



Assessing D×D oil palm (*Elaeis guineensis*) genotypes for relevant bunch traits: Implication for promising breeding lines development

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ABSTRACT

The study was carried out during 2021, 2022 and 2023 at ICAR-Indian Institute of Oil Palm Research, Pedavegi, Eluru, Andhra Pradesh with aim to improve characterization and utilization of oil palm genotypes developed from African mother palms (*Elaeis guineensis* Jacq.). The clustering pattern, variability, correlation, principal component analysis and path analysis of 143 genotypes were done with the support of bunch parameters to better know the variations among them. Genotypic correlations among factors impacting oil yield describe the true link by excluding any environmental impacts. It has been noted that *dura* genotypes exhibit a wide range of variability in terms of yield and bunch components, which can be exploited and expanded for oil palm breeding lines development. Six oil palm *dura* genotypes (G9, G44, G119, G77, G142, and G124) have been identified as superior for commercial production of D × P hybrid oil palm planting materials due to their high oil to bunch percentage (OB) (>20%). Genotype G77 identified as the best performer in terms of high OB (26%), weight of oil (2%) and mesocarp-to-fruit ratio (83.20%). It is concluded that mesocarp-to-fruit ratio, oil to wet mesocarp, fruit to bunch ratio, bunch weight, total number of fruits and weight of oil are the best traits for selection and utilization to improve the existing oil palm germplasm. Further, use of these selected materials for commercial production could boost oil yield compared to the presently cultivated oil palm genotypes.

Keywords: Bunch analysis, Correlation, Dura, Genotypes

Palm oil, which is obtained from the mesocarp of the African oil palm (*Elaeis guineensis* Jacq.) fruit, is the most cost-effective vegetable oil due to much larger yields than other oil crops. The productivity of fresh fruit bunches (FFB) has a direct impact on palm oil production, which is also influenced by plant genotype and environment. The genetic correlations among bunch components allow for inferences about how bunch composition will change in an improved population, predicting which should be the target of positive (increase in value) or negative (reduction in value) selection. When there is an intense genetic tie-up amidst two qualities, the likelihood of indirect selection can be considered, which also takes into account the costs, logistics and infrastructure, complexity, and time required to analyze the traits. Correlation analysis usually helps to comprehend the link between investigated traits and provides deeper insight into the contribution of each trait for enhancing the crop's genetic makeup. As a result, association studies

identify the most appropriate features to prioritize in future breeding programmes. This is especially significant when a large number of genotypes must be examined and preliminary progeny selection tests are required. It is important to harvest bunches at the right maturation phase for physico-chemical study. During palm fruit development, oil accumulates in the mesocarp, resulting in water loss but no increase in non-oil solids content. Perhaps it has a direct impact on oil yield of oil palm or takes a different path in terms of overall influence, allowing each trait's contribution to yield to be recognized. The yield components do not occur individually rather, they are interrelated, resulting in oil yield in oil palm *dura* genotypes. Path coefficient statistical study investigates how predictor parameters as first and second-order component variables affect a dependent variable, such as oil yield (Khan *et al.* 2022). This method is used as a selection aid in plant breeding programmes to improve both genetic and yield characteristics. Yield is a complex variable impacted by a number of factors, including polygenes, the environment, and genetic heterogeneity (Barcelos *et al.* 2015). Because of the complexity and interplay of yield-enhancing characteristics, selection for higher oil yield should not be limited to yield (Cadena 2013). As a result, certain yield-enhancing properties should be evaluated. Selecting progenies based on

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one or more descriptors can cause unwanted modifications in others due to negative correlations between them. To resolve this issue, principal component analysis (PCA) is utilized as a multivariate method to discover and make out the independent descriptors that influence plant traits. Keeping all these points in view an experiment was planned to improve characterization and utilization of oil palm genotypes developed from African mother palms.

