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Genetic diversity of vegetative and bunch traits of African oil palm (*Elaeis guineensis*) germplasm in India

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ABSTRACT

Knowledge on genetic diversity among breeding materials could be an invaluable aid in oil palm (*Elaeis guineensis* Jacq.) improvement strategies. Germplasm from primary/secondary centres of origin were collected during 1994 under FAO programme and planted in the gene bank at DOPR Research Centre, Palode during 1998 were studied for genetic diversity. Twenty six accessions representing three African countries (Guinea Bissau, Tanzania and Zambia) were studied using 50 individual palms. Thirty numbers of vegetative and bunch component traits recorded during 2008 to 2013 were analysed in this study. An attempt was made using Shannon-Weaver Diversity Index (SWDI) with an objective to understand the level of diversity in these traits. In general, mean of all the accessions exhibited high levels (0.694) of diversity. Mean diversity estimate (0.778) was highest in Tanzanian source closely followed by Zambia (0.727) and least value (0.576) was observed in Guinea Bissau. Low diversity values (<0.32) for bunch weight, shell thickness, single fruit, and nut weight noticed in Guinea Bissau when compared to other sources. Highest level of homozygosity (SWD=0) for spine length was observed in Guinea Bissau population and similar trend of homzygosity noticed in other traits also in GB accessions. These findings combined with other evaluation results suggest that 'Tanzanian population' possess adequate genetic variability that is potentially useful for oil palm improvement program in India. More palms should be preserved for populations that have higher diversity and those with rare traits.

Key words: African germplasm, Diversity, India, Oil palm, Shannon-Weaver diversity index, Vegetative and bunch traits

Knowledge on genetic diversity among oil palm (*Elaeis guineensis* Jacq.) germplasm materials could be an invaluable aid in oil palm improvement strategies. Diversity in genetic makeup of oil palm parents induces wide variation in yield and growth among families (Agata 1994). Presence of genetic variability in germplasm helps to increase the breeding efficiency and these resulted into high selection gain. In Reciprocal Recurrent Selection (RRS) of breeding method, *dura* population is improved by crossing complementary *dura* and selected individual palms are selfed and *inter se* mated and planted as seed garden in the female block and selected individual *duras* are artificially hybridised with complimentary *pisifera* tested by progeny testing. Since hybrid vigor is contributed by genetic complementation between divergent parents, it can be assumed that parents with high genetic distance coefficients have the tendency to produce more vigorous hybrids. In breeding and selection apart from focus on fresh fruit bunch yield, vegetative characters are also taken into account to select desirable palms (Basri *et al*. 2003). Fruit component characters are of prime importance in classifying oil palm germplasm (Corley and Tinker 2003). Petiole characteristics give the indirect estimate of the dry weight of the entire leaf in oil palm (Corley *et al*. 1971). Rachis length and height increment are important traits for planting at high density and spacing in commercial plantations (Murugesan and Shareef 2014). Since 1960s, there has been very little diversification of oil palm (*Elaeis guineensis*) seed production, with mainly Deli × La Mé and Deli × Congo type crosses. Previously, seed production solely relied on the Deli *dura* as the maternal parent with the exclusive use of the AVROS *pisifera* as the pollen source (Corley and Tinker 2003). Oil palm seed production in India has been

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based on the Thodupuzha × NIFOR (Nigerian Institute for Oil Palm Research) *pisiferas* as they have high yield potential and utilized as genetic base for oil palm industry in India (Pillai and Nampoothiri 1981). In India, introduction of new material to increase variability should remain a priority for oil palm breeding programme. Guinea Bissau is one of the primary centres of origin and Tanzania and Zambia are the secondary diversity hotspots in Africa for oil palm. Oil palm germplasm from these countries collected under FAO programme, planted and conserved as field gene bank in India. Identification of the individual genetic factors underlying quantitative traits will provide the potential for improved oil palm breeding programmes (Rance *et al*. 2001). Study on diversity of vegetative and bunch quality traits in oil palm germplasm in India have not been reported so far. So, this effort was made to document the diversity of vegetative and bunch traits of African oil palm germplasm maintained at Directorate of Oil Palm Research, Research Centre, Palode, Kerala.

