EVALUATION OF BUNCH INDEX IN MPOB OIL PALM (*Elaeis guineensis* Jacq.) GERMPLASM COLLECTION

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ABSTRACT

Eleven oil palm (Elaeis guineensis *Jacq.*) *germplasm collections from Nigeria, Cameroon, Zaire (now known as the Democratic Republic of the Congo), Tanzania, Madagascar, Angola, Senegal, Gambia, Sierra Leone, Guinea and Ghana were evaluated at the Malaysian Palm Oil Board (MPOB) for bunch index (BI),* i.e. *the ratio of bunch dry matter to total dry matter production. Besides fresh fruit bunch (FFB), yield estimation of BI requires the measurement of trunk height, trunk diameter, rate of frond production and petiole cross-section. Four consecutive years of FFB yield was used to calculate BI. The Tanzanian germplasm showed the highest BI and was significantly different from other germplasm for both* dura *(BI = 0.53) and* teneras *(BI = 0.54) accessions. High variation for BI among* duras *was noted in the Madagascar germplasm (CV = 70.69%), while among* teneras *high variation was observed in Guinea germplasm (CV = 43.34%). Broad-sense heritability estimate of BI for Sierra Leone was highest for* dura *(h^2B = 75.27%) while that of Zaire was highest for* tenera *(h^2B = 66.17%). Phenotypic correlations were high and positive between BI and FFB yield components. Therefore, increasing BI is likely to increase FFB yield. High BI palms (more than 0.6) would be introgressed into advanced breeding populations to generate high yielding planting materials. Additionally,* tenera *palms with high BI may also be multiplied by cloning.*

Keywords: oil palm, bunch index, germplasm, heritability.

Date received: 4 May 2016; **Sent for revision:** 8 June 2016; **Received in final form:** 4 September 2016; **Accepted:** 6 September 2016.

INTRODUCTION

Among cultivated oil crops, African oil palm has the highest productivity and adequate to fulfill the increasing global demand for vegetable oils which may reach 240 million tonnes by the year 2050 (Barcelos *et al.*, 2015). Malaysia supplied 42% of the global palm oil trade in 2014 (PMD, 2014). In 2015, the Malaysian palm oil industry produced crude palm oil (CPO) of 19.96 million tonnes, average fresh fruit bunch (FFB) yield of 18.48 t ha^{-1} with average oil extraction rate (OER) of 20.46% (MPOB, 2015). Improved planting materials could be a better option to meet worldwide demand for palm oil without increasing the sizes of plantations (Youmbi *et al.*, 2015). The improved planting material in Malaysia is targeted to increase yield per unit land area and in achieving the national Vision of 35:25 (FFB yield of 35 t ha^{-1} yr^{-1} and OER of 25%) by 2020 (Kushairi *et al.*, 2010).

Donald (1962) described harvest index as the proportion of total dry matter in the harvested product. Increased yield of rice, barley and wheat is attributed to the increased harvest index values of more than 50% for these cereals (Fageria *et al.*, 2006). In oil palm, harvest index is the product of bunch index (BI), *i.e.* bunch yield as a proportion of total dry matter production and oil to bunch ratio. Some

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studies reported that one of the ways to increase the oil production is by increasing the BI (Hardon *et al*., 1972; Breure and Corley, 1983). Corley *et al*. (1971) stated that it is important to consider BI and vegetative dry matter (VDM) production in breeding experiment as they are highly heritable characters in which they can be inherited from parent to offspring.

The Malaysian Palm Oil Board (MPOB) has the largest collection of oil palm germplasm in the world (Rajanaidu *et al*., 2011). Collections of *E. guineensis* germplasm were carried out in Africa since 1973 from 11 countries namely, Nigeria, Cameroon, Zaire (now known as the Democratic Republic of the Congo), Tanzania, Madagascar, Angola, Senegal, Gambia, Sierra Leone, Guinea and Ghana. The germplasm collection is essential to broaden the genetic base of current oil palm breeding material as well as to conserve a wide range of oil palm genetic resources for posterity (Rajanaidu, 1994). In this study, BI of all collections of *E. guineensis* germplasm were evaluated to facilitate future selection programmes for development of new planting materials in raising oil yield in plantations.

MATERIALS AND METHODS

The oil palm genetic materials collected in Africa were planted from 1976 to 2000 in the form of 'open-pollinated' families as trials at the MPOB Kluang Research Station, Johor, Malaysia (*Table 1*). Both the *dura* and *tenera* fruit forms in this evaluation were evaluated from trials involving eight germplasm collections, namely, Nigeria (Trial 0.150), Cameroon (Trial 0.218), Zaire (Trial 0.226), Tanzania (Trial 0.256), Angola (Trial 0.311), Sierra Leone (Trial 0.355), Guinea (0.353) and Ghana (Trial 0.397). However, only *dura* palms were evaluated from Madagascar (Trial 0.240), Senegal (Trial 0.352) and Gambia (Trial 0.398) germplasms.