MATERIALS AND METHODS

This study was carried out during 2021, 2022, 2023 at ICAR-Indian Institute of Oil Palm Research, Pedavegi, Eluru, Andhra Pradesh. Total 143 *dura* × *dura* crosses of oil palm genotypes were evaluated for their fresh fruit bunch (FFB) yield and oil content. The parent *dura* material was brought from Africa in 1995 and planted in field gene bank of ICAR-Indian Institute of Oil Palm Research, Pedavegi, Eluru, Andhra Pradesh. The oil palm bunch traits like bunch weight (BW), total number of fruits (TNF), fruit to bunch ratio (FBR), weight of oil (WO), mesocarp to fruit ratio (MF), kernel to fruit ratio (KF), shell to fruit ratio (SF), oil to dry mesocarp (ODM), oil to wet mesocarp (OWM); and oil to bunch ratio (OB) were recorded. Harvesting index of all mature selected mother palms for their oil estimation is pivotal, since oil confirmation in peak period occurs during the final two weeks of oil palm bunch maturity. Fully ripe three bunches were harvested for analysis of oil content and expressed in percentage of oil per fresh fruit bunch. The weight of freshly harvested *dura* bunches measured incontinently all bunch parameters after loading back to bunch analysis lab and separated the spikelets from the stalk. The fruitlets from inner and external layers of fruit bunch were separated and counted. The 250 g of dried mesocarp samples in three replications were taken randomly for oil solvent extraction using semiautomatic soxhlet

apparatus. The inner and outer layer fruit samples were taken separately and oil estimation done independently as per the methodology given by Mandal and Kochu Babu (2008).

For studying of complete bunch parameters by a process called bunch analysis, 143 *dura* type palms were selected for oil estimation. The instrument used for oil estimation and other bunch quality traits evaluation was soxhlet extraction apparatus. The bunch analysis repeated thrice for all palms in different seasons and calculated mean values, standard deviation (SD) and measure of variations (CV) and were cataloged, and statistical analysis was performed using SPSS software. The dot plots, clustering study, correlation, principal component analysis and path analysis were done using graphic pad software (Hammer *et al.* 2001) and OPSTAT.

RESULTS AND DISCUSSION

The present study revealed detailed information by examination of bunch traits in order to understand its nature or to determine its oil content in different oil palm genotypes using ANOVA and $P < 0.01$ of 143 D×D genotypes produced from African germplasm and its bunch traits depicted in box and jitter plots. We found lot of variability in all the palms used in the present study for bunch qualitative and quantitative parameters like BW (5.77–30.58), TNF (310–2830), FBR (0.32–0.82 kg), WO (1.54–2.11 g), MF (28.20–83.20%), KF (4.40–82.20), SF (5.40–42.00%), ODM (61.60–84.53%), OWM (19.22–70.27%) and OB (5.20–28.24%). Among the 143 genotypes studied, G9 identified as superior oil yielding (28.35%) having higher mesocarp content (72%) and thin shell (10.4%) followed by G27 (26.28%). Whereas, G64 produced the highest fruit to bunch ratio (0.82) followed by G125 (0.80). G77 was identified as the best genotype for high OB (26%), WO (2%) and MF (83.20%) (Table 1, Fig. 1). The amount of oil to bunch was raised, mostly by

Table 1 Comparative analyses of 143 *dura* oil palm genotypes

	BW	TNF	FBR	WO	MF	KF	SF	ODM	OWM	OB
Number of genotypes	143.00	143.00	143.00	143.00	143.00	143.00	143.00	143.00	143.00	143.00
Minimum	5.77	310.00	0.32	1.54	28.20	4.40	5.40	61.60	19.22	5.20
Maximum	30.58	2830.00	0.82	2.11	83.20	82.20	42.00	84.53	70.27	28.24
Mean	13.04	1164.41	0.66	1.92	50.27	12.70	27.75	76.90	43.49	14.39
Standard error	0.38	37.45	0.01	0.01	0.88	0.59	0.53	0.30	0.63	0.38
Variance	21.11	200509.40	0.01	0.01	110.33	50.10	40.92	12.98	56.26	20.20
Standard deviation	4.59	447.78	0.09	0.09	10.50	7.08	6.40	3.60	7.50	4.49
Median	12.59	1123.00	0.67	1.92	49.00	11.80	28.60	76.67	43.90	14.04
25%	9.85	811.00	0.61	1.87	43.40	8.80	24.80	74.93	38.31	11.42
75%	15.10	1394.00	0.72	1.98	57.00	15.40	31.80	79.33	48.24	16.74
Skewness	0.90	0.93	-1.13	-0.73	0.60	6.74	-1.12	-0.73	-0.01	0.47
Kurtosis	1.06	0.94	1.86	2.27	0.61	65.44	2.45	2.27	1.12	0.13
Geometric mean	12.28	1084.29	0.65	1.92	49.21	11.70	26.69	76.82	42.81	13.68
Coefficient of variance	35.24	38.46	13.77	4.69	20.89	55.72	23.05	4.69	17.25	31.24

