MPOB OIL PALM (*Elaeis guineensis* Jacq.)
GERMPLASMS LINKED TO COMPACT TRAIT
FOR HIGH DENSITY PLANTING

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**ABSTRACT**

The compact trait in oil palm was evaluated amongst the 11 germplasms collected from Nigeria, Cameroon, Zaire (now known as the Democratic Republic of Congo), Tanzania, Madagascar, Angola, Senegal, Gambia, Sierra Leone, Guinea and Ghana. The evaluation was based on the shortness of the rachis and a low height increment (HTi). However, priority was given to selection for short rachis length (RL). The MPOB-Madagascar germplasm showed the shortest RL and was significantly different from other germplasms for *dura* (RL = 3.22 m, HTi = 0.21 m yr\(^{-1}\)). As for *tenera*, the shortest RL was found in MPOB-Tanzania germplasm (RL = 4.44 m, HTi = 0.19 m yr\(^{-1}\)) but not significantly different from MPOB-Guinea (RL = 4.49 m, HTi = 0.39 m yr\(^{-1}\)). The coefficient of variation (CV) for both *dura* and *tenera* accessions were considerably low with most germplasm showing CV of less than 20%. The highest RL CV among *duras* was noted in MPOB-Madagascar germplasm (CV = 18.09%), while among *teneras*, high variation was observed in MPOB-Guinea germplasm (CV = 13.72%). Broad-sense heritability estimate of RL for MPOB-Madagascar was highest for *dura* (\(h^2_B = 100\%\)) while that for MPOB-Zaire was highest for *tenera* (\(h^2_B = 100\%\)). Phenotypic correlations were moderately positive between RL and HTi for most germplasms providing the possibility of developing compact palms suitable for higher density planting which consequently would result in increased oil palm yield per hectare. In summary, MPOB-Tanzania germplasm showed good potential for further introgression into advanced breeding populations for the generation of future compact planting materials.

**Keywords:** oil palm, compact, germplasm.

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**INTRODUCTION**

Oil palm (*Elaeis guineensis* Jacq.) is the most efficient oil bearing crop compared to other vegetable oils. With the limitation of arable land for planting, oil palm breeding is geared towards increasing yield per hectare of land (Phalan et al., 2016). Kushairi et al. (2018) reported that integrated pest and *Ganoderma* management, intensified mechanisation, advanced breeding and biotechnology as well as good agricultural practices help boost oil palm yields for both plantations and smallholdings. Oil palm germplasms that possess economically important characteristics are valuable resources for oil yield improvement. In realising this, *E. guineensis* germplasms were collected from Africa to broaden the genetic base of the current oil palm germplasm...
breeding materials in Malaysia. The first effort was accomplished through the collection from Nigeria in 1973 and was evaluated at MPOB Research Station at Kluang, Johor, Malaysia (Rajanaidu, 1986). Besides Nigeria, prospection was broadened to include other countries in Africa such as Angola, Cameroon, Zaire (now known as the Democratic Republic of Congo), Ghana, Guinea, Gambia, Madagascar; Sierra Leone, Senegal and Tanzania (Rajanaidu and Rao, 1987; Rajanaidu et al., 2013). Extensive screenings are continuously being carried out on these materials in order to exploit their genetic potential in oil palm breeding programmes.

Evaluation of the Nigerian germplasm highlighted several interesting attributes such as dwarfism, high iodine value (IV) and high kernel content (Rajanaidu et al., 2000). High oleic acid breeding populations were also obtained from the Nigeria germplasm (Isa et al., 2006). Whilst, the Angola palms exhibited large fruit dura (Kushairi et al., 2003) which is similar to the Deli duras. Besides that, Angola palms were found to have unique long stalks that can be used for improving harvesting efficiency (Noh et al., 2005). Angola germplasms have also exhibited wide variability in fatty acid composition (FAC) as compared to those in the existing DXP materials (Noh et al., 2002). There were palms from Nigeria and Madagascar exhibiting IV of more than 60, which is relatively higher than the current levels (<50) found in most oils (Kushairi et al., 1999). Apart from the Nigerian germplasm, high content of vitamin E was observed in genetic materials from Zaire, Tanzania, Angola, and Cameroon. It is obvious that this rich collection of germplasm is Malaysia’s treasure trove and should be rapidly mined for potential genetic gains towards improving productivity and a sustainable future. This simultaneously provides Malaysia the competitive advantage despite the challenges faced by the industry.

One practical approach to improving oil palm yield is by increasing the number of productive oil palms per hectare. Oil palms are commercially planted with a density of 120-150 palms ha\(^{-1}\) (Woittiez et al., 2017). Jusoh et al. (2003) mentioned that the maximum income could be achieved from a planting density of 148 palms ha\(^{-1}\), in contrast to the conventional practice of 136-148 palms ha\(^{-1}\). Palat et al. (2012) stated that an effective strategy for yield maximisation is high-density planting followed by selective thinning at 8-9 years after planting. Compact palm leaves are 6.5 m which allow a very high density planting at 180-200 palms ha\(^{-1}\) compared to 7-8 m leaves of standard commercial planting (Barcelos et al., 2015).

