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Identification and selection of elite oil palm (*Elaeis guineensis* Jacq.) genotypes for utilisation in a breeding program

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Abstract

Oil palm is a vegetable oil yielding, cross-pollinated crop belonging Arecaceae family, having a high potential for increasing oil yield to fulfil the requirement of edible oil in the country. Evaluation of oil palm germplasm was carried out at ICAR-IIOPR, Pedavegi, in 73 genotypes. A correlation study reported that the height of the palm was positively correlated with height increment, rachis length, number of a leaflet, bunch number, and FFB yield. In contrast, the girth of the palm was negatively correlated with the bunch index. Two *Dura* genotypes *viz.,* IC0610049-40 and IC0610051-71 with high FFB yield (276.2 and 234.6 kg palm^{-1} year^{-1}, respectively) with more number of bunches palm^{-1} year^{-1} (15.3 and 16.7, respectively) and high oil to bunch ratio (20.9% for both) and one *Tenera* genotype IC0610049-39 with 202.5 kg FFB with 11.7 bunches palm^{-1} year^{-1} and 23.0 per cent oil to bunch ratio were selected. One low height increment *Dura* palm IC0610045-3 with 19.56 cm year^{-1} and these genotypes can be used in the future breeding program for developing mother palms for production of *Tenera* hybrid**.**

Keywords: Breeding, genotypes, hybrid, oil palm

Introduction

Oil palm is perennial vegetable oil yielding crop with 4 to 6 tonnes of oil yield per hectare. Being one of the highest consumers of palm oil, and the production does not meet consumption, India is still importing oil from other countries. Due to the COVID-19 pandemic and several changes in import duties, the import of oil is also reduced. An effective breeding program for high-yielding varieties can be developed by selecting elite genotypes of high FFB and oil yield and evolving dwarf varieties or hybrids for easy harvesting. By using an annual oil yielding crop, it is very difficult to meet the edible oil requirement of the Indian population. For this, we need to develop elite planting material with increased fresh fruit bunches (FFB) and oil yield. Hence, it is needed to continuously evaluate the oil palm germplasm material to select parent material to improve the yield.

Based on correlation and path coefficient analysis (Balakrishna *et al.,* 2018), major emphasis should be placed on the selection process with the high number of bunches, Average bunch weight (ABW), total dry matter (TDM), and bunch index (BI) for better genotype with superior oil quality and realising higher FFB yield. Selection based on bunch yield alone will not be sufficient to get the best hybrids, looking for plants with high bunch index and other bunch traits may produce superior yield and uniform palms (Corley, 1976). The main objective of this study was to select elite oil palm genotypes by morphological evaluation.

Materials and methods

Evaluation of oil palm germplasm in the field gene bank of ICAR-IIOPR was conducted. Seventy-three genotypes (Table 1) were used in the study in a non-replicated trial, and descriptive analysis was

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Table 1. Details of accession name and number of genotypes used in the study

Sl. No.	Genotype	Sl. No.	Genotype
1.	Nam1-1	37.	TG8-54
2.	Nam1-3	38.	TG8-55
3.	Nam1-4	39.	TG8-56
4.	Nam1-5	40.	TG8-57
5.	Nam1-6	41.	TG8-58
6.	Nam1-8	42.	TG8-59
7.	Nam1-10	43.	TG8-60
8.	Nam1-11	44.	TG8-62
9.	Nam1-12	45.	TG8-63
10.	Nam1-13	46.	TG9-64
11.	Nam2(small)-16	47.	TG9-65
12.	Nam2(small)-20	48.	TG9-67
13.	Nam2(Big)-22	49.	TG9-68
14.	Nam2(Big)-23	50.	TG9-69
15.	Nam2(Big)-24	51.	TG9-70
16.	Nam2(Big)-25	52.	TG9-71
17.	Nam2(Big)-26	53.	TG9-72
18.	Nam2(Big)-27	54.	TG9-73
19.	Nam3-28	55.	TG9-74
20.	Nam3-33	56.	TG9-75
21.	TG7-34	57.	TG9-76
22.	TG7-36	58.	TG9-77
23.	TG7-37	59.	TG9-78
24.	TG7-38	60.	And. Pisifera-79
25.	TG7-39	61.	And. Pisifera-80
26.	TG7-40	62.	And. Pisifera-81
27.	TG7-43	63.	And. Pisifera-83
28.	TG7-44	64.	And. Pisifera-84
29.	TG7-45	65.	And. Pisifera-85
30.	TG7-46	66.	And. Pisifera-86
31.	TG7-48	67.	And. Pisifera-88
32.	TG8-49	68.	Unknown-90
33.	TG8-50	69.	Unknown-91
34.	TG8-51	70.	Unknown-92
35.	TG8-52	71.	Unknown-93
36.	TG8-53	72.	Unknown-94