Bunch yield was recorded over four years in Trial 0.150 (1982 – 1985), Trial 0.218 (1992 – 1995), Trial 0.226 (1992 – 1995), Trial 0.240 (1995 – 1998), Trial 0.256 (1997 – 2000), Trial 0.311 (2000 – 2003), Trial 0.352 (2002 – 2005), Trial 0.353 (2002 – 2005), Trial 0.355 (2001 – 2004), Trial 0.397 (2006 – 2009) and Trial 0.398 (2005 – 2008) by recording the bunch weight (BWT) and bunch number (BNO) on individual palm basis. FFB was the sum of BWT while BNO was the total bunch count. Average bunch weight (ABW) was the quotient between FFB and BNO. The yield record was summarised within a 12-month period, between January and December for each year. One complete round of vegetative measurements using the non-destructive method (Corley and Breure, 1981) was carried out eight years after field planting.

BI is derived from the ratio of bunch dry matter (BDM) to total dry matter (TDM) production. The estimation requires the measurement of trunk height, trunk diameter, rate of frond production and petiole cross-section from vegetative measurements, as well as FFB from the yield recording activity (average of four consecutive recording years). Root system was excluded in calculating BI as root growth may not show the same consistency as above-ground vegetative growth. There are large variations in measured root biomass between different soils and environments (Corley and Tinker, 2016). Calculation of BI as well as formulas for vegetative characters and physiological parameters are shown in *Appendix 1*.

BI values from each trial were analysed using analysis of variance (ANOVA), while comparison between means was by Fisher's Least Significant Difference (LSD) at 5% level of probability. Broad-sense heritability (h^2B) of BI for each germplasm was estimated using variance components method, while the relationship between BI and other traits was determined by the simple correlation method.

TABLE 1. GERMPLASM EVALUATED FOR BUNCH INDEX AT MPOB KLUANG RESEARCH STATION, JOHOR, MALAYSIA

No.	Germplasm	Trial No.	Date planted	Statistical design	No. of replications	No. of accessions
1.	Nigeria	0.150	April 1976	6 cubic lattice	3	146
2.	Cameroon	0.218	Nov. 1986	RCBD	2	91
3.	Zaire	0.226	Jan. 1987	RCBD	3	56
4.	Tanzania	0.256	Aug. 1990	RCBD	4	51
5.	Madagascar	0.240	July 1990	CRD	1	11
6.	Angola	0.311	April 1994	RCBD	3	30
7.	Senegal	0.352	June 1996	ICRD	2	38
8.	Gambia	0.398	May 2000	Progeny row	1	31
9.	Sierra Leone	0.355	June 1996	RCBD	2	30
10.	Guinea	0.353	June 1996	RCBD	2	21
11.	Ghana	0.397	April 2000	RCBD	4	50

Note: RCBD - randomised complete block design, CRD - completely randomised design, ICRD - improperly complete randomised design.

RESULTS AND DISCUSSION

ANOVA

Tables 2 and *3* show mean squares and variance components for BI of the *dura* and *tenera*, respectively. As for *dura*, the ANOVA showed highly significant differences between families in all germplasm except Madagascar. The broad-sense heritabilities for BI of *dura* ranged from 9.26% (Tanzania) to 75.27% (Sierra Leone).

As for *tenera*, there were highly significant differences for BI between families in all collections except Angola, Sierra Leone and Guinea. The heritabilities for BI of *tenera*s were low to moderate, with the highest estimate recorded in Zaire germplasm (66.17%).

High heritability estimates for BI of *dura* from Sierra Leone and *tenera* from Zaire were due to high variation between families from these germplasms. Therefore, it will be advantageous to select high BI materials among *dura* in Sierra Leone and *tenera* in Zaire germplasm. Conversely, Tanzania which had low heritability estimates for both *dura* and *tenera* forms were due to low variation between families.

Germplasm Performance

The frequency distribution of BI for *dura* is shown in *Figure 1*. Most of the germplasm had negatively skewed distributions with varying mean values. The distribution of *dura* from Tanzania germplasm showed tendency towards high BI with the majority or 44% between 0.55 and 0.60. The Tanzania germplasm also recorded the highest BI for *dura* with a mean value of 0.53, indicating that palms from Tanzania were more efficient in converting bulk of TDM to BDM (*Table 4*). High BI breeding population or PS7 comprising six *dura* and six *tenera* palms with BI of more than 0.6 had been selected from Tanzania and Nigeria germplasm (Junaidah *et al*., 2004).

In this article, only 17 *dura* palms from Madagascar germplasm were evaluated for BI. The lowest BI of 0.08 was recorded in *dura* from Madagascar and is attributed to the poor FFB yields in the range of 0.63 to 39.00 kg palm^{-1} yr^{-1}. Madagascar germplasm also had the highest coefficient of variation (CV) of 70.69% for BI among *dura* whilst the lowest was for Angola at 16.04%.