BW, Bunch weight; TNF, Total number of fruits; FBR, Fruit-to-bunch ratio; WO, Weight of oil; MF, Mesocarp-to-fruit ratio; KF, Kernel to fruit ratio; SF, Shell to fruit ratio; ODM, Oil to dry mesocarp; OWM, Oil to wet mesocarp; OB, Oil to bunch ratio.

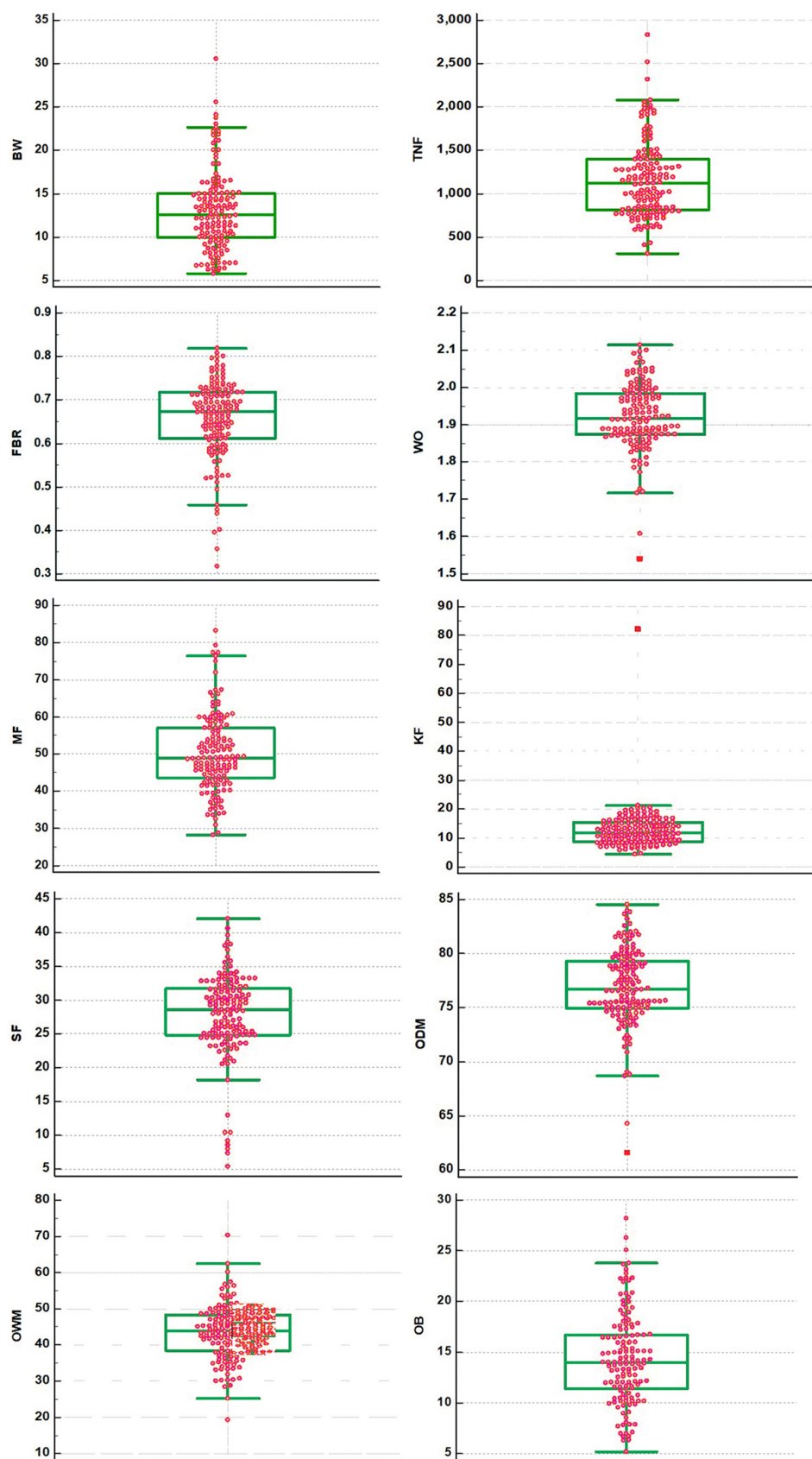


Fig. 1 *Dura* oil palm genotypes displayed in box and jitters plots.