carried out to know the performance of individual genotypes. This germplasm was planted in 2010, and at every harvest, FFB yield was recorded in the individual genotype. The oil to bunch ratio was estimated by bunch analysis for three bunches. The seventh-year (2017) to ninth-year (2019) data was used to select genotype, and data are given in Table 2. Twenty-three quantitative traits were analysed among the genotypes. For a selection of low height increment of genotypes, every year height of the palm was recorded at 41st leaf base from the ground and height increment was calculated by using the formula:

$$\frac{\text{Height of the palm}}{(\text{age of the palm-2})}$$

All the morphological traits were recorded based on standard methods (Corley, 1976 and Bhagya *et al.,* 2018). Three years of data were compiled for the selection elite genotype.

Table 2. The mean and range of 23 quantitative traits among oil palm 73 genotypes

Traits	Mean	Range
Sex ratio (SR)	0.55	0.09-1.00
Number of leaves (NL)	23.3	21.7-24.7
Petiole width (PW) (cm)	9.0	5.3-19.8
Petiole depth (PD) (cm)	6.8	3.8-9.7
Girth (cm)	284.7	199.7-378.0
Height (cm)	299.7	123.0-522.3
Height increment (cm)	47.9	19.6-83.2
Number of leaflet (NLL)	311.3	259.3-346.7
Rachis length (RL) (cm)	519.9	319.3-651.5
Leaflet length (LLL) (cm)	103.2	71.6-125.4
Leaflet width (LLW) (cm)	5.1	3.0-6.5
Leaf area (LA) (cm^2)	9.5	3.2-13.6
Leaf dry weight (LDW) (kg)	6.6	2.4-16.8
Specific leaf weight (SLW) (kg $sqcm^{-1}$)	0.70	0.42-1.34
Total leaf dry weight (TLDW) (kg/palm/year)	154.5	55.8-400.1
Bunch number (BN)	10.1	1.7-16.7
Fresh Fruit bunch (FFB) (kg $palm^{-1}year^{-1}$)	145.2	14.4-276.3
Average bunch weight (ABW) (kg)	14.8	5.6-24.4
Bunch dry weight (BDW) (kg)	76.6	7.6-145.7
Vegetative dry matter (VDM) (kg $palm^{-1}year^{-1}$)	200.5	82.9-476.2
Total dry matter (TDM) (kg $palm^{-1}year^{-1}$)	277.1	129.4-561.4
Bunch index (BI)	0.27	0.03-0.44
*Oil to bunch ratio	19.7	14.0-23.0

*Selected genotype data only used

Morphological data were statistically analysed using JMP software (JMP, v9.0.0. SAS, Cary, USA).