Figure 2 illustrates the frequency distribution of BI for *tenera*. Tanzania germplasm had high BI with most individuals of the Tanzania germplasm recording values between 0.55 and 0.60. The mean BI of the Tanzania germplasm was significantly higher than other germplasm collections (*Table 5*). The lowest BI was recorded in *tenera* from Ghana germplasm with a mean of 0.38 and similar low

TABLE 2. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR BUNCH INDEX OF *DURA*

Source	df	NGA	df	CMR	df	ZAR	df	TZA	df	MDG	df	AGO	df	SEN	df	GAM	df	SLE	df	GUI	df	GHA
Family	145	0.0390**	90	0.0275**	55	0.0344**	50	0.0288**	10	0.0041ns	29	0.0322**	37	0.0343**	30	0.0184**	29	0.0691**	20	0.0244**	49	0.1476**
Within family	2 435	0.0049	1 269	0.0073	589	0.0065	1 999	0.0103	6	0.0025	713	0.0047	317	0.0077	166	0.0066	517	0.0058	365	0.0118	2 416	0.0096
σ^2_f	-	0.0019	-	0.0014	-	0.0024	-	0.0005	-	-	-	0.0011	-	0.0029	-	0.0019	-	0.0035	-	0.0007	-	0.0028
σ^2_w	-	0.0049	-	0.0073	-	0.0065	-	0.0103	-	-	-	0.0047	-	0.0077	-	0.0066	-	0.0058	-	0.0118	-	0.0096
Total	-	0.0068	-	0.0087	-	0.0089	-	0.0108	-	-	-	0.0058	-	0.0106	-	0.0085	-	0.0093	-	0.0125	-	0.0124
Heritability (h^2B)	-	55.88%	-	32.18%	-	53.93%	-	9.26%	-	-	-	37.93%	-	54.72%	-	44.71%	-	75.27%	-	11.20%	-	45.16%

Note: ** Significant at P≤0.01, PubMed otherwise non-significant.
NGA - Nigeria, CMR - Cameroon, ZAR - Zaire, TZA - Tanzania, MDG - Madagascar, AGO - Angola, SEN - Senegal, GAM - Gambia, SLE - Sierra Leone, GUI - Guinea, GHA - Ghana.

TABLE 3. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR BUNCH INDEX OF *TENERA*

Source	df	NGA	df	CMR	df	ZAR	df	TZA	df	AGO	df	SLE	df	GUI	df	GHA
Family	145	0.0344**	57	0.0124**	18	0.0233**	50	0.0170**	24	0.0072ns	10	0.0108ns	10	0.0313ns	33	0.0253**
Within family	1 952	0.0052	268	0.0066	49	0.0089	514	0.0088	160	0.0056	15	0.0091	9	0.0228	109	0.0093
σ^2_f	-	0.0020	-	0.0010	-	0.0044	-	0.0008	-	-	-	-	-	-	-	0.0039
σ^2_w	-	0.0052	-	0.0066	-	0.0089	-	0.0088	-	-	-	-	-	-	-	0.0093
Total	-	0.0072	-	0.0076	-	0.0133	-	0.0096	-	-	-	-	-	-	-	0.0132
Heritability (h^2B)	-	55.56%	-	26.32%	-	66.17%	-	16.67%	-	-	-	-	-	-	-	59.09%

Note: ** Significant at P≤0.01, PubMed otherwise non-significant.
NGA - Nigeria, CMR - Cameroon, ZAR - Zaire, TZA - Tanzania, AGO - Angola, SLE - Sierra Leone, GUI - Guinea, GHA - Ghana.

TABLE 4. BUNCH INDEX OF *DURA* IN MPOB GERMPLASM COLLECTIONS

No.	Germplasm	Bunch index (BI)					Bunch yield components		
		N	Mean	Minimum	Maximum	Coeff. of variation (CV)	Fresh fruit bunch (kg palm^{-1} yr^{-1})	Bunch number (No. palm^{-1} yr^{-1})	Average bunch weight (kg palm^{-1} yr^{-1}
1.	Nigeria	2 581	0.47^{b}	0.01	0.74	17.59	156.01	14.92	10.97
2.	Cameroon	1 360	0.48^{b}	0.01	0.72	19.37	111.34	13.60	8.51
3.	Zaire	645	0.43^{c}	0.08	0.63	21.84	112.58	12.67	9.28
4.	Tanzania	2 050	**0.53^{a}**	0.03	0.74	19.71	135.80	12.26	11.36
5.	Madagascar	17	**0.08^{h}**	0.01	0.22	70.69	16.94	7.52	2.19
6.	Angola	743	0.476^{Bb}	0.09	0.67	16.04	185.46	11.83	16.56
7.	Senegal	355	0.39^{e}	0.07	0.60	26.12	98.63	20.08	4.91
8.	Gambia	197	0.34^{g}	0.01	0.49	27.05	76.06	21.22	3.61
9.	Sierra Leone	547	0.40^{de}	0.11	0.61	23.83	109.56	19.16	5.81
10.	Guinea	386	0.42^{cd}	0.01	0.71	26.36	115.99	15.64	7.70
11.	Ghana	2 466	0.36^{f}	0.01	0.61	30.60	95.68	11.70	8.57
	Mean	11 347	0.46	0.01	0.74	25.56	-	-	-
	LSD	0.02	-	-	-	-	-	-	-

