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Genetic variability analysis and selection of *pisifera* palms for commercial production of high yielding and dwarf oil palm planting materials

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ABSTRACT

This study was carried out to evaluate the performance of *pisifera* (male parent) palms, their general combining ability, and to identify suitable *pisifera* palms for large scale production of oil palm planting materials. Twenty-four (24) Deli *dura* palms were nested into 10 Nigerian *pisifera* male parent palms to produce 1056 *tenera* (D × P) palms. *Tenera* palms were planted in two replicates with 16 palms/progeny/replicate. Data collection on yield and yield component traits carried out consecutively for six years. Analysis of variance (ANOVA) followed by the mean comparison and general combining ability were carried out. These were done to know the performance of each of the *pisifera* parent palms. Additionally, multivariate analysis in form of cluster analysis was done using the quantitative traits. ANOVA showed significant variability among the *pisifera* palms based on the traits. Fresh fruit bunch (FFB) of each *pisifera* palm ranged from 173.80 to 211.46 kg/palm/year (kg/p/yr) with a trial mean of 191.92 kg/p/yr, while the oil yield (OY) ranged from 60.24 to 44.06 kg/p/yr with a trial mean of 53.72 kg/p/yr. Based on their mean comparison and the general combining ability, four palms (P01, P03, P09 and P06) have been ranked to be high yielding and good general combiner for FFB and oil yield. While palm P04, P06 and P09 were found to be good combiners for palm height. From these result, four *pisifera* palms (P01, P03, P09 and P06) have been identified to be high yielding (in terms of FFB and OY), dwarf height and suitable as pollen sources for commercial production of D × P planting materials.

1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a tropical perennial tree plant known for its great economic and developmental contribution in tropical regions of the world. Until today, oil palm is regarded as the highest edible oil producing plant among the other world known oil seeds (Mielke, 2013). One hectare of oil palm is capable of producing up to 10 times oil more than any other leading oil seeds with about 25 years economic lifespan. Among the ten major edible oil producing crops, oil palm accounts for 5.5% global land use of seed oil cultivation, producing more than 32.0% global oil and fat (Oil World Annual, 2014).

Oil palm as a perennial tree crop requires large area of land for cultivation, usually 136–140 palms/ha. With this, continuous increase in production of oil palm product to feed ever growing consumers seems to be impossible. However, this could be realized through breeding of high yield planting materials to ensure increased production per unit area. The rapid rate of industrialization coupled with environmental sustainability issues also hinders the availability of land for establishing new oil palm plantation (Gan and Li, 2014; Lam et al., 2009). With these scenarios, breeding of

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new high yielding planting materials to replant the existing old trees becomes imperative (Rafii et al., 2002; Corrêa et al., 2015).

Narrow genetic base of the oil palm has necessitated the introduction and continuous evaluation of germplasm materials obtained from abroad. Biologically, oil palms are categorized based on the presence or absence of shell in their fruits. The one with a thick shell having thin mesocarp is referred to as *dura* ($sh^{+}sh^{+}$), while the second type without shell is known as *pisifera* ($sh^{-}sh^{-}$). The hybrid of the two parents (*dura* × *pisifera*) with thin shell and thick mesocarp known as *tenera* ($sh^{+}sh^{-}$) is used as the planting materials. Oil palm germplasm prospection to Nigeria was embarked upon in 1973 covering 21 areas ranging from North central, to Southern region of Nigeria. Since then, the germplasm has been subjected to continuous evaluation, selection and utilization for yield improvement and widening of the genetic base (Rajanaidu, 1986, 1994). Nigerian *pisifera* palms were known for their low height increment and high yield thus making them one of the most desirable pollen sources for oil palm breeding program (Rajanaidu and Ainul, 2013). Short to dwarf palms are desirable for mechanization of harvesting process and ease agronomical practices. The first generation oil palm germplasm of Nigerian origin has been improved upon and released to the industry as a source of new planting material with great value added features (Rajanaidu et al., 2008).

Half-sib is a mating design in which the siblings have one parent in common, mostly male (Comtock and Robison, 1952). North Carolina mating design I (NCM I) is a widely used mating design for progeny testing, yield evaluation, combining ability, genetic variability and estimation of heritability and other variance components of male parent palms and finally breeding new planting materials in oil palm breeding program. In NCM I, a *pisifera* palm is crossed with at least two different *dura* palms with each *dura* palm appearing once throughout. The use of NCM I enables simultaneous evaluation of many *pisifera* palms, their suitability and yield potentials. In oil palm improvement program breeding, evaluation and selection of male palms (*pisifera*) are done through their progenies testing. This is because the *pisifera* palms are female sterile thus unable to bear fruits, and this makes them to be used as pollen source. *Pisifera* palms (male parent) with outstanding pedigree and proven records of high yield, short-dwarf height and good combining ability for other economic important traits are selected as pollen sources for commercial production of D × P planting materials (Noh et al., 2012).