Results and discussion

Oil palm is a cross-pollinated and highly variable crop. Commercially growing variety is the hybrid *Tenera* crossing between fertile *Dura* and sterile *Pisifera.* Phenotypic analysis indicated that the sex ratio ranged from 0.09 to 1.00 with a mean of 0.55. The number of leaves produced varied from 21.8 to 24.7 with a mean of 23.3; petiole width variers from 5.3 to 19.8 with a mean of 9.0, petiole depth varied from 4.0 to 9.6 with a mean of 6.8, the girth of genotypes varied from 199.7 to 378.0 cm with a mean of 284.7 cm. Sex ratio, number of leaves, petiole width, and petiole depth results are congruent with Balakrishna *et al.* (2018). The height of the palm varied from 123.0 to 522.3, with a mean of 299.7 cm. Genotypes with 300 to 1100 cm height were reported by Murugesan *et al.* (2015) in an African oil palm germplasm study in India with 50 individual palms. In our study, the girth of the palms were less (199.7-378.0 cm); this may be due to the difference in age of the plantation. These findings are supported by previous studies in oil palm (Rance *et al.* 2001; Noh *et al.,* 2012; 2014).

Height increment varied from19.6-83.2 with a mean of 47.9 cm. The mean height increment was 37.5, with the range of 19.0 to 71.2 cm in a similar study (Bhagya *et al.,* 2020). The number of leaflets varied from 259.3 to 346.7 with a mean of 311.3, rachis length varied from 319.3 to 651.5 with the mean value of 519.9 cm, leaflet length varied from 71.6 to 125.4 cm with a mean of 103.2 cm, leaflet width varied from 3.0-6.5 cm with an average of 5.1 cm, leaf area varied from 3.2-13.6 cm^2 with an average of 9.5 cm, leaf dry weight varied from 2.4-16.8 kg with a mean value of 6.6 kg $leaf^{-1}$, specific leaf weight ranged from 0.42-1.34 kg with an average value of 0.70 kg, total leaf dry weight varied from 55.8 to 400.1 kg $palm^{-1}$ $year^{-1}$ with a mean of 154.5 kg. Concerning yield traits, bunch number varied from 1.67 to 16.67 with a mean of 10.11, fresh fruit bunches varied from 14.4 kg to 276.3 kg with a mean of 145.2 kg, average bunch weight varied from 5.6 to 24.4 kg with a mean value of 14.8 kg, bunch dry weight varied from 7.6 to 145.7 kg with a mean value of 76.6 kg, VDM varied from 82.9 to 476.2 kg with an average value of 200.5 kg, TDM varied from 129.4 to 561.4 kg with a mean of 277.1 kg and bunch index varied from 0.03 to 0.44 with a mean value of 0.27. In the previous reports, the mean number of leaflet (NLL) was 455.11 cm (Bhagya *et al.,* 2020; Balakrishna *et al.,* 2018).

A correlation study was done in these oil palm genotypes for 11 traits, and it was reported that the height of the palm was positively correlated with

Table 3. The correlation coefficient of morphological and yield traits in oil palm genotypes

	HT	HTINCR	GT	NLL	RL	LLL	LW	SR	BN	FFB	BI
HT	1										
HTINCR	1^{**}	1									
GT	0.049^{NS}	0.051^{NS}	1								
NLL	0.367^{*}	0.369^{*}	0.275^{*}	1							
RL	0.296^{*}	0.299^{*}	0.322^{*}	0.614^{*}	1						
LLL	-0.137^{NS}	-0.138^{NS}	0.242^{*}	-0.056^{NS}	0.019^{NS}	1					
LW	-0.072^{NS}	-0.072^{NS}	0.308^{*}	-0.036^{NS}	0.066^{NS}	0.942^{*}	1				
SR	-0.066^{NS}	-0.066^{NS}	0.309^{*}	0.014^{NS}	0.111^{NS}	0.029^{NS}	0.126^{NS}	1			
BN	0.239^{*}	0.236^{*}	-0.147^{NS}	0.116^{NS}	0.113^{NS}	0.047^{NS}	0.081^{NS}	0.142^{NS}	1		
FFB	0.673^{*}	0.673^{*}	-0.096^{NS}	0.396^{*}	0.374^{*}	-0.098^{NS}	-0.043^{NS}	-0.081^{NS}	0.624^{*}	1	
BI	0.205^{NS}	0.204^{NS}	-0.406^{*}	0.029^{NS}	-0.045^{NS}	-0.02^{NS}	-0.026^{NS}	-0.166^{NS}	0.687^{*}	0.715^{*}	1