Note: Means with the same letter are not significantly different at p≤0.05 based on Least Significant Difference (LSD). Figures in bold within the mean column are minimum and maximum values.

TABLE 5. BUNCH INDEX OF *TENERA* IN MPOB GERMPLASM COLLECTIONS

No.	Germplasm	Bunch index (BI)					Bunch yield components		
		N	Mean	Minimum	Maximum	Coeff. of variation (CV)	Fresh fruit bunch (kg palm^{-1} yr^{-1})	Bunch number (No. palm^{-1} yr^{-1})	Average bunch weight (kg palm^{-1} yr^{-1})
1.	Nigeria	2 098	0.48^{b}	0.01	0.71	17.58	166.40	16.96	10.19
2.	Cameroon	326	0.50^{b}	0.23	0.73	17.40	125.38	14.75	8.98
3.	Zaire	68	0.40^{c}	0.12	0.60	27.91	115.38	11.11	10.68
4.	Tanzania	565	**0.54^{a}**	0.04	0.74	18.14	143.60	11.82	12.59
5.	Angola	185	0.48^{b}	0.06	0.63	15.86	193.09	15.08	13.27
6.	Sierra Leone	26	0.49^{b}	0.31	0.64	20.00	193.16	18.17	11.01
7.	Guinea	20	0.38^{c}	0.02	0.64	43.34	110.23	16.15	6.93
8.	Ghana	143	**0.38^{c}**	0.04	0.57	30.02	106.65	10.94	10.46
	Mean	3 431	0.49	0.01	0.74	19.63	-	-	-
	LSD	0.03	-	-	-	-	-	-	-

Note: Means with the same letter are not significantly different at p≤0.05 based on Least Significant Difference (LSD). Figures in bold within the mean column are the minimum and maximum values.

