.5	4.3	3.7	4.5	3.5	3.1	4.0		
General mean									3.7		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	1.1	1.1	4.8*	4.6	8.8					
Within progenies (Error) N-n	14	3.2	0.2								
Total	15	4.3									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, *Statistically the variance is significant at p=< 0.1%.

TABLE 10
ANOVA OF SHELL TO FRUIT PERCENT BETWEEN SABAH AND PENINSULAR MALAYSIA

	Shell to fruit percent										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	18.8	18.1	21.0	18.9	18.0	20.7	17.8	18.1	18.9	2.2	7.1
Batu Anam	20.1	20.4	22.5	19.7	20.7	24.3	20.1	20.1	21.0		
General mean									20.0		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	17.8	17.8	8.8**	4.6	8.9					
Within progenies (Error) N-n	14	28.4	2.0								
Total	15	46.2									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least significance difference, p=< 5% significance level, CV%= Coefficient of variation, **Statistically the variance is significant at p=< 5% and marginally significant at p=<0.1%

TABLE 11
ANOVA OF MEAN FRUIT WEIGHT IN BUNCH BETWEEN SABAH AND PENINSULAR MALAYSIA

	Fruit weight (g)										
Progeny (N)	IDD61	IDD62	IDD63	IDD67	IDD69	IDD71	IDD72	IDD73	Mean	LSD p=<5 %	CV%
Pamol Sabah	14.1	15.6	13.3	14.8	16.2	14.2	16.0	15.7	15.0	1.4	7.1
Batu Anam	13.6	14.5	12.7	13.6	14.6	13.5	14.6	15.3	14.0		
General mean									14.5		
Sources of variation	Degrees of freedom	Sum of squares	Mean squares (variance)	Variance ratio	F=p= <5%	F=p= <0.1%					
Between locations n-1	1	3.6	3.6	4.0 ns	4.6	8.9					
Within progenies (Error) N-n	14	12.6	0.9								
Total	15	16.2									

Note: F= Fisher's table value p=< 5% significance level, F=Fisher's table value p=< 0.1% significance level, LSD= Least Significance Difference, p=< 5% significance level, CV%= Coefficient of variation, ns=Statistically the variance is not significant at p=<5%

TABLE 12
CORRELATION MATRIX AND REGRESSION ANALYSIS

		x-axis					
	Bunch components	*Oil to bunch %*	*Fruit to bunch %*	*Wet mesocarp to fruit %*	*Oil to dry mesocarp %*	*Kernel to fruit %*	*Shell to fruit %*
	Oil to bunch %		r= 0.9* y=0.2x+5.8	r=-0.6** y=-0.4x+45.5	r=0.8* y=0.8x-43.8	r=0.5 ** y=1.6x+10.5	r=0.6** y=0.6x+5.1
	Fruit to bunch %	r=0.9* y=4.0x-17.8		r=-0.8* y=-2.1x+202.8	r= 0.7** y=0.2x+66.6	r= 0.6** y=7.5x+21.0	r=0.8* y=3.2x-15.9
y-axis	Wet mesocarp to fruit %	r= -0.6** y=-1.0x+88.9	r= -0.8* y=-0.3x+86.6		r= -0.4ns y= -0.7x+124.1	r= -0.8* y= -4.2+87.9	r= -1.0* y= -1.5x+102.5
	Oil to dry mesocarp%	r=0.8* y=0.8x+61.6	r=0.7** y=3.1x+186.9	r= -0.4 ns y= -0.3x+95.7		r=0.4ns y=0.1x+71.2	r=0.4ns y=0.4x+67.6
	Kernel to fruit%	r=0.5** y=0.2x+1.1	r=0.6** y=0.04x+1.7	r=-0.8* y=-0.2x+15.5	r=0.4 ns y=0.1x+4.2		r=0.7** y=2.3x+11.3
	Shell to fruit%	r=0.6** y=0.6x+10.0	r=0.8* y=0.2x+10.8	r=-1.0* y=-0.6x+65.7	r=0.4 ns y=0.4x-9.6	r=0.7** y=0.2x-0.6	

Note: *Highly significant at p=<0.1% significance level, ** Significant at p=< 5% significance level, ns= not significant

This could be substantiated with the negative correlation of -0.8, which was significant between the wet mesocarp and fruit to bunch percent as shown in *Table 12*. This correlation between the wet mesocarp to fruit and fruit to bunch percent was highly significant at p=<0.1 per cent.