HT-Height, HTINCR-Height increment, GT-Girth, NLL-Number of a leaflet, RL-Rachis Length, LLL-Leaflet length, LLW-Leaflet width, SR-Sex ratio, BN-Number of bunches, FFB-Fresh fruit bunches, BI-Bunch index height increment, NLL, rachis length (RL), bunch number (BN), and FFB. Height increment was positively correlated with NLL, RL, and BN and highly correlated with FFB, and these results are supported by previous studies in oil palm (Rafii *et al.,* 2013). The girth of the palm was positively correlated with NLL, RL, LLL, leaflet width (LLW), sex ratio (SR) and negatively correlated with bunch index. NLL was positively correlated with RL and FFB. Rachis length was positively correlated with FFB. LLL was positively correlated with LLW. BN had a significantly positive correlation with FFB and BI and FFB (Table 3). In this correlation study, we found out that an increase in the height of the palm will increase the bunch number and yield. It indicates the low height increment genotypes will have a low yield in terms of FFB and oil yield. These results coincide with previous reports (Bhagya *et al.,* 2020; Balakrishna *et al.,* 2018; Rafii *et al.,* 2013). In a previous study in oil palm, the height of the plant was strongly correlated with height increment (0.838) reported by Bhagya *et al.* (2020). These findings are congruent with earlier reports in oil palm (Mathur and Kumar, 2015).

One of the *Dura* genotypes yielded 276.2 kg FFB palm^{-1} year^{-1}, with an average of 15.3 bunches palm^{-1} year^{-1}, and the oil to bunch ratio was 20.9 per cent. Another *Dura* palm yielded 234.6 kg with 16.7 bunches and a 20.9 per cent oil to bunch ratio (Table 4). These *Dura* base materials can be used to develop the mother palms by crossing or inter se mating with D X D, and in the next generation, *Dura* will give more yield than the base material. These can be used to develop the mother seed garden due to the good yielding nature to develop *Tenera* commercial planting material production. Farmers are facing the problem of harvesting after 15-20 years of plantation due to more height of palm for this we can use low height increment dura palms gene can be utilized for development low height increment dura population by crossing programme..

Based on the descriptive analysis in 73 genotypes, four were selected for elite traits in a breeding point of view *viz.* low height increment, high FFB and oil yield. Among these four selected genotypes, the low height increment genotype (IC0610045-3) is *Dura* fruit form and height was 123 cm, and height increment was 19.16 cm (Fig. 1) as compared to other genotypes IC0610049-40 (435.3 and 75.4 cm), IC0610051-71 (487.3 and 77.2 cm) and IC0610049-39 (306.3 and 50.8 cm). Not much variation was observed in the girth of these genotypes. Rachis length, number of leaflet, leaflet length and leaflet width, sex ratio, number of bunches, FFB yield, bunch index and oil to bunch ratio was less in IC0610045-3 (319.3 cm, 262, 71.6 cm