In line with this, MPOB has developed a clone, P126 that showed rachis length (RL) at an average of 4.4 m which is shorter than the standard RL normally recorded for most palms at 5-6 m. This short RL is ideal for high density planting and trials of P126 planted at 198 palms ha\(^{-1}\) as opposed to the conventional 148 palms ha\(^{-1}\) have been yielding positive results (Zamzuri, 2011). In addition to being compact, P126 has been found to produce medium-sized bunches which are favourable for harvesting (Samsul et al., 2018).

Many studies on the development of compact palms have been reported. Guzman and Peralta (2010) stated that six compact clones with excellent agronomic characteristics such as short leaves and stems, precocious and high yielding have been selected for commercial production. Standard E. guineensis lines such as Deli, Ghana and Nigeria crossed with COMPACT (E. oleifera x E. guineensis) palms showed 6.6-6.9 m long leaves and can be planted at a density of 170 palms ha\(^{-1}\) which is higher than the industry standard of 136-148 palms ha\(^{-1}\) (Corley and Tinker, 2003). Alvarado et al. (2010) mentioned that seeds of such hybrids are more affordable to smallholder farmers, who can get such genetic materials as a chance to boost production and make better use of scarce land resources as compared to clones.

Expansion of current plantation area to increase oil palm production is no longer a feasible option. The only alternative to increase productivity is by improving yield and profitability per hectare on existing land. Therefore, the introduction of exotic germplasm to increase genetic variability was an important strategy for the oil palm breeding programme. Based on the extensive screening of MPOB germplasm, breeding for shorter RL and lower height increment (HTi) will open up the possibility of developing compact palms which are suitable for higher density planting resulting in increased yield per hectare. The objective of this study is to screen and evaluate all MPOB oil palm (Elaeis guineensis Jacq.) germplasms with good potential for compactness with reasonable yields as breeding materials. The compact trait will be introgressed into advanced breeding populations to generate value-added commercial planting materials.

### MATERIALS AND METHODS

**Materials**

The *duras* and *teneras* used in this evaluation were from eight breeding trials planted at the MPOB Research Station Kluang, Johor, Malaysia involving eight germplasm collections from Nigeria, Cameroon, Zaire, Tanzania, Angola, Sierra Leone, Guinea and Ghana. However, only *dura* palms were evaluated from three trials namely, Madagascar, Senegal and Gambia. These trials were initiated from 1976 to 2000 with various statistical designs and replications as shown in Table 1.
Yield Record

Bunch yield was recorded from 36 months after field planting onwards with two rounds per month by taking readings of bunch weight (BWT) and bunch number (BNO) of individual palms. Fresh fruit bunch (FFB) refers to the weight of bunches produced by a particular palm (BWT x BNO).

Vegetative Measurement

One complete round of vegetative measurement using the non-destructive method was carried out eight years after field planting (Corley and Breure, 1981). RL was measured from the first rudimentary leaf at the petiole to the tip of the rachis. Meanwhile, palm height was measured from ground level to the base of frond 41. HTi is the height at year t divided by t-2, where t is the number of years after field planting.

Data Analysis

RL and HTi values from each trial were analysed by using analysis of variance (ANOVA), while the comparison between the germplasm means used Fisher’s Least Significant Difference (LSD) at 5% level of probability.

Heritability of RL and HTi for each germplasm collection was estimated using the ANOVA variance components method. Variance components were estimated from appropriate expectations of mean squares in Table 2. Based on the variance components data, heritability estimates are as follows:

\[
\text{Phenotypic variance (} \sigma^2_p) = \sigma^2_g + \sigma^2_w
\]

\[
\text{Heritability (} h^2) = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2_w} \times 100
\]

\[
\text{Heritability (} h^2_g) = 2h^2
\]

Intra-class correlation was used to estimate variance components and heritability ( Falconer and Mackay, 1996). In full sib families, broad-sense heritability is the ratio of the total genetic variance to phenotypic variance is equal to 2h^2.

The relationship between RL, HTi and selected traits were determined by simple correlation using the SAS software version 9.4. Correlations between traits of interest are to determine whether selection for one trait will have an effect on another.
RESULTS AND DISCUSSION

ANOVA

Tables 3 and 4 show mean squares for RL of duras and teneras of each collection, respectively. As for duras, the ANOVA showed highly significant difference between families in all germplasm except for Gambia. This finding indicates that significant amount of genetic variability between families exists for RL. As for teneras, there was a highly significant difference in RL between families in all collections except for Sierra Leone and Guinea. Therefore, Sierra Leone and Guinea germplasms could not be selected as the source of male parents for compact palm. The broad-sense heritability for RL of duras ranged from 19.32% (Tanzania) to 100.00% (Madagascar). The heritability estimates for RL of teneras were low to high, with the highest heritability for RL being recorded in Zaire germplasm (100.00%).