The difference between the oil to dry mesocarp percent at Pamol Sabah and Batu Anam is as seen in *Table 6*. The oil analysed in dry mesocarp was significantly low in Pamol Sabah as compared to Batu Anam. All the progenies of *dura* planted in Sabah showed significantly low oil in dry mesocarp. The oil to dry mesocarp was highly significant and positively correlated (+0.8) to oil to bunch percent as given in *Table 12*. The correlation value of +0.8 is highly significant at p=<0.1 per cent. The oil in the dry mesocarp is the second major component that contributed to low oil to bunch. Low oil to dry mesocarp in Sabah could be due to higher rainfall, where the moisture in the fruits could be greater for all progenies planted there. It was interesting to note that the differences of general mean and mean square of oil to wet mesocarp percent of 48.6 per cent in Sabah and 47.1 per cent in Peninsular Malaysia were not significant at all (*Table 7*).

The oil to bunch percent of Pamol Sabah and Batu Anam, where the general mean of oil to bunch of 15.1 per cent in Pamol Sabah was significantly lower than 18.0 per cent in Peninsular Malaysia is indicated in *Table 8*. In the overall study, the major components that affect the oil to bunch percent were fruit to bunch percent followed by oil to dry mesocarp percent as substantiated in *Table 12*, where both components were positively and significantly correlated to the oil to bunch percent. These two components showed a lower value in Sabah as compared to Peninsular Malaysia (*Tables 4* & *6*) resulting in low oil to bunch percent in Sabah.

However, the oil to bunch percent is a multiple combination of traits comprising of fruit to bunch percent, wet mesocarp to fruit percent and oil to dry mesocarp percent. Among these three traits, the degree of magnitude of relationship can be expressed through the correlation study to understand the trait of high importance in the present study. Based on the correlation value, the trait fruit to bunch percent had the highest correlation value of 0.9, followed by oil to dry mesocarp percent of 0.8 and wet mesocarp to fruit percent of -0.6. This again provides the importance of fruit to bunch and oil to dry mesocarp percent to contribute high oil to bunch in *dura* materials for the selection of mother palms.

The ANOVA analysis in Sabah and Peninsular Malaysia, on characteristics of fruits on the bunch such as kernel to fruit percent is shown in *Table 9*, shell to fruit percent in *Table 10* and fruit weight (in grammes) is in *Table 11*. The value of kernel to fruit in Sabah progenies was lower than that in Peninsular Malaysia, the mean squares of Fisher's test was not significant at p=<0.1 per cent, but marginally significant at p=<5 per cent. As for kernel to fruit, the least significance difference (LSD) p=<5 per cent was not significant between the two locations. When the percentage of kernel to fruit is recalculated independently from the fruit weight in terms of absolute weight of kernel in the fruit, then there was no significant difference between the weights of the two regions. The general mean weight of kernel in Pamol Sabah was 0.5 g per kernel as compared to 0.6 g in Peninsular Malaysia and the difference of 0.04 g was not statistically significant. The shell to fruit percent in Pamol Sabah was lower than that of Peninsular Malaysia. The mean sum of squares for shell to fruit was marginally significant under Fisher's test when p=<0.1 per cent but significantly different when p=<5 per cent. The least significant difference of shell to fruit was also significant at p=<5 per cent. When the shell to fruit percent is recalculated in terms of absolute weight (g), the shell in the fruit of Pamol Sabah was about 2.8 g and that of Batu Anam was 3.0 g, the difference of 0.2 g between the locations was not significant. Both kernel to fruit (-0.8) and shell to fruit percent (-1.0) were negatively correlated to wet mesocarp to fruit and significant at p=<0.1 per cent. This means that with an increase in wet mesocarp to fruit percent, a decrease in shell to fruit and kernel to fruit percent can be expected. In general, the wet mesocarp to fruit percent was significantly higher in Pamol Sabah than in Peninsular Malaysia (*Table 5*) and this could be the reason for the lower kernel to fruit and shell to fruit percent in Sabah. The mean fruit weight of the progenies in Sabah was higher than that of Peninsular Malaysia, however the difference between the fruit weights of both locations was not significant.