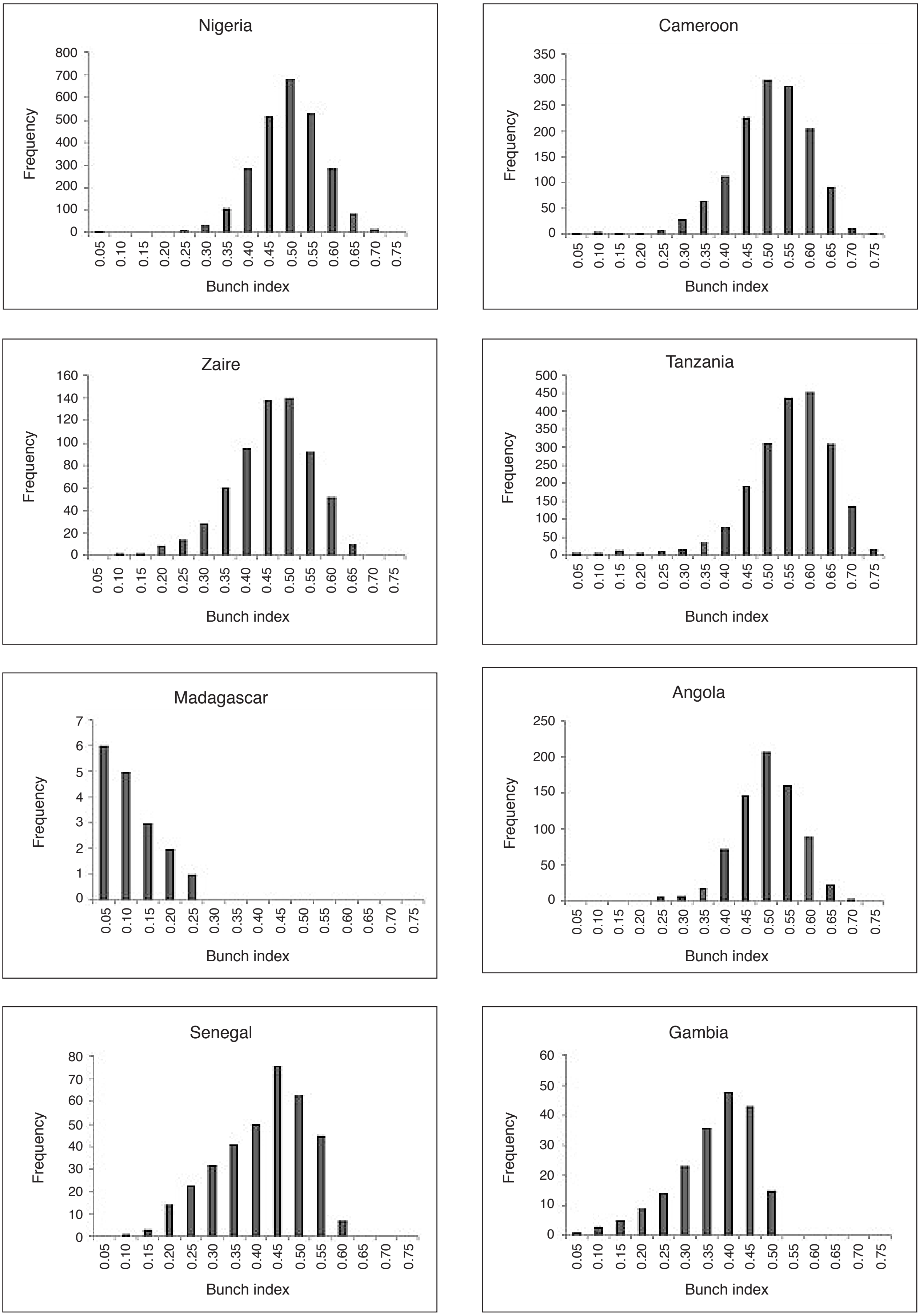

Figure 1. Frequency distribution of bunch index among dura *in MPOB germplasm collections.*

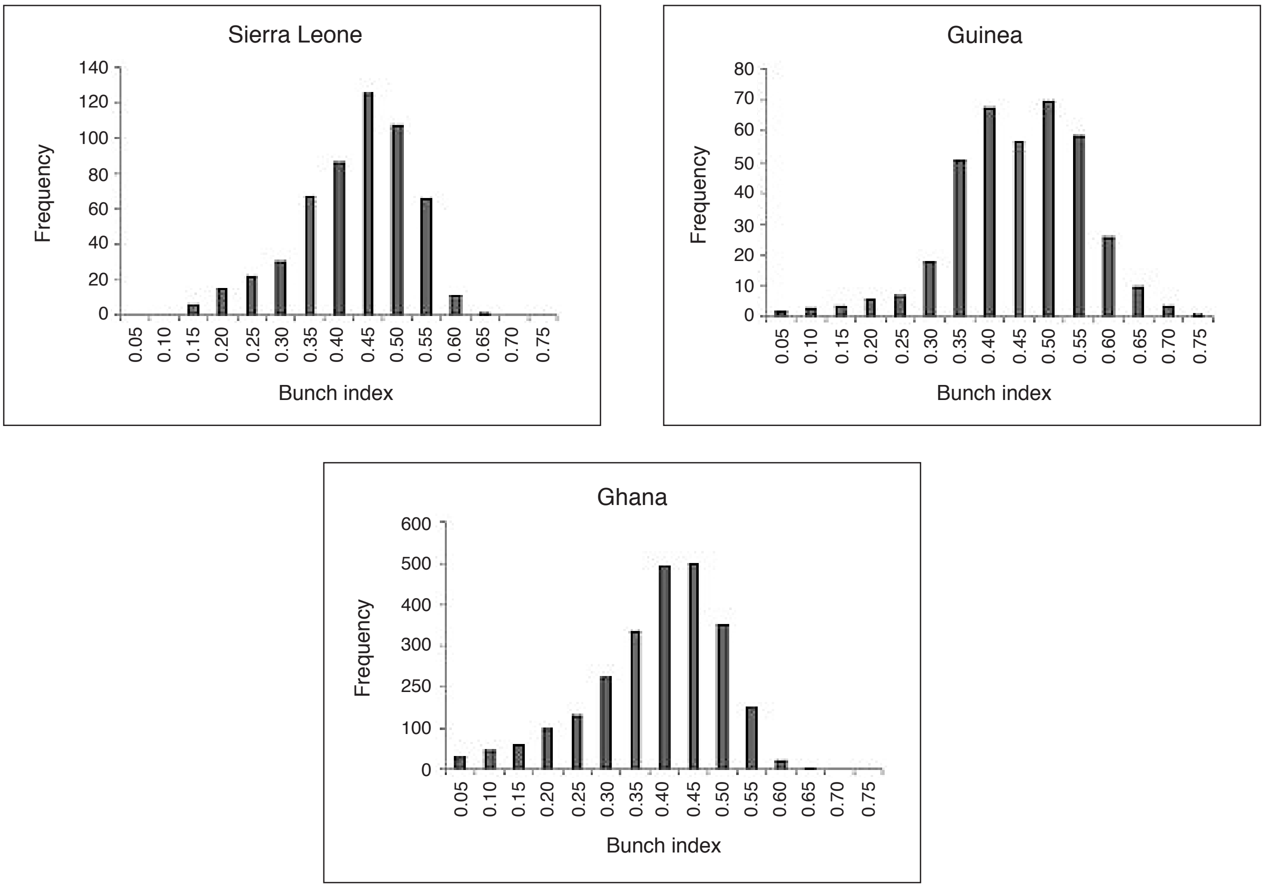

Figure 1. Frequency distribution of bunch index among dura *in MPOB germplasm collections (continued).*