Mean squares for HTi of duras and teneras of each collection are presented in Tables 5 and 6, respectively. The ANOVA showed highly significant difference for HTi between families in all germplasm except for Guinea. The results showed that there were variations in family effects for HTi in all germplasm excluding Guinea. The broad-sense heritability for HTi of duras ranged from 28.51% (Tanzania) to 93.39% (Guinea), whilst those of teneras were medium to high, with the highest heritability for HTi being recorded in Zaire and Sierra Leone (100.00%). This significant genetic variability suggests that selection based on HTi will produce good response if their variability could be exploited in the population (Okoye et al., 2009).

The broad-sense heritabilities of RL and HTi for both duras and teneras were high indicating good genetic control over the traits. This was expected as Breure and Corley (1983) mentioned that heritability appears high in vegetative characters. Besides that, high heritabilities were observed because the palms were derived from wild groves where the palms were highly variable. Corley and Tinker (2003) stated that the selection is likely to be more successful when the major proportion of total variation is due to genetic factors (broad-sense heritability). Therefore, it will be an advantage to select compact materials among duras in Madagascar and among teneras in Zaire germplasms.

Germplasm Performance

The frequency distribution of RL among duras and teneras, respectively is shown in Figure 1. The frequencies were close to normal distribution with mean values of 4.87 m for duras and 5.46 m for teneras. Meanwhile, Figure 2 shows the frequency distribution of HTi for duras and teneras, respectively. The frequencies were normally distributed with mean values of 0.34 m yr\(^{-1}\) for duras and 0.40 m yr\(^{-1}\) for teneras. RL and HTi values of 11 051 duras from 11 germplasm and 3372 teneras from eight germplasm involved were analysed (Tables 7 and 8). The Madagascar germplasm showed the shortest RL and was significantly different from other germplasm for dura (RL = 3.22 m, HTi = 0.21 m yr\(^{-1}\)). For tenera, Tanzania and Guinea germplasms showed the shortest RL compared to other germplasm. The coefficient of variation (CV) for both dura and tenera accessions were considerably low with most germplasm showing CV less than 18% for RL. For HTi, the CV ranged from 14.49% (Madagascar) to 35.93% (Tanzania) for duras. As for teneras, the CV ranged from 13.72% (Guinea) to 35.34% (Ghana). The CV observed among the germplasm for these respective traits evaluated indicates low genetic diversity within germplasm. Okoye et al. (2018) reported that differences in CV among the populations could be described by genotype, environment, or genotype-environment interaction.

Based on scatter plots for combination of both characters (RL and HTi) (Figure 3), six germplasm (Zaire, Ghana, Cameroon, Tanzania, Guinea and Madagascar) were located below the grand mean. However, Madagascar germplasm was the most compact evaluated for duras. Figure 4 shows the scatter plots for combination of both characters. However, only those with FFB yield at more than 100 kg palm\(^{-1}\) yr\(^{-1}\) were included in the analyses. Based on the scatter plot, the Tanzania germplasm was the most compact evaluated for duras with reasonable yield. As for teneras, the compact trait was shown by Zaire, Ghana and Cameroon and the most compact trait being shown by Tanzania germplasm (Figure 5). Based on Figure 6, compact trait with good yield was shown by Tanzania germplasm.

Correlations

Simple correlation coefficients between RL and selected traits for bunch yield and vegetative characters for duras and teneras are shown in Tables 9 and 10, respectively. Correlation analysis was conducted to show how close the relationship between two variables. When such association exists, a change in the value of one trait directly affects the value of the other due to strong selection pressures in breeding (Simmonds, 1986). In general, correlation between RL and these selected traits showed the same trend as observed in both duras and teneras. RL correlated positively and significantly with FFB and average bunch weight (ABW). There were negative relationships between RL and BNO in most of the germplasm.
### TABLE 3. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR RACHIS LENGTH 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 | df |
|-----------------|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|
| Family          | 145| 1.8308*** | 89 | 1.5767*** | 55 | 0.8897*** | 50 | 0.9839*** | 10 | 0.5225*** | 29 | 4.9892*** | 29 | 0.6275*** | 31 | 0.1180ns | 29 | 2.9526*** | 20 | 1.3101** | 49 | 5.8964** |
| Within family   | 2.363| 0.2732 | 2.633| 0.1987 | 657 | 0.1668 | 1.962 | 0.1889 | 6 | 0.0357 | 710 | 0.2785 | 317 | 0.1298 | 151 | 0.1385 | 517 | 0.1805 | 369 | 0.1676 | 2388 | 0.2040 |
| $\sigma^2_f$    | 0.0908 | 0.0918 | 0.0570 | 0.0202 | 0.3284 | 0.1913 | 0.0551 | - | - | 0.1521 | 0.0615 | 0.1170 |
| $\sigma^2_w$    | 0.2732 | 0.1987 | 0.1668 | 0.1889 | 0.0357 | 0.2785 | 0.1298 | - | - | 0.1805 | 0.1676 | 0.2040 |
| Total           | 0.3640 | 0.2905 | 0.2238 | 0.2091 | 0.3641 | 0.4698 | 0.1849 | - | - | 0.3326 | 0.2291 | 0.3210 |
| Heritability ($h^2_B$) | 49.89% | 63.20% | 50.94% | 19.32% | 100.00% | 81.44% | 59.60% | - | - | 91.46% | 53.69% | 72.90% |

Note: ** Significant at P≤0.01, otherwise non-significant (ns).


df - degree of freedom.