MATERIALS AND METHODS

Pillai *et al.* (2000) collected African oil palm germplasm during 1994 under FAO programme and planted in seven locations of India. In this article, twenty six accessions representing three countries sources (Guinea Bissau, Tanzania and Zambia) which were planted during 1998 at DOPR Research Centre, Palode were studied for genetic diversity utilising 30 traits of vegetative and bunch quality parameters. The details of the accessions used are given in Table 1.

The fresh fruit bunch yield data collection started in 2007-2008 from each palm and continued for six years consecutively. The measurement of each of the vegetative traits was carried according to the procedure proposed by Corley (1991) in the year 2013 at 16^{th} year after planting. Thickness of the shell and spine of leaf frond were measured with the help of digital vernier caliper. Bunch quality analysis was carried out during 2008-2013 and four bunches from each individual palms were taken for analysis and average of the different bunch components were included for diversity estimate. Procedure has been followed according to Blaak *et al.* (1963). All the values were summed to get total in each character state and scores were used to construct the diversity index. A total of 50 individuals representing 26 accessions native to three countries are used in the study. Proportion (Pi) of occurrence of each character state was used in each trait (i) and the Shannon and Weaver (1949) estimates have been worked out using the formula

$$H' = -\sum_{i=1}^{n} P_i \log_2 p_i$$

where n is the total number of character states, pi = proportion of individuals in the i^n state of character. Calculations were performed using the example of studies in sorghum (Grenier *et al*. 2001). Each H′ estimate is normalized by dividing $\log_2 n$.

Table 1 Details of African oil palm germplasm sources used in the study

Source	Altitude (M above MSL)	Longitude	Temperature (ºC)	Climate
Guinea Bissau	2.8 to 83.1	11º18' to 12º29'N	11-39	Hot and humid
Tanzania	0 to 1 200	1º to11ºS	14-30	Dry and hot
Zambia	1 280	5º to 20º S	11-30	Dry

RESULTS AND DISCUSSION

Variability of the vegetative and bunch quality traits is given in Table 2.

Tanzanian palm ZS 68 had highest height (11 m) with a height increment of 3.38 m. African population has a mean height increment of 0.44 m and GB10 had lowest increment of 0.2 m, whereas ZS 68 showed vigorous vertical growth (0.75 m). Palm no 84 from TS 11 had highest (92 cm) leaflet length coupled with high bunch weight (18.5 kg). There

Table 2 Variability of vegetative and bunch traits in African oil palm germplasm collections in India

Vegetative and bunch traits	Max	Min	SD	Mean
Height (m)	11.00	3.00	1.80	6.54
Girth (m)	4.63	1.80	0.54	3.12
Height increment (m)	0.75	0.20	0.11	0.44
Rachis length (m)	6.92	1.39	1.08	5.07
Rachis fresh weight (kg)	11.00	1.18	2.87	4.49
Rachis dry weight (kg)	3.94	0.50	0.77	1.82
Petiole length(cm)	120.00	35.00	16.15	89.92
Petiole depth (cm)	15.00	3.00	2.55	8.00
Peduncle length (cm)	31.06	11.08	5.58	19.68
Spine length (cm)	11.31	3.23	1.23	4.41
Spine thickness (mm)	4.43	1.89	0.60	3.05
Leaflet length (cm)	92.00	60.83	7.34	75.54
Leaf let breadth (cm)	5.95	2.16	0.97	4.08
Bunch weight (kg)	18.50	2.75	4.53	7.64
Stalk weight (kg)	2.30	0.11	0.57	0.79
Bunch length (cm)	51.26	18.50	7.42	31.46
Bunch circumference (cm)	115.00	41.50	17.78	73.32
Fruit to bunch (%)	67.45	31.62	8.40	49.33
Mean10 fruit weight (g)	168.00	17.00	44.41	68.27
Shell thickness (mm)	3.68	0.66	0.60	2.10
Mean 10 nut weight (g)	117.03	11.00	25.03	36.92
Shell to fruit (%)	55.33	14.41	7.88	36.89
Kernel to fruits (%)	27.34	5.47	5.12	16.57
Mesocarp to fruits (%)	70.33	30.34	8.65	46.59
Oil to wet mesocarp (%)	59.78	38.95	5.24	51.24
Single fruit weight (g)	16.77	1.70	4.44	6.83
Single nut weight (g)	11.79	1.08	2.51	3.69
Kernel oil to fruit (%)	12.43	1.33	2.51	6.79
Kernel oil to bunch (%)	7.71	0.69	1.44	3.36
Oil to bunch (%)	19.51	5.61	3.26	11.70