BW, Bunch weight; TNF, Total number of fruits; FBR, Fruit-to-bunch ratio; WO, Weight of oil; MF, Mesocarp-to-fruit ratio; KF, Kernel to fruit ratio; SF, Shell to fruit ratio; ODM, Oil to dry mesocarp; OWM, Oil to wet mesocarp; and OB, Oil to bunch ratio.

improving the mesocarp content to fruit percentage; changes in other bunch components were minor, but the rise in MF reveals a substantial shift in OB, oil content depends on FBR, MF and OWM content of the fruits (Mohd *et al.* 2024)

Kernel to fruit ratio observed as having the greatest CV (55.72) on par with TNF (38.46), BW (35.24), whereas lowest CV identified for both WO and ODM (4.69). The top and lower quartiles represent the 75th and 25th percentiles of the accession, respectively. To illustrate genetic variability, the frequency distribution for 10 important traits (Table 1) among 143 oil palm genotypes was displayed as box and jitters plots (Fig. 1). Skewness refers to the asymmetry of data distribution (Rashmi and Mayuri 2022). Traits with negative skewness included the FBR (-1.13), WO (-0.73), SF (-1.12), ODM (-0.73), and OWM (-0.01). While positive skewness was identified in variables such as bunch weight (0.90), TNF (0.93), MF (0.60), KF (6.74), and OB (0.47). Traits with positive skewness are connected with complimentary gene interactions (Savitha and Usha 2015). Maximizing genetic gain for these qualities necessitates intensive selection from existing variability. The genes that influence traits with skewed distributions are generally dominant, regardless of whether they have an increasing or decreasing effect on the trait (Kanavi 2020). Positive kurtosis indicates that traits are governed by few genes.

To further understand the best oil yielding palm among 143 genotypes, we sought to ascertain whether the genotypes had any commonalities. We did this using Ward's clustering method for grouping different *dura*'s used in this study with