DISCUSSIONS AND CONCLUSIONS

Rajanaidu *et al*. (1992) studied the impact of genotype and environment (GxE) on *dura* crossed with several *pisiferas* of different origin and concluded that the high yielding fresh fruit bunches of planting materials were sensitive to environmental factors such as rainfall and type of soils. The high yielding planting materials yielded lower than the low yielding materials under unfavourable climatic and soil conditions. Their study was focussed on the fresh fruit bunch, average bunch weight and bunch number. They also reported pooled ANOVA analysis and found differences in performance in progenies at five sites. Lee and Toh (1992) reported that the Deli *dura* x AVROS (BM119) progenies performed somewhat equal to the higher limit of the fresh fruit bunch production in both coastal and inland soils within Peninsular Malaysia with good oil extraction ratio and adaptability. Yong and Chan (1992) studied 24 sites in Peninsular Malaysia with Guthrie Ulu Remis *dura* x URT *pisiferas* and found fresh fruit bunches of 14 tonnes per hectare in Malacca (Typic Hapluodox) soil under less rainfall condition and 31 tonnes fresh fruit bunches per hectare in Durian series (Typic Hapludult) soil under favourable rainfall. The mean square (variance) of ANOVA analysis in their studies was significantly different for fresh fruit bunch, bunch weight and bunch number at p=<0.01 per cent significance level. All these studies were related to variations in fresh fruit bunches of identical/different genotypes in different environments. Chin (1992) studied the D x P and D x T crossed with several *pisiferas* AVROS, NIFOR, Yangambi and La Me and *teneras* derived from these *pisiferas*. In their oil to bunch studies, IRHO x Nigerian and IRHO x Yangambi gave better extraction rates. However, their studies were related to the performance of different types of *pisiferas* at the same location at Sg. Tekam. Rao *et al*. (1992) showed the significant yield variance of palms planted at different densities of 125, 175 and 225 per hectare. They showed high significance on fruit to bunch, kernel to fruit and lower mesocarp to fruit ratio at 225 palms per hectare. The higher fruit to bunch in high densities was due to higher number of male inflorescence and increased pollination. However, the oil to bunch percent among all three densities were not significant. In the present study, the identical progenies were planted at two geographical distant locations, where one location was in Batu Anam, Peninsular Malaysia and the other was in Pamol Sabah. The identical progenies of a common parent, PSh 1593, were either crossed in a full/half sibling or selfing manner. The common grandparent of the parents was Pkg 118 from LBP cycle 1. Among the progenies, IDD62, IDD67, IDD69 and IDD72 were reciprocal sibling crosses. All the progenies were closely related and showed the significant differences in bunch analysis components, when planted at two different environments.

In the present study there was a clear difference in the oil to bunch percent at the young palm age, when identical sets of eight inbred *dura* progenies were planted at two geographically distant locations. The effect of seasonal low fruit to bunch in Pamol Sabah and other parts of Sabah have been reported by Donough *et al*. (1996), Hoong and Donough (1998), Rao and Law (1998). Mathews *et al.* (2000) and Foong *et al.* (2004) observed seasonal poor fruit set in 35 000 hectares of young oil palm *tenera* plantings in Sabah. Similar seasonal low fruit to bunch cases in young mature palms have been reported in West Kalimantan and the improvement in low fruit to bunch percent was seen when the anthesising female flowers were pollinated manually to produce higher fruit to bunch percent in young bunches (Mathews *et al.*, 2016). Mathews (2018) in another study in Central Kalimantan indicated that high rain days of 6 months before harvesting had stronger negative correlation of -0.74 at polynomial sixth degree leading to declination of oil extraction rate (OER) from rain days of more than 15 days in a month. High rain days of more than 15 days were observed in Pamol Sabah from October to January. It can be concluded that seasonal low OER or kernel extraction rate (KER) are dependent on the high rainfall for Borneo Island and may have an influence in the general fruit to bunch percent of a fresh fruit bunch.