### TABLE 4. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR RACHIS LENGTH OF *Tenera*

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>NGA</th>
<th>df</th>
<th>CMR</th>
<th>df</th>
<th>ZAR</th>
<th>df</th>
<th>TZA</th>
<th>df</th>
<th>AGO</th>
<th>df</th>
<th>SLE</th>
<th>df</th>
<th>GUI</th>
<th>df</th>
<th>GHA</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>145</td>
<td>1.3512***</td>
<td>57</td>
<td>1.0680***</td>
<td>12</td>
<td>0.9898***</td>
<td>50</td>
<td>0.3473***</td>
<td>24</td>
<td>1.3825***</td>
<td>10</td>
<td>0.5691ns</td>
<td>10</td>
<td>0.5589ns</td>
<td>35</td>
<td>0.6211**</td>
<td></td>
</tr>
<tr>
<td>Within family</td>
<td>1.889</td>
<td>0.2408</td>
<td>266</td>
<td>0.1989</td>
<td>32</td>
<td>0.2162</td>
<td>515</td>
<td>0.1881</td>
<td>160</td>
<td>0.2859</td>
<td>15</td>
<td>0.3174</td>
<td>9</td>
<td>0.1812</td>
<td>131</td>
<td>0.2392</td>
<td></td>
</tr>
<tr>
<td>$\sigma^2_f$</td>
<td>0.0798</td>
<td>0.1583</td>
<td>0.2566</td>
<td>0.0146</td>
<td>0.1501</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0859</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma^2_w$</td>
<td>0.2408</td>
<td>0.1898</td>
<td>0.2162</td>
<td>0.1881</td>
<td>0.2859</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.2392</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.3206</td>
<td>0.3481</td>
<td>0.4728</td>
<td>0.2027</td>
<td>0.4360</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.3251</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heritability ($h^2_B$)</td>
<td>49.78%</td>
<td>90.95%</td>
<td>100.00%</td>
<td>14.41%</td>
<td>52.85%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ** Significant at P≤0.01, otherwise non-significant (ns).

NGA - Nigeria, CMR - Cameroon, ZAR - Zaire, TZA - Tanzania, AGO - Angola, SLE - Sierra Leone, GUI - Guinea, GHA - Ghana.

df - degree of freedom.

### TABLE 5. MEAN SQUARES, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR HEIGHT INCREMENT 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 | df |
|-----------------|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|
| Family          | 145| 5.4049*** | 89 | 0.8858** | 55 | 0.5857*** | 50 | 1.1100*** | 10 | 0.0444ns | 29 | 2.7946*** | 29 | 1.2272** | 31 | 0.1810** | 29 | 2.8248** | 20 | 3.1327** | 49 | 3.1195** |
| Within family   | 2.363| 0.5115 | 2.633| 0.1304 | 657 | 0.1104 | 1.962 | 0.1471 | 6 | 0.0166 | 710 | 0.3108 | 317 | 0.2867 | 151 | 0.2346 | 517 | 0.3502 | 369 | 0.1919 | 2388 | 0.2154 |
| $\sigma^2_f$    | 0.28381 | 0.05028 | 0.03749 | 0.02446 | - | 0.10086 | 0.10945 | 0.10286 | 0.13578 | 0.16811 | 0.05969 |
| $\sigma^2_w$    | 0.51151 | 0.13041 | 0.11039 | 0.14713 | - | 0.31080 | 0.28665 | 0.23459 | 0.35019 | 0.19189 | 0.21538 |
| Total           | 0.79532 | 0.18069 | 0.14788 | 0.17159 | - | 0.41166 | 0.39610 | 0.33745 | 0.48597 | 0.36000 | 0.27507 |
| Heritability ($h^2_B$) | 71.37% | 55.65% | 50.70% | 28.51% | - | 55.26% | 60.96% | 55.88% | 93.39% | 43.40% |

Note: ** Significant at P≤0.01, otherwise non-significant (ns).


df - degree of freedom.
TABLE 6. MEAN SQUARE, VARIANCE COMPONENTS AND HERITABILITY ESTIMATES FOR HEIGHT INCREMENT OF Tenera