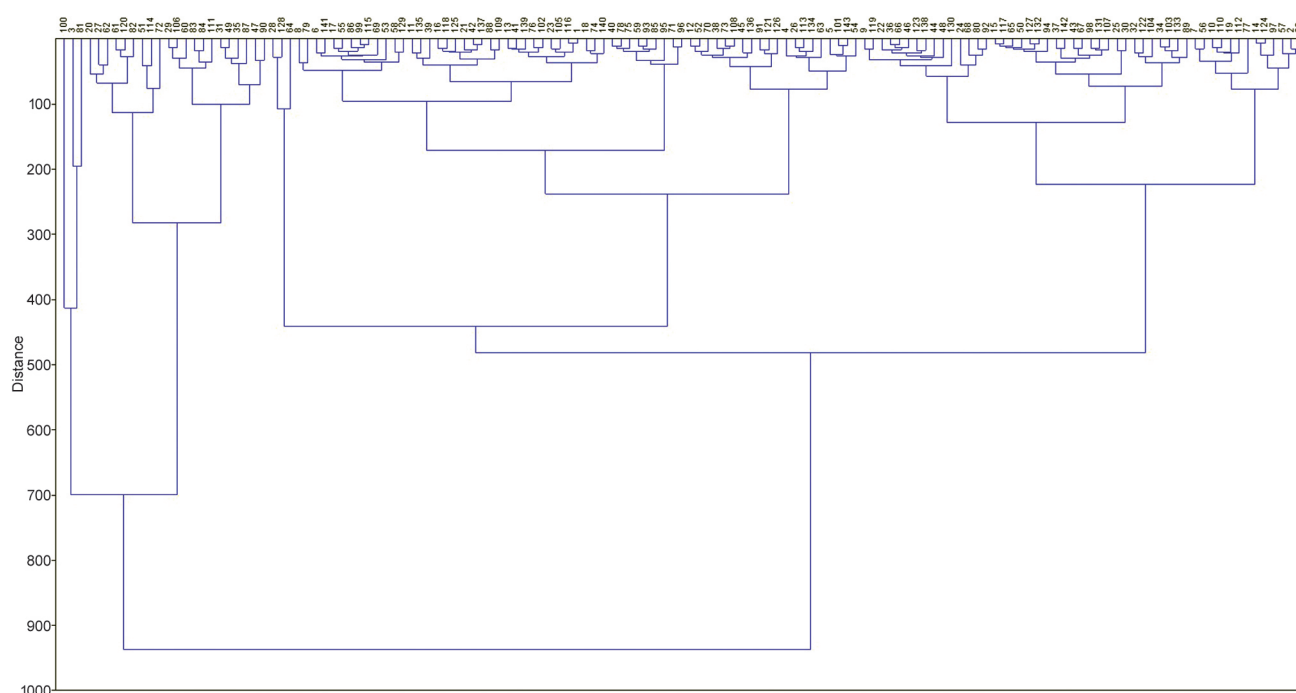


Fig. 2 Dendrogram of 143 *dura* oil palm genotypes.

respect of their similarities among all measured bunch traits and thus having three clusters (Fig. 2). The first cluster consisted of 24 genotypes with three sub clusters. Cluster II contained genotypes of more BW (15–30 kg) having 66 genotypes (Fig. 2) with four sub clusters. Cluster III was the biggest cluster with 53 genotypes contained genotypes (G9, G44, G119, G77, G142, G124, G14, G32, G68, G89 and G57) of high OB (18–25%). Similar findings were observed by Murugesan *et al.* (2015), Suzana *et al.* (2020) and Pedapati *et al.* (2021).

Prior to performing the PCA, Person's correlation analysis was used to identify the variables that had a strong link with one another. One may get the conclusion that two or more variables can explain the same phenomenon when they have a strong correlation with one another. In this sense, reducing the dimensionality of the main components and preventing multi collinearity during PCA can be achieved by choosing variables that do not correlate with one another (Yirgu *et al.* 2022). Simple correlations between bunch attributes, when analyzed across 143 genotypes, revealed both positive and negative correlations observed between the oil palm bunch parameters and oil content per bunch. The highlights of the present study were the positive and extremely significant ($P \leq 0.01$) associations between the TNF (0.85) and bunch weight. Similarly, OB was emphatically profoundly critical ($P \leq 0.01$) with BW (0.25), TNF (0.29), FBR (0.44), WO (0.48), MF (0.75), ODM (0.48), OWM (0.53); however, it was negatively significant with KF (-0.39) and SF (-0.63). Fruit-to-bunch ratio had significant correlations with BW (0.206) and TNF (0.182). There was positive and significant relationships between the WO and bunch features such as BW (0.200) and the TNF (0.225), but not with the FBR (-0.071). Furthermore, the MF revealed

an optimistic association with BW (0.20) and was highly significant ($P \leq 0.01$) with total number of fruits (0.28) and oil weight per sample. The ODM was found to be highly significant ($P \leq 0.01$) with BW (0.20) TNF (0.26), WO (1.00), mesocarp-to-fruit ratio (0.37), and non-significant with FBR (-0.07) and KF (-0.16). The OWM was also profoundly huge significant ($P \leq 0.01$) with WO (0.46). This negative association indicates that these features have a detrimental influence on the OB matrix of correlation coefficients of bunch traits in oil palm *dura* genotypes (Fig. 3)

In the present work, the positive and significant correlation between MF, ODM, and OB shows how these characteristics affect the amount of bunch oil. Findings in this work are consistent with prior studies of Okoye *et al.* (2009) and Krualee *et al.* (2013). In view of the current findings, we may conclude that these variables can be used in breeding strategies (Pedapati *et al.* 2021). The obtained data indicated that BW, TNF, FBR, WO, MF, KF, ODM, and OWM had substantial positive relationships with oil production. As a result, these qualities are significant in breeding programmes to increase fruit yield. Although correlation studies are useful for identifying related traits to oil yield, they make it difficult to comprehend the direct and indirect contributions of each trait. Path analysis can help break down the correlation coefficients into immediate and backhanded impacts of that each character's relative value (Popet *et al.* 2022, Wan *et al.* 2023). Any trait's direct and indirect impacts can have a positive or negative impact on the performance of another trait.