Donough *et al*. (1996) indicated that the seasonal decline in OER could be due to the low population of weevils coupled with high sex ratio resulting in low availability of pollen from the male inflorescences. The high rainfall months affect pollen viability resulting in poor pollination 6 months later. Hoong and Donough (1998) showed significant negative correlation between 6 months prior to rainfall and reduction in KER and OER in Sandakan, Lahad Datu and Tawau regions extending from May to August of the year. The bunches collected during that period will definitely show low fruit to bunch and coincidentally it happened during relatively lower rainfall months. Rao and Law (1998) concluded that drastic reduction of pollinating weevils in wet months resulted in poor pollination 5 to 6 months later. The parasitism by nematodes in the wet months could be the reason for the reduction of weevils. They too indicated that the high sex ratio could have resulted in scarcity of pollen. Foong *et al*. (2004) showed that the new generation of weevils emerging from the spikelet was directly related to the preceding parental population that visited the spikelet for laying eggs. It seems that the high day time rainfall 2 weeks prior to emergence of the new population showed a generally low emerging population with a negative correlation of -0.64. Moreover, they too observed that the weevils do not fly from the artificial shelter during rain. It stays in the shelter box till the rain is over. They also observed that under natural conditions during rainfall the weevils tend to stay in the spathe sheaths of the male inflorescences.

The SIRIM standard for inbred *dura* palms of known pedigree to qualify as mother palms for seed production requires mesocarp to fruit

(M/F) 57 per cent, shell to fruit (S/F) 33 per cent, kernel to fruit (K/F) 5 per cent, oil to dry mesocarp (O/DM) 75 per cent and oil to bunch (O/B) 19 per cent. According to SIRIM standard, the fresh fruit bunch yields may be ignored for inbred *dura* in the selection of mother palms. As the current same progenies planted in Batu Anam and Pamol Sabah were the third cycle of LBP material and second generation of inbred lines, the fresh fruit bunches yields in general were ignored in the study. The improvement of a particular character in the bunch fruits e.g. oil bearing mesocarp size to fruit through larger fruits will affect the other bunch component character like kernel to fruit. In the present work, the general mean of wet mesocarp to fruit in the current studied progenies of 72.2 per cent was about 27 per cent higher than the SIRIM standard of 57 per cent in the fruit that weighed 14.5 g. Similarly, the shell to fruit size of 20.0 per cent was 65 per cent lower than the SIRIM standard of 33 per cent. In Sabah, although some palms have oil to bunch percent of 19 and higher, somehow these *dura* palms had to struggle in fulfilling the SIRIM standard on kernel to fruit percent (mean 3.4%) due to larger fruit size and low oil to dry mesocarp percent (mean 73.7%) due to high rainfall or soil high water table. Unlike in Peninsular Malaysia, the Sabah conditions were difficult for *dura* palms to meet the all SIRIM standard completely. The three bunch components mostly affected in the present study in Pamol Sabah are mean oil to dry mesocarp, kernel to fruit and oil to bunch percent, although the fruit to bunch percent is not included in the SIRIM standard. The expression in kernel to fruit in percentage could be the difference in fruit weight and mesocarp to fruit size, both these components were higher in Sabah when compared to Peninsular Malaysia. However, in absolute term of weight in grammes, the kernel in the fruit of both locations were not significant. The type of soil in Sabah may have played a role to have low oil in dry mesocarp. The soil in Bayok is recent alluvium Typic Endoaquept, where the soil water table is generally high as compared to sub recent alluvium soil of Typic Kandiudox in Batu Anam. Bayok fields are generally flooded during high rainfall months in the presence of tidal water and probably the soil moisture could have played a role for low oil in dry mesocarp in Pamol Sabah. The present study confirms there is a low oil content in the dry mesocarp of the same genotype planted in Pamol Sabah. SIRIM perhaps could look into the possibility of including oil in wet mesocarp as an alternate option of the standard for high rainfall and water table soils. The oil in wet mesocarp in both locations studied were not significant (*Table 8*). The correlation between oil to dry mesocarp and wet mesocarp (in a separate analysis) showed only -0.3 and was not significant. If oil to wet mesocarp percent is included instead of oil to dry mesocarp percent, the oil to bunch percent of the bunch will not be changed. Evidences indicate that when the standard for selection is considered, there is a need to take into account the nation's variation in environment, where the *dura*, *pisifera* and *tenera* are planted. The wet seasons with high water table in soil can play a role in reducing oil to bunch percent in Sabah, especially through low fruit to bunch percent and low oil to dry mesocarp percent by natural reasons.

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