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>NGA df</th>
<th>CMR df</th>
<th>ZAR df</th>
<th>TZA df</th>
<th>AGO df</th>
<th>SLE df</th>
<th>GUI df</th>
<th>GHA df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>145</td>
<td>4.842**</td>
<td>0.2902**</td>
<td>0.4059**</td>
<td>0.3855**</td>
<td>1.4995**</td>
<td>1.1294**</td>
<td>0.4815nss</td>
<td>0.5870**</td>
</tr>
<tr>
<td>Within family</td>
<td>1889</td>
<td>0.4819</td>
<td>0.0958</td>
<td>0.0672</td>
<td>0.1103</td>
<td>0.2450</td>
<td>0.2788</td>
<td>0.1786</td>
<td>0.2223</td>
</tr>
<tr>
<td>$\sigma_i^2$</td>
<td>0.31326</td>
<td>0.03504</td>
<td>0.11238</td>
<td>0.02269</td>
<td>0.17171</td>
<td>0.37742</td>
<td>-0.08201</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$\sigma_w^2$</td>
<td>0.48193</td>
<td>0.09581</td>
<td>0.06715</td>
<td>0.11034</td>
<td>0.24501</td>
<td>0.27880</td>
<td>-0.22234</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>0.79519</td>
<td>0.13085</td>
<td>0.17953</td>
<td>0.13303</td>
<td>0.41672</td>
<td>0.65622</td>
<td>-0.30435</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Heritability ($h^2_B$)</td>
<td>78.79%</td>
<td>53.56%</td>
<td>100.00%</td>
<td>34.11%</td>
<td>82.41%</td>
<td>100.00%</td>
<td>-53.89%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: ** Significant at P≤0.01, otherwise non-significant.

NGA - Nigeria, CMR - Cameroon, ZAR - Zaire, TZA - Tanzania, AGO - Angola, SLE - Sierra Leone, GUI - Guinea, GHA - Ghana. df - degree of freedom.

TABLE 7. EVALUATION OF COMPACTNESS AMONG Duras IN THE MPOB GERMPLASM

<table>
<thead>
<tr>
<th>No.</th>
<th>Germplasm</th>
<th>N</th>
<th>Rachis length (m) Mean</th>
<th>Coef. of variation (CV)</th>
<th>Height increment (m yr$^{-1}$) Mean</th>
<th>Coef. of variation (CV)</th>
<th>Yield performance</th>
<th>Bunch analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Nigeria</td>
<td>5.92a</td>
<td>10.19</td>
<td>0.40</td>
<td>22.45</td>
<td>0.19</td>
<td>15.74a</td>
<td>12.85</td>
</tr>
<tr>
<td>2.</td>
<td>Cameroon</td>
<td>4.62a</td>
<td>11.56</td>
<td>0.27a</td>
<td>25.37</td>
<td>0.27</td>
<td>91.83e</td>
<td>14.02</td>
</tr>
<tr>
<td>3.</td>
<td>Zaire</td>
<td>4.73a</td>
<td>9.93</td>
<td>0.25a</td>
<td>25.43</td>
<td>0.25</td>
<td>92.21ae</td>
<td>12.92</td>
</tr>
<tr>
<td>4.</td>
<td>Tanzania</td>
<td>4.41d</td>
<td>10.37</td>
<td>0.19d</td>
<td>35.93</td>
<td>0.19</td>
<td>124.04f</td>
<td>9.45</td>
</tr>
<tr>
<td>5.</td>
<td>Madagascar</td>
<td>3.22a</td>
<td>18.09</td>
<td>0.21a</td>
<td>14.49</td>
<td>0.21</td>
<td>14.01b</td>
<td>2.78</td>
</tr>
<tr>
<td>6.</td>
<td>Angola</td>
<td>5.56e</td>
<td>12.21</td>
<td>0.45e</td>
<td>23.63</td>
<td>0.45</td>
<td>159.73e</td>
<td>13.34</td>
</tr>
<tr>
<td>7.</td>
<td>Senegal</td>
<td>3.87e</td>
<td>11.41</td>
<td>0.47e</td>
<td>22.30</td>
<td>0.47</td>
<td>100.11d</td>
<td>5.04</td>
</tr>
<tr>
<td>8.</td>
<td>Gambia</td>
<td>3.52e</td>
<td>10.44</td>
<td>0.46e</td>
<td>20.89</td>
<td>0.46</td>
<td>66.17f</td>
<td>3.12e</td>
</tr>
<tr>
<td>9.</td>
<td>Sierra Leone</td>
<td>4.15f</td>
<td>13.81</td>
<td>0.45f</td>
<td>25.61</td>
<td>0.45</td>
<td>115.09e</td>
<td>6.77</td>
</tr>
<tr>
<td>10.</td>
<td>Guinea</td>
<td>4.00e</td>
<td>11.90</td>
<td>0.34e</td>
<td>29.34</td>
<td>0.34</td>
<td>98.20ae</td>
<td>7.69e</td>
</tr>
<tr>
<td>11.</td>
<td>Ghana</td>
<td>4.69f</td>
<td>11.80</td>
<td>0.27bf</td>
<td>31.83</td>
<td>0.27</td>
<td>87.87f</td>
<td>6.60</td>
</tr>
<tr>
<td>12.</td>
<td>Advanced Dura</td>
<td>3.50e</td>
<td>11.19</td>
<td>0.40</td>
<td>32.65</td>
<td>0.40</td>
<td>103.38</td>
<td>13.23</td>
</tr>
</tbody>
</table>