values were obtained with Guinea and Zaire germplasm *tenera*s. The highest variation of BI for *tenera* was in Guinea germplasm with CV value of 43.34% while Angola showed lower variation for BI values (CV = 15.86%) compared with other germplasm collections.

Correlations

Simple correlation coefficients between BI and some selected traits, namely, bunch yield, vegetative characters and physiological parameters for *dura* and *tenera* are given in *Tables 6* and *7*. In general, correlation between BI and these traits showed the same trend in both *dura* and *tenera*. BI correlated positively and significantly with FFB and BNO. This is expected, as the FFB is required in the estimation of BDM where BDM is the numerator and denominator of the equation of BI. There were positive relationships between BI and ABW in majority of the germplasm. However, the magnitudes of the correlation were low. The results were comparable with the correlation analysis by Junaidah *et al*. (2004), in which BI was highly correlated to FFB production, BNO and oil yield (OY).

Rajanaidu *et al*. (2011) stated that yield might be increased by selection of palms with low vegetative growth such as short height, low trunk and lower leaf production whereby greater proportion of the dry matter photosynthesised become incorporated in fruit bunches. However, in this study, there was low to medium negative correlation between BI and frond production (FP), petiole cross-section (PCS), palm height (HT), leaf dry weight (LDW), trunk dry weight (TDW) and frond dry weight (FDW). It was also noted that there were no significant correlation between BI of most germplasms to trunk diameter (DIA).

Meanwhile, correlation between BI to TDM were positive (low to medium) among the germplasm. Planting material with high TDM or biomass is now a great demand due to the recent greenhouse gas (GHG) emission and global warming concerns (Rajanaidu *et al*., 2011). Palms with high TDM have capability to absorb large amount of CO_2 and this indicate possibility of a role of high BI palms in the reduction of GHG emissions.

BI in Senegal, Gambia, Sierra Leone, Guinea and Ghana collections show high positive correlation to VDM. According to Corley *et al*. (1971) and Kushairi *et al*. (1999), it would be important to consider VDM in selection as it has been shown that selection for yield alone without considering vegetative growth is likely to favour tall, vigorous and competitive palms. Contrastingly, there was high and positive