Path analysis during selection of genotypes in breeding aspects is used to find out the immediate and backhanded impacts of various bunch characters on OB. Results identified MF (0.610) quick and underhanded direct effects on OB

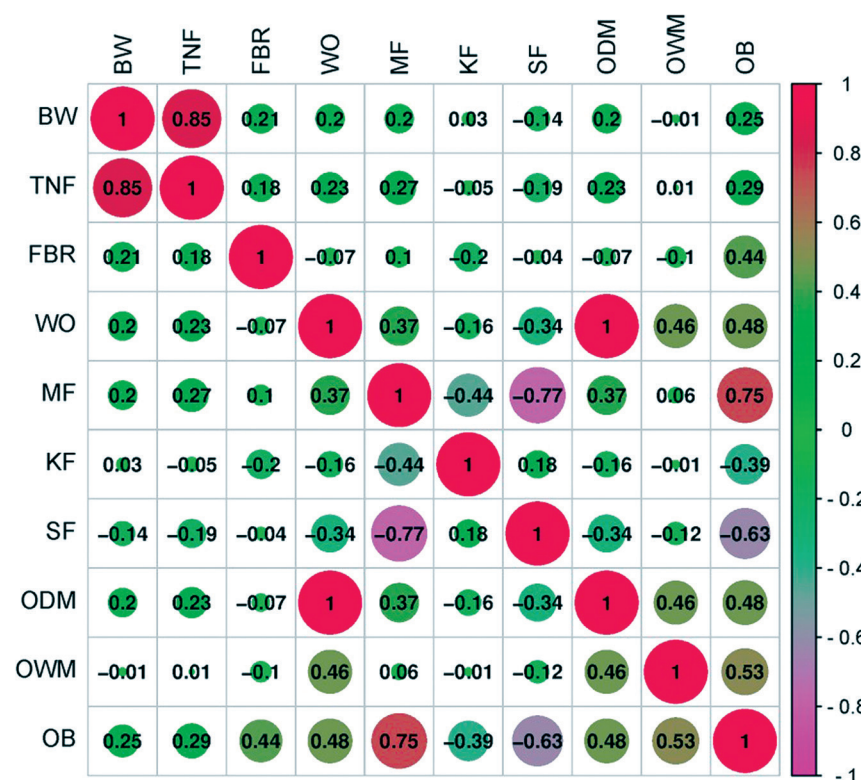


Fig. 3 Matrix of correlation coefficients of bunch traits in oil palm *dura* genotypes.

BW, Bunch weight; TNF, Total number of fruits; FBR, Fruit-to-bunch ratio; WO, Weight of oil; MF, Mesocarp-to-fruit ratio; KF, Kernel to fruit ratio; SF, Shell to fruit ratio; ODM, Oil to dry mesocarp; OWM, Oil to wet mesocarp; and OB, Oil to bunch ratio.

followed by OWM (0.526) and FBR (0.415). However, the direct effect of bunch weight (0.039), TNF (0.004), and WO (0.119) was very negligible (Table 2). Furthermore, the other important oil fixing oil palm bunch traits, KF (-0.020), SF (-0.068), ODM (-0.115), had a negative contrastingly direct effect on OB as observed in present study. Similar types of findings were also reported by Sara *et al.* (2018).

The immediate and backhanded impacts of several

bunch features on OB outcomes are consistent with earlier findings (Okoye *et al.* 2009, Kruallee *et al.* 2013, Shaheen *et al.* 2021) which reported that OWM has an impact on both the proportion of oil per bunch and the oil output per palm. Among the different oil palm traits, very important oil determining and deciding bunch character like shell-to-fruit ratio and ODM had a negative direct effect on OB. The same type of results noted in the findings of Peng *et al.* (2019), who reported that the oil palm kernel and its shell may be having an oblique effect on OB. Additionally, correlations and path analysis in oil palm were assessed in the same *dura* genotypes, and it was determined with clarity that the oil output could be raised if fresh mesocarp/fruit and fruit/bunch were enhanced (Mohd *et al.* 2002, Patcharin *et al.* 2013, Pedapati *et al.* 2021). In order to improve the discriminating power to categorize the measured qualities based on connections across genotypes, the PCA was performed on the experimental dataset including 10 bunch variables or traits and 143 *dura* entries. According to the study work

mentioned above, 82.13% of the variance was explained by the first four components (PCs) with eigen values ≥ 1 .