| Mean         | 4.87 | 11.17 | 0.34 | 27.19 |
| LSD          | 0.13 | 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 8. EVALUATION OF COMPACTNESS AMONG **Tenera** S IN THE MPOB GERMPLASM

<table>
<thead>
<tr>
<th>No.</th>
<th>Germplasm</th>
<th>N</th>
<th>Rachis length (m) Mean</th>
<th>Coeff. of variation (CV)</th>
<th>Height increment (m yr(^{-1})) Mean</th>
<th>Coeff. of variation (CV)</th>
<th>Yield performance</th>
<th>Bunch analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fresh fruit bunch (kg palm(^{-1}) yr(^{-1}))</td>
<td>Bunch number (No.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Nigeria</td>
<td>2035</td>
<td>5.90(^a)</td>
<td>0.40(^a)</td>
<td>22.42</td>
<td>161.98(^a)</td>
<td>14.72(^a)</td>
<td>11.49(^a)</td>
</tr>
<tr>
<td>2.</td>
<td>Cameroon</td>
<td>324</td>
<td>4.80(^c)</td>
<td>0.26(^c)</td>
<td>22.90</td>
<td>101.59(^c)</td>
<td>14.81(^c)</td>
<td>7.18(^c)</td>
</tr>
<tr>
<td>3.</td>
<td>Zaire</td>
<td>45</td>
<td>5.03(^b)</td>
<td>0.24(^b)</td>
<td>27.78</td>
<td>91.10(^b)</td>
<td>10.67(^b)</td>
<td>8.53(^b)</td>
</tr>
<tr>
<td>4.</td>
<td>Tanzania</td>
<td>566</td>
<td><strong>4.44</strong> (^e)</td>
<td><strong>0.19</strong> (^e)</td>
<td>32.07</td>
<td><strong>130.89</strong> (^e)</td>
<td><strong>12.89</strong> (^e)</td>
<td><strong>10.38</strong> (^e)</td>
</tr>
<tr>
<td>5.</td>
<td>Angola</td>
<td>189</td>
<td>5.75(^a)</td>
<td>0.57(^a)</td>
<td>24.69</td>
<td>161.23(^a)</td>
<td>12.52(^a)</td>
<td>13.22(^a)</td>
</tr>
<tr>
<td>6.</td>
<td>Sierra Leone</td>
<td>26</td>
<td>4.74(^d)</td>
<td>0.40(^d)</td>
<td>32.57</td>
<td>193.16(^d)</td>
<td>18.17(^d)</td>
<td>11.01(^d)</td>
</tr>
<tr>
<td>7.</td>
<td>Guinea</td>
<td>20</td>
<td>4.49(^d)</td>
<td>0.39(^d)</td>
<td>13.72</td>
<td>139.92(^d)</td>
<td>14.18(^d)</td>
<td>9.98(^d)</td>
</tr>
<tr>
<td>8.</td>
<td>Ghana</td>
<td>167</td>
<td>4.90(^e)</td>
<td>0.26(^e)</td>
<td>35.34</td>
<td>95.28(^e)</td>
<td>12.48(^e)</td>
<td>7.86(^e)</td>
</tr>
<tr>
<td>9.</td>
<td>Standard cross</td>
<td>19</td>
<td>5.04</td>
<td>0.49</td>
<td>21.17</td>
<td>174.75</td>
<td>12.31</td>
<td>14.33</td>
</tr>
</tbody>
</table>

| Mean | 3372 | 5.46 | 10.21 | 0.40 | 24.87 |
| LSD  | 0.20 | 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 minimum and maximum values.