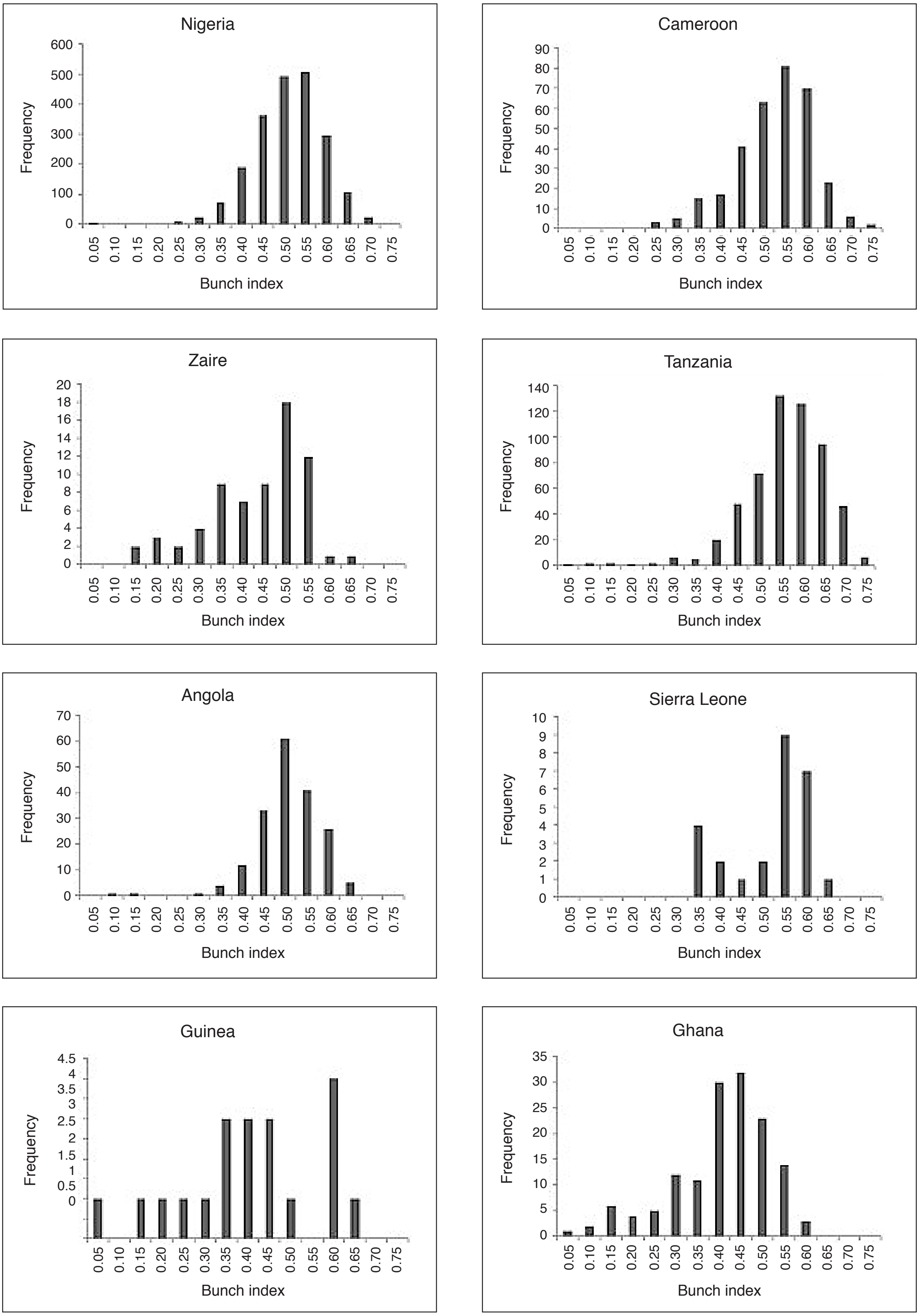

Figure 2. Frequency distribution of bunch index among tenera *in MPOB germplasm collections.*

TABLE 6. PHENOTYPIC CORRELATION OF BUNCH INDEX (BI) TO BUNCH YIELD, VEGETATIVE CHARACTERS AND PHYSIOLOGICAL PARAMETERS OF *DURA*

	FFB	BNO	ABW	FP	PCS	HT	DIA	LDW	TDW	FDW	VDM	BDM	TDM
BI-NGA	0.58**	0.59**	-0.19**	-0.42**	-0.45**	-0.40**	-0.31**	-0.45**	-0.46**	-0.63**	-0.68**	0.58**	-0.19**
BI-CMR	0.72**	0.71**	-0.01ns	-0.22**	-0.31**	0.06*	-0.09**	-0.03ns	-0.31**	-0.39**	-0.39**	0.72**	0.21**
BI-ZAR	0.76**	0.77**	-0.18**	-0.13**	-0.39**	-0.05ns	-0.32**	-0.39**	-0.24**	-0.45**	-0.45**	0.76**	0.18**
BI-TZA	0.73**	0.70**	0.09**	-0.24**	-0.22**	0.05*	-0.02ns	-0.22**	0.02ns	-0.30**	-0.27**	0.73**	0.39**
BI-MDG	0.98**	0.95**	0.43ns	-0.09ns	0.10ns	-0.16ns	0.42ns	0.11ns	0.10ns	0.05ns	0.07ns	0.98**	0.44ns
BI-AGO	0.58**	0.58**	-0.06ns	-0.32**	-0.43**	-0.35**	-0.21**	-0.43**	-0.38**	0.58**	0.58**	-0.59**	-0.08*
BI-SEN	0.84**	0.76**	0.43**	-0.08ns	-0.36**	-0.25**	-0.28**	-0.36**	-0.38**	-0.38**	0.84**	-0.44**	0.28**
BI-GAM	0.85**	0.81**	0.23**	-0.29**	-0.29**	-0.26**	-0.28**	-0.29**	-0.38**	-0.36**	0.85**	-0.43**	0.16*
BI-SLE	0.78**	0.61**	0.41**	-0.39**	0.05ns	-0.20**	-0.28**	0.05ns	-0.32**	-0.09*	0.78**	-0.20**	0.36**
BI-GUI	0.85**	0.57**	0.46**	-0.17**	-0.35**	-0.25**	-0.15**	-0.35**	-0.29**	0.43**	0.85**	-0.44**	0.40**
BI-GHA	0.85**	0.78**	0.09**	-0.18**	-0.16**	-0.09**	-0.33**	-0.16**	-0.27**	-0.27**	0.85**	-0.31**	0.38**

Note: *, ** Significant at P≤0.05 PubMed and P≤0.01 PubMed, respectively. Otherwise, non-significant.
FFB - fresh fruit bunch, BNO - bunch number, ABW - average bunch weight, FP - frond production, PCS - petiole cross-section, HT - palm height, DIA - trunk diameter, LDW - leaf dry weight, TDW - trunk dry weight, FDW - frond dry weight, VDM - vegetative dry matter, BDM - bunch dry matter, TDM - total dry matter.