was wide variation in rachis length with a range of 1.39 to 6.92 which was recorded in palm no 77 and 57 of ZS 8 accession, respectively. Other promising palms with notable bunch quality parameters are ZS 55 (0.66 shell thickness), TS 82 (mesocarp to fruit = 70.33%), ZS 55 (Single nut weight = 11.79), TS 61 (Oil to Bunch = 20). Tanzania and Zambia samples reported to have higher pulp content at the time of exploration and collection of germplasm samples by Pillai *et al.* (2000). All the individual palms from Guinea Bissau have lower values for single fruit and nut weights with range between 1.72 to 6.12 for single fruit weight and 1.19 to 2.75. Among the vegetative parameters, spine thickness has lowest (0.11) standard deviation and petiole length had high value (16.15). In case of bunch quality traits mean 10 fruit weight showed highest (44.41) deviations followed by mean 10 nut weights (25.03). Stalk weight and shell thickness had low SD values of 0.57 and 0.60, respectively. Diversity estimates for each trait in each group are given in Table 3. Average estimate of total diversity in the study is 0.694 indicating the richness of the oil palm germplasm diversity in the different sources of collection.

Table 3 Shannon–Weaver index of diversity in African oil palm germplasm collection in India

Vegetative and bunch traits	Guinea Bissau	Tanzania	Zambia	Mean
Height (m)	0.858	0.905	0.805	0.856
Girth (m)	0.859	0.493	0.470	0.607
Height increment (m)	0.859	0.905	0.805	0.856
Rachis length (m)	0.497	0.697	0.780	0.658
Rachis fresh weight (kg)	0.133	0.727	0.624	0.495
Rachis dry weight (kg)	0.473	0.727	0.775	0.658
Petiole length (cm)	0.728	0.696	0.728	0.717
Petiole depth (cm)	0.895	0.785	0.825	0.835
Peduncle length (cm)	0.683	0.947	0.775	0.802
Spine length (cm)	0.000	0.531	0.488	0.340
Spine thickness (mm)	0.886	0.916	0.734	0.845
Leaflet length (cm)	0.718	0.86	0.874	0.817
Leaf let breadth (cm)	0.939	0.843	0.857	0.880
Bunch weight (kg)	0.235	0.947	0.833	0.672
Stalk weight (kg)	0.321	0.966	0.802	0.696
Bunch length (cm)	0.66	0.726	0.598	0.661
Bunch circumference (cm)	0.71	0.979	0.663	0.784
Fruit to bunch (%)	0.71	0.889	0.531	0.710
Mean10 fruit weight (g)	0.367	0.863	0.833	0.688
Shell thickness (mm)	0.315	0.693	0.697	0.568
Mean 10 nut weight (g)	0.235	0.693	0.833	0.587
Shell to fruit (%)	0.589	0.469	0.520	0.526
Kernel to fruits (%)	0.911	0.966	0.734	0.870
Mesocarp to fruits (%)	0.43	0.272	0.587	0.430
Oil to wet mesocarp (%)	0.866	0.947	0.850	0.888
Single fruit weight (g)	0.235	0.863	0.833	0.644
Single nut weight (g)	0.235	0.693	0.833	0.587
Kernel oil to fruit (%)	0.746	0.898	0.775	0.806
Kernel oil to bunch (%)	0.601	0.772	0.775	0.716
Oil to bunch (%)	0.589	0.671	0.587	0.616
Mean	0.576	0.778	0.727	0.694