### TABLE 9. PHENOTYPIC CORRELATION OF RACHIS LENGTH TO BUNCH YIELD AND VEGETATIVE CHARACTERS OF **Dura**

<table>
<thead>
<tr>
<th>FFB</th>
<th>BNO</th>
<th>ABW</th>
<th>BI</th>
<th>FP</th>
<th>PCS</th>
<th>LL</th>
<th>LW</th>
<th>LN</th>
<th>HT</th>
<th>DIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL-NGA</td>
<td>0.17**</td>
<td>-0.16**</td>
<td>0.31**</td>
<td>-0.22**</td>
<td>-0.20**</td>
<td>0.63**</td>
<td>0.33**</td>
<td>0.52**</td>
<td>0.49**</td>
<td>0.25**</td>
</tr>
<tr>
<td>RL-CMR</td>
<td>0.36**</td>
<td>0.42**</td>
<td>-0.01ns</td>
<td>-0.23**</td>
<td>0.52**</td>
<td>0.52**</td>
<td>0.38**</td>
<td>0.47**</td>
<td>0.26**</td>
<td>0.22**</td>
</tr>
<tr>
<td>RL-ZRE</td>
<td>0.15**</td>
<td>-0.13**</td>
<td>0.39**</td>
<td>-0.20**</td>
<td>-0.17**</td>
<td>0.49**</td>
<td>0.37**</td>
<td>0.50**</td>
<td>0.25**</td>
<td>0.29**</td>
</tr>
<tr>
<td>RL-TZA</td>
<td>0.39**</td>
<td>0.22**</td>
<td>0.48ns</td>
<td>0.04ns</td>
<td>0.38**</td>
<td>0.26**</td>
<td>0.22**</td>
<td>0.47**</td>
<td>0.36**</td>
<td>0.12**</td>
</tr>
<tr>
<td>RL-MDG</td>
<td>0.60ns</td>
<td>0.42ns</td>
<td>0.26ns</td>
<td>0.60**</td>
<td>0.42ns</td>
<td>0.60**</td>
<td>0.34ns</td>
<td>0.75**</td>
<td>0.32ns</td>
<td>0.20ns</td>
</tr>
<tr>
<td>RL-AGO</td>
<td>0.28**</td>
<td>-0.25**</td>
<td>0.46**</td>
<td>-0.15**</td>
<td>-0.39**</td>
<td>0.61**</td>
<td>0.43**</td>
<td>0.37**</td>
<td>0.55**</td>
<td>0.10ns</td>
</tr>
<tr>
<td>RL-SEN</td>
<td>0.18**</td>
<td>-0.07ns</td>
<td>0.34**</td>
<td>-0.08ns</td>
<td>-0.24**</td>
<td>0.60**</td>
<td>0.47**</td>
<td>0.18**</td>
<td>0.34**</td>
<td>-0.06ns</td>
</tr>
<tr>
<td>RL-GAM</td>
<td>0.15*</td>
<td>-0.01ns</td>
<td>0.31**</td>
<td>-0.02ns</td>
<td>-0.23**</td>
<td>0.50**</td>
<td>0.15*</td>
<td>0.26**</td>
<td>0.30**</td>
<td>0.05ns</td>
</tr>
<tr>
<td>RL-SLE</td>
<td>0.62**</td>
<td>0.50**</td>
<td>0.26**</td>
<td>-0.43**</td>
<td>0.75**</td>
<td>0.48**</td>
<td>0.47**</td>
<td>0.63**</td>
<td>0.19**</td>
<td>0.18**</td>
</tr>
<tr>
<td>RL-GUI</td>
<td>0.37**</td>
<td>-0.03ns</td>
<td>0.50**</td>
<td>0.13*</td>
<td>-0.37**</td>
<td>0.59**</td>
<td>0.45**</td>
<td>0.35**</td>
<td>0.40**</td>
<td>0.17**</td>
</tr>
<tr>
<td>RL-GHA</td>
<td>0.27**</td>
<td>-0.16**</td>
<td>0.48**</td>
<td>-0.03ns</td>
<td>-0.48**</td>
<td>0.70**</td>
<td>0.40**</td>
<td>0.46**</td>
<td>0.50**</td>
<td>0.17**</td>
</tr>
</tbody>
</table>

Note: *, ** Significant at P≤0.05 and P≤0.01, respectively. Otherwise, non-significant (ns).

FFB - fresh fruit bunch, BNO - bunch number, ABW - average bunch weight, BI - bunch index, FP - frond production, PCS - petiole cross-section, LL - leaflet length, LW - leaflet width, LN - leaflet number, HT - palm height, DIA - trunk diameter.
TABLE 10. PHENOTYPIC CORRELATION OF RACHIS LENGTH TO BUNCH YIELD AND VEGETATIVE CHARACTERS OF Tenera