This research article reports the analysis of variance, general combining ability, covariance structure analysis (cluster analysis) of elite Nigerian *pisifera* parent palms and their performance in Deli *dura* × Nigerian *pisifera* cross. This article also highlight the new pollen sources for commercial production of high yielding and dwarf planting materials. To the best of our knowledge, this article contains the first published report regarding the performance of these elite *pisifera* male parental palms.

2. Materials and method

2.1. Plant materials

The progenies of Deli *dura* × Nigerian *pisifera* were planted in trial Kulim Plantation estate in Sungai Papan, Johor, Malaysia in 2004. The Deli *dura* materials used as female parent came from the Sabah Breeding Programme (SBP). The SBP was established using reciprocal recurrent selection (RRS) by Hartley for Sabah state in 1964 (Corley and Tinker, 2003). The Deli *dura* materials used for establishing the SBP are sourced from Socfin and three other sources which could be traced to the four Bogor palms. The *pisifera* palms are the offspring of Nigeria population 12 materials planted in 1994 at Malaysia palm oil board (MPOB) Research Station in Ulu Paka, Terrenganu. Nigerian oil palm germplasm materials were collected in 1973 in East central state of Nigeria by Rajanaidu of the MPOB then under Malaysia agricultural research and development institute and, other officials from Nigerian Institute of Oil palm Research (NIFOR) (Rajanaidu et al., 1979). NCM I was used as the breeding design with 24 Deli *dura* nested into 10 Nigerian *pisifera* palms. The experimental design was randomized complete block design with two replicates, and 16 palms/progeny/replicate. The planting density was 136 plant/ha in an equilateral triangle pattern. The trial site mean annual rainfall (2004–2014) was 2814 mm/year, with mean ranging from 1957 to 3813 mm/yr.

2.2. Data collection

Data collection on individual palms for yield traits started five years after field planting and continued for six years (2009–2014), while the vegetative measurement was done once in 2012. The fresh fruit bunches (FFB) were harvested at two weeks interval with bunch number (BNO) and average bunch weight (ABW) recorded. FFB was further analyzed for bunch quality traits using the universally acceptable method of Blaak et al. (1963) The bunch quality traits recorded are mean fruit weight (MFW), fruit to bunch (F/B), oil to bunch (O/B), kernel to bunch (K/B), mesocarp to fruit (M/F), shell to fruit (S/F), oil to dry mesocarp (O/DM), oil to wet mesocarp (O/WM), oil yield (OY), kernel yield (KY), total economic yield (TEP). The vegetative traits are plant height (HT), frond production (FP), petiole cross section (PCS), rachis length (RL), leaflet number (LN), leaflet length (LL), leaflet width (LW), leaf area (LA), leaf area index (LAI), diameter (Dia).

2.3. Statistical analysis

The means of the data obtained were subjected to analysis of variance using general linear model (Proc glm) due to some missing data. The linear additive model solved for NCM1 analysis of variance was

$$Y_{ijkn} = u + r_i + m_j + f_{jk} + e_{ijkn}$$

where:

Y_{ijkn} = observations
U = overall mean
r_i = effect of i^{th} replications
m_j = effect of j^{th} males
f_{jk} = effect of k^{th} females to j^{th} males
e_{ijkn} = error associated with each observation

The means of the significant traits were separated using Duncan New Multiple Range test (DNMRT) using SAS 9.4 software (SAS Inc.). Combining ability of each *pisifera* palms was calculated for all the traits using this mathematical equation

$$G_i = \frac{X_i}{n_1} - \frac{X}{n_2}\ldots, \quad (1)$$

where, Gi is the GCA value for the ith male; Xi is the Total value for the ith male; X . . . is the grand total, n_1 and n_2 are the number of observations on n_1 and n_2, respectively. Multivariate analysis (cluster analysis) was done using DARwin 6.2 as explained by Perrier and Jacquemoud-Collet (2006) to see the covariance structure of the *pisifera* palms.

3. Results and discussion

3.1. Yield and yield components

The analysis of variance as presented in Supplementary Table S1 showed that influence of *pisifera* palms and, *dura* within *pisifera*