The depicted first PC (eigen value: 3.82) accounted for 38.25% of the whole set of variation in the data and was significantly correlated with the BW, TNF, FBR, WO, MF, ODM, OWM and OB. The PC2 (eigen value: 1.79) explained 17.96% of the entire set of variation and was mainly influenced by BW, TNF and FBR. PC3 (eigen

Table 2 Path-coefficient analysis showing direct and indirect effects of different bunch traits of oil palm

Trait	BW	TNF	FBR	WO	MF	KF	SF	ODM	OWM	rg
BW	0.039	0.003	0.092	0.025	-0.136	-0.002	-0.001	0.004	0.012	0.691**
TNF	0.008	0.004	0.122	0.635	-0.251	-0.005	0.015	0.368	0.018	0.228**
FBR	-0.020	-0.001	0.415	-0.120	-0.187	-0.003	-0.002	0.125	-0.035	-0.307
WO	0.021	-0.009	-0.004	0.119	0.030	0.002	-0.052	-0.021	-0.005	0.246**
MF	0.006	0.005	0.016	0.019	0.610	0.004	0.001	-0.325	0.251	0.532**
KF	0.004	0.012	-0.052	0.006	-0.017	-0.020	-0.001	0.072	-0.465	-0.159
SF	-0.012	0.003	0.069	0.025	0.068	-0.0258	-0.068	-0.001	0.078	-0.034
ODM	0.009	0.004	0.008	0.268	0.317	0.018	0.052	-0.115	0.054	0.136*
OWM	0.001	-0.005	0.039	0.187	0.015	0.007	-0.037	0.0158	0.526	0.421**
Residual are 0.01914										

Independent variables: BW, Bunch weight; TNF, Total number of fruits; FBR, Fruit-to-bunch ratio; WO, Weight of oil; MF, Mesocarp-to-fruit ratio; KF, Kernel to fruit ratio; SF, Shell to fruit ratio; ODM, Oil to dry mesocarp; OWM, Oil to wet mesocarp.

Dependent variables: OB, Oil to bunch ratio. *, Significant difference at $P \leq 0.05$; **, Significant difference at $P \leq 0.01$.

value: 1.55) accounted for 15.54% of the full amount of variability and was significantly correlated with BW, TNF, WO, KF, SF, ODM and OWM. While PC4 (eigen value: 1.03) accounted a slight correlation of 8.13% which was mainly correlated with FBR, SF, OWM and OB. Since the first two PCs showed the highest percentage of variance, based on the results obtained we created a PCA-based biplot (Supplementary Fig. 1). Thus, the evaluated *dura* genotypes observed in depicted PC1–PC4 will be significant and should be selected for further evaluation in selective breeding programme.

The current observations have shown that, these exceptional *dura* genotypes exhibit a broad range of yield variability and bunch components, which can be exploited and expanded upon for development. Six palm genotypes have been identified as the best for commercial production of D × P hybrid oil palm planting materials due to their high OB (>20%). Genotypic correlations among factors impacting oil yield describe the true link by excluding any environmental impacts (Rance *et al.* 2001).

A path coefficient analysis is extremely effective at simplifying the exact interrelationship and contribution of each component with yield which is highly dependable variable. As an outcome of the present investigation, breeders are more likely to center on the set of components that have a high direct effect on yield and select for characteristics with positive moderate indirect effects in order to maximize selection efficiency. Based on the above analysis, we finalized the results that oil yield of oil palm could be very effectively enhanced through direct selection by considering some traits which are independent of each other and do not affect oil yield negatively through indirect effects. Hence, it can be concluded that MF, OWM, FBR, BW, TNF and WO are the best traits for selection to pick up the global oil yields of oil palm per hectare investigated in this work. Six oil palm *dura* genotypes (G9, G44, G119, G77, G142, and G124) have been identified as superior breeding lines for commercial production of D × P hybrid oil palm planting materials. Using these selected breeding lines promising hybrids may produce, and these hybrids could boost global oil yield compared to present genetic materials.

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