<table>
<thead>
<tr>
<th></th>
<th>FFB</th>
<th>BNO</th>
<th>ABW</th>
<th>BI</th>
<th>FP</th>
<th>PCS</th>
<th>LL</th>
<th>LW</th>
<th>LN</th>
<th>HT</th>
<th>DIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL-NGA</td>
<td>0.18**</td>
<td>-0.12**</td>
<td>0.27**</td>
<td>-0.17**</td>
<td>0.18**</td>
<td>0.60**</td>
<td>0.39**</td>
<td>0.35**</td>
<td>0.51**</td>
<td>0.02ns</td>
<td>0.13**</td>
</tr>
<tr>
<td>RL-CMR</td>
<td>0.42**</td>
<td>-0.10ns</td>
<td>0.58**</td>
<td>0.04ns</td>
<td>-0.42ns</td>
<td>0.65**</td>
<td>0.58**</td>
<td>0.50**</td>
<td>0.56**</td>
<td>0.24**</td>
<td>0.18**</td>
</tr>
<tr>
<td>RL-ZRE</td>
<td>0.59**</td>
<td>0.19ns</td>
<td>0.71**</td>
<td>0.15ns</td>
<td>-0.29ns</td>
<td>0.88**</td>
<td>0.58**</td>
<td>0.84**</td>
<td>0.70**</td>
<td>0.30**</td>
<td>0.28ns</td>
</tr>
<tr>
<td>RL-TZA</td>
<td>0.44**</td>
<td>0.21**</td>
<td>0.39**</td>
<td>0.28**</td>
<td>0.002ns</td>
<td>0.41**</td>
<td>0.28**</td>
<td>0.23**</td>
<td>0.62**</td>
<td>0.36**</td>
<td>0.15**</td>
</tr>
<tr>
<td>RL-AGO</td>
<td>0.32**</td>
<td>-0.10ns</td>
<td>0.34**</td>
<td>-0.10ns</td>
<td>-0.37**</td>
<td>0.62**</td>
<td>0.42**</td>
<td>0.38**</td>
<td>0.44**</td>
<td>0.27**</td>
<td>0.12ns</td>
</tr>
<tr>
<td>RL-SLE</td>
<td>0.40*</td>
<td>-0.23ns</td>
<td>0.58**</td>
<td>0.40*</td>
<td>-0.53**</td>
<td>0.30ns</td>
<td>0.25ns</td>
<td>0.22ns</td>
<td>0.55**</td>
<td>-0.10ns</td>
<td>-0.24ns</td>
</tr>
<tr>
<td>RL-GUI</td>
<td>0.44ns</td>
<td>0.11ns</td>
<td>0.58**</td>
<td>0.14ns</td>
<td>0.03ns</td>
<td>0.69**</td>
<td>0.13ns</td>
<td>0.21ns</td>
<td>0.84**</td>
<td>0.65**</td>
<td>0.18ns</td>
</tr>
<tr>
<td>RL-GHA</td>
<td>0.20*</td>
<td>-0.26**</td>
<td>0.49**</td>
<td>-0.12ns</td>
<td>-0.48**</td>
<td>0.70**</td>
<td>0.31**</td>
<td>0.62**</td>
<td>0.65**</td>
<td>0.39**</td>
<td>0.14ns</td>
</tr>
</tbody>
</table>

Note: *, ** Significant at P≤0.05 and P≤0.01, respectively. Otherwise, non-significant (ns).

FFB - fresh fruit bunch, BNO - bunch number, ABW - average bunch weight, BI - bunch index, FP - frond production, PCS - petiole, cross-section, LL - leaflet length, LW - leaflet width, LN - leaflet number, HT - palm height, DIA - trunk diameter.

Figure 1. Frequency distribution of rachis length (RL) among duras (a) and teneras (b) in MPOB germplasms.

Figure 2. Frequency distribution of height increment (HTi) among duras (a) and teneras (b) in MPOB germplasms.
Note: (–) - grand mean.
RL - rachis length.
HTi - height increment.

**Figure 3.** Scatter plot of compact palms excluding duras with fresh fruit bunch yield of less than 100 kg palm$^{-1}$ yr$^{-1}$ in MPOB germplasm.

Note: (–) - grand mean.
RL - rachis length.
HTi - height increment.

**Figure 4.** Scatter plot of compact palms among duras in MPOB germplasm.
RL of all germplasms was negatively correlated to frond production (FP) except for Madagascar which was positive and high (>0.50) in *duras*. As for *teneras*, RL was found to be positively and significantly correlated with frond production in Nigeria. Correlation analysis also showed strong relationships for other pairs of traits. There was medium to high positive correlation between RL
and petiole cross-section (PCS), leaflet length (LL), leaflet width (LW) and leaf number (LN). However, there was low to medium positive correlation between RL and palm height (HT) among the germplasms. Selection of one trait will bring along the effect of other traits. Therefore, selecting for low RL coincided with lower height increment. Isa et al. (2008) reported that the oil palms with lower HTi found in some Nigerian derived progenies are amenable to easier harvesting and mechanisation. The correlation between RL and trunk diameter (DIA) was low to medium amongst the germplasm in *duras*. It was also noted that there was no significant correlation between RL of most germplasms to DIA in *teneras*.

**CONCLUSION**

Based on the results from this study, the Tanzania germplasm showed good potential as breeding material for compactness with reasonable yield. It is envisaged that the introduction of these materials into commercial populations would improve planting materials in this country. Further efforts would be to introgress the short RL (less than 5 m) and low HTi (less than 0.3 m yr⁻¹) palms into advanced breeding populations. Through the new combination, the best materials would be further evaluated and later exploited for future commercial seed production. It is recommended that progeny testing and evaluation of genotype-environment (GxE) interactions should be obtained before the germplasm can be used commercially.

**ACKNOWLEDGEMENT**

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**REFERENCES**