As per the genetic variability parameters that were calculated, the oil palm germplasm collections from Africa exhibited higher level of polymorphism compared to the Deli dura population (Maizura *et al*. 2006). Diversity estimate varied from 0.00 (spine length of GB) to 0.979 (bunch circumference of Tanzania). Other characters recorded high mean diversity estimates are height (0.856), height increment (0.856), petiole depth (0.835), spine thickness (0.845), leaflet breadth (0.880) and kernel to fruits (0.870). Mean lower diversity recorded for spine length (0.340) and mesocarp to fruits (0.430). Highest level of homozygosity (SWD = 0) for spine length was observed in Guinea Bissau population followed by rachis fresh weight (0.133), mean 10 nut weight (0.235) and single nut weight (0.235). Over all, Guinea Bissau population showed high level of homozygosity as revealed by mean SWD of 0.576 followed by Zambia (0.727) and highest (0.778) heterozygosity reported in Tanzanian germplasm Palms from Guinea Bissau accession were highly homogenous in comparison to other groups and the same accession was genetically more distant from others (Mandal and Sushmita 2006). Oil palm was naturally found in Guinea Bissau and its coasts and island. The samples of GB were collected from an area at the edge of natural distribution (Pillai *et al*. 2000). Indigenous people used oil palm for wine extraction. In 1879, Portugal declared Guinea-Bissau as a Portuguese province and was made into a vast plantation of peanuts and oil palm (Carrere 2010). Hence current oil palm groves in Guinea Bissau could be homogenous commercial plantations established by Portuguese. Oil palm germplasm from Tanzania recorded high mean number of alleles per locus (1.7) and percentage of polymorphic loci (62.1%) in RFLP marker loci (Maizura *et al*. 2006). They also reported high diversity in Nigeria, Cameroon, Congo and low diversity in Ghana, Madagascar and Gambia. Bakoume *et al*. (2014) reported Chankabwimba location of Tanzania to possess very high (21) rare alleles of microsatellite marker loci. They also found no rare alleles in oil palm accessions from other locations of Tanzania. The oil palm groves collected from Tanzania are normally sparse and denser ones could be seen only in river banks near Ujiji. High degree of variation was observed for yield, fruit size and colour. Thin-shelled *duras* could be obtained from the collected palms in which the mesocarp percentage exceeded 60% (Pillai *et al*. 2000).

Consequently, preference would be given to selection of high mesocarp to fruit, considering the requirements for palm oil (Okoye *et al*. 2009). Accordingly, the practical information derived from this study on comparative values of important traits of individual palms of three different sources will be utilised while planning for *dura* improvement through hybridisation. Some of traits of practical importance are height increment, rachis length, spine length, bunch weight, shell thickness and other bunch quality components. Homozygosity reported in GB could be selectively utilised for improvement of specific traits namely development of medium size bunches which are desirable in palm oil processing. The minimum shell thickness of 0.66 mm recorded in ZS accession is one of the important results for oil palm breeding strategies. The shell-thickness gene has a clear commercial value, with the heterozygotes having at least a 30% yield advantage over either homozygote (Rance *et al*. 2001). Corley and Tinker (2003) reported shell thickness of more than 3 mm in *tenera* and less than 3mm in *dura*. The shell thickness gene has major effects on bunch composition with *teneras* typically having 30% more mesocarp and 30% higher oil content in bunches than *duras* (Murugesan and Gopakumar 2010). According to Hartley (1988), selection for the more bunch quality components such as mesocarp to fruit and kernel to fruit may be more effective to improve the overall potential of the palms. Diversity for most of the traits in Tanzanain indicates that this germplasm collection is having rich source of genes for oil palm improvement and Tanzania and Zambian population could be grouped together and Guinea Bissau could be placed in isolation. This coincides with geographical origin of the population as GB is located in western part of Africa, whereas TS and ZA located in central Africa. Low level differences in TS and ZS genetic diversity may be due to continuous distribution of *E. guineensis* in the land area, without geographical barrier to gene flow and the great human influence on material dispersion for this species (Zeven 1964). The palms from Guinea Bissau exhibited a low level of diversity. This is possible due to populations sampled during the expeditions might have been derived from a narrow gene pool. On the other hand samples from Tanzania and Zambia had wide gene pool. The results obtained in the study are of great benefits to the oil palm genebank manager and breeders. Knowledge derived from this work would serve as complementary information for developing the core collection and other genebank management activities. Maintaining *ex situ* living collections is very expensive. In order to reduce cost, conservator can reduce the number of palms for populations that relatively showed lower level of diversity for future conservation. More palms should be preserved for populations that have higher diversity and those with rare traits.

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