TABLE 7. PHENOTYPIC CORRELATION OF BUNCH INDEX (BI) TO BUNCH YIELD, VEGETATIVE CHARACTERS AND PHYSIOLOGICAL PARAMETERS OF *TENERA*

	FFB	BNO	ABW	FP	PCS	HT	DIA	LDW	TDW	FDW	VDM	BDM	TDM
BI-NGA	0.61**	0.56**	-0.07**	-0.44**	-0.45**	-0.38**	-0.27**	-0.45**	-0.42**	-0.64**	-0.67**	0.61**	-0.15**
BI-CMR	0.69**	0.68**	-0.11*	-0.32**	-0.34**	0.01ns	0.00ns	-0.02ns	-0.34**	-0.52**	-0.52**	0.69**	0.14**
BI-ZAR	0.82**	0.82**	0.06ns	-0.22ns	-0.08ns	-0.23ns	-0.40**	-0.08ns	-0.38**	-0.24ns	-0.29*	0.82**	0.37**
BI-TZA	0.72**	0.65**	0.11**	-0.32**	-0.13**	0.08ns	0.03ns	-0.13**	0.06ns	-0.28**	-0.24**	0.72**	0.40**
BI-AGO	0.64**	0.60**	0.05ns	-0.19**	-0.30**	-0.23**	-0.16*	-0.30**	-0.26**	-0.43**	0.64**	-0.44*	0.11ns
BI-SLE	0.78**	0.37ns	0.49*	0.09ns	-0.37ns	0.27ns	-0.35ns	-0.37ns	-0.05ns	-0.32ns	0.78**	-0.26ns	0.43*
BI-GUI	0.91**	0.78**	0.39ns	-0.36ns	-0.57**	-0.46*	-0.33ns	-0.57**	-0.48*	-0.65**	0.91**	-0.67**	0.27ns
BI-GHA	0.82**	0.73**	0.05ns	-0.04ns	-0.34**	-0.23**	-0.16ns	-0.34**	-0.30**	-0.38**	0.82**	-0.40**	0.29**

Note: *, ** Significant at P≤0.05 PubMed and P≤0.01 PubMed, respectively. Otherwise, non-significant.
FFB - fresh fruit bunch, BNO - bunch number, ABW - average bunch weight, FP - frond production, PCS - petiole cross-section, HT - palm height, DIA - trunk diameter, LDW - leaf dry weight, TDW - trunk dry weight, FDW - frond dry weight, VDM - vegetative dry matter, BDM - bunch dry matter, TDM - total dry matter.

correlation between BI and BDM in Cameroon, Zaire, Tanzania and Madagascar germplasm.

CONCLUSION

The results have facilitated further screening and selection of palms with high BI (more than 0.6). Besides Tanzania, three other germplasms, namely, Cameroon, Nigeria and Angola are potentially with high BI. Amongst them, Nigerian germplasm is more promising based on heritability estimates for BI and correlation studies. Future efforts would be to introgress the high BI palms (more than 0.6) into advanced breeding populations to generate value-added planting materials. Additionally, *tenera* palms with high BI may also be multiplied by cloning where the palms can be selected based on the Malaysian Standard for ortet selection (MS 2099:2008).

BI is an important trait to consider for selection of materials towards increasing yields. It is recommended that progeny testing and evaluation of genotype-environment (G x E) interactions should be obtained before the germplasm can be used commercially.

ACKNOWLEDGEMENT

The authors would like to thank the Director-General of MPOB for permission to publish this article.

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Appendix 1

CALCULATION OF BUNCH INDEX (BI)

BI	- bunch index	= BDM/(BDM + VDM)
BDM	- bunch dry matter (kg palm^{-1} yr^{-1})	= 0.53 × FFB
VDM	- vegetative dry matter (kg palm^{-1} yr^{-1})	= FDW + TDW
FDW	- frond dry weight (kg)	= FP × LDW
TDW	- trunk dry weight (kg)	= 3.142 ×(DIA/2)^2 × (HT/trial age) × 1000 × 0.17
FP	- frond production (No. palm^{-1} yr^{-1})	= Number of fronds produced in one year
LDW	- leaf dry weight (kg)	= (0.1023 × PCS) + 0.2062
DIA	- trunk diameter (m)	= Diameter of trunk at 1 m from ground
HT	- trunk height (m)	= Height from ground level to base of frond 41
PCS	- petiole cross-section (cm^2)	= Petiole depth x petiole width
TDM	- total dry matter (kg palm^{-1} yr^{-1})	= VDM + BDM

Note:
FFB - fresh fruit bunch (kg palm^{-1} yr^{-1}).