Table 4. Morphological and yield data of selected oil palm genotypes

Trait	Nam-3 (IC0610045-3) (Dwarf *Dura*)			TG7-40 (IC0610049-40) (High yielding *Dura*)			TG9-71 (IC0610051-71) (High yielding *Dura*)			TG7-39 (IC0610049-39) (High yielding *Tenera*)		
	Mean	SE	CV	Mean	SE	CV	Mean	SE	CV	Mean	SE	CV
Height of palm (cm)	123.0	15.0	21.2	435.3	43.3	17.2	487.3	70.4	25.0	306.3	35.8	20.2
Height increment (cm)	19.6	65.0	5.7	75.4	17.4	66.7	77.2	4.1	9.1	50.8	2.5	9.1
The girth of the palm (cm)	217.7	2.8	2.3	312.1	78.7	67.3	266.0	3.5	2.3	294.1	14.0	8.2
Number of a leaflet (NLL)	262.0	26.0	17.2	332.7	9.0	4.7	331.3	18.0	9.4	314.7	6.4	3.5
Rachis length (cm)	319.3	19.4	10.5	577.7	21.4	6.4	541.1	13.6	4.4	559.2	5.9	1.8
Leaflet length (cm)	71.6	1.0	2.4	101.0	4.7	8.0	103.3	3.1	5.3	102.1	1.0	1.6
Leaflet width (cm)	3.0	0.2	9.1	6.5	0.3	8.5	5.2	0.2	6.0	5.3	0.5	15.5
Sex ratio	0.44	0.03	12.02	0.64	0.15	49.75	0.59	0.21	61.12	0.66	0.18	46.35
No. of bunches	7.3	1.2	28.4	15.3	4.8	54.3	16.7	2.2	24.4	11.7	3.4	50.2
FFB yield (Kg palm^{-1}year^{-1})	40.6	11.0	47.1	276.2	71.6	44.9	234.6	21.5	15.9	202.5	55.3	47.3
Bunch index	0.16	0.04	43.05	0.30	0.06	34.87	0.35	0.01	5.71	0.34	0.07	36.18
Oil to Bunch %	14.0	0.3	3.6	20.9	0.1	0.8	20.9	1.2	10.0	23.0	1.8	13.7

Fig. 1. Photograph of dwarf *Dura* genotype -IC0610045-3

and 3.0 cm, 0.44, 7.3, 40.6 kg, 0.16 and 14 per cent, respectively) as compared to other genotypes IC0610049-40 (577.7 cm, 332.7, 101.0 cm, 6.5 cm, 0.64, 15.3, 276.2 kg, 0.30 and 20.9%, respectively), IC0610051-71 (541.1 cm, 331.3, 103.3, 5.2 cm, 0.59, 16.7, 234.6 kg, 0.35 and 20.9%, respectively) and IC0610049-39 (559.2 cm, 314.7, 102.1 cm, 5.3 cm, 0.66, 11.7, 202.5 kg, 0.34 and 23.0%, respectively). By analysing other phenotypic traits, elite genotypes were analysed for the oil to bunch ratio. In our study oil to bunch ratio varied from 14 to 23.0 per cent. Nigerian *Dura* and Deli *Dura* progenies reported 19.4 per cent oil to bunch (Noh *et al.,* 2014), and other studies in oil palm reported 5.6 to 19.5 per cent oil to bunch with a mean of 11.7 per cent (Murugesan *et al.,* 2015). This indicates that if the height increment is more, all other parameters will be more, with a highly positive correlation and *vice versa.*

Conclusion

This evaluation study concluded that, among the 73 genotypes, four were promising for utilisation in the breeding programme. Nam-3 (IC0610045-3) for dwarf *Dura* character and TG7-40 (IC0610049-40) and TG9-71 (IC0610051-71) for high FFB yield and oil to bunch ratio *Dura* genotypes and TG7-39(IC0610049-39) genotype for *Tenera* with high FFB yielding and oil to bunch ratio. These selected genotypes were utilised to develop a seed garden for developing *Dura* blocks and *Pisifera* blocks (T x T crosses). *Dura* will be used as mother palm, and sterile pisifera palms obtained from T x T crossing will be used as a male parent to develop a hybrid *Tenera* for commercial plantation. Identified dwarf genotype is useful in biotechnological studies to identify the dwarf gene. This dwarf gene can be used to develop dwarf hybrids or varieties in the future for ease of harvesting and can extend oil palm plantation life**.**

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