YIELD STABILITY OF OIL PALM PROGENIES IN EARLY AND LATER YEARS OF PRODUCTION

B. O. OPEKE and M. A. B. FAKOREDE
Department of Plant Science,
Obafemi Awolowo University,
Ile-Ife, Nigeria.

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ABSTRACT

The production of cultivars that are high yielding and stable in performance over a wide range of environments is a major objective in the breeding of oil palm (Elaeis sp.). Progenies resulting from mine crosses of oil palm were evaluated in the early (1-10 years), late (11-20 years), and the combined (1-20 years) periods of production for number of bunches (NB), fresh fruit bunch yield (FFB) and mean bunch weight (MBW). There were significant progeny differences for all periods of production for the three traits. Generally, about 70% of the variation in each trait was due to factors which were common to all environments; i.e. E-linear. Progeny x E-linear was also significant in a few cases. Mean for each trait was positively correlated with the regression coefficient (b-value).

In these progenies, the pattern of genotype x environment interaction, as shown by the joint regression approach, appeared to be determined in the early years of production and remains more or less the same in later years. NB and FFB were less variable than MBW over all production environments; therefore, MBW may not be a good selection criterion for yield in the oil palm.

KEYWORDS: Elaeis guineensis, genotype x environment interaction, environmental response

INTRODUCTION

Crop varieties commonly fail to respond consistently to variable environments and this is termed genotype x environment (G x E) interactions. G x E interaction reduces the predictability of genotypic performance from phenotypic measurements. In order to reduce biases associated with G x E interaction, plant breeders usually evaluate potential varieties in a sample of environments for which they are being developed. The common approach used to isolate the effect of G x E interaction is a conventional analysis of variance followed by a joint regression analysis. This procedure was first proposed by YATES and COCHRAN (1938) and later modified by FINLAY and WILKINSON (1963). The latter authors regressed mean yields of individual cultivars on mean yield of all cultivars tested in the same environments. The regression index (b-value) of each of the cultivars was used as a measure of adaptation or stability to these environments. EBERHART and RUSSELL (1966) regressed mean yield of individual cultivars on environmental indices, which were obtained by subtracting the grand mean from the mean yield of all genotypes in each environment. The regression provides two stability parameters: the regression coefficient (b-value), which is used as a measure of environmental response, and the mean square deviation from regression (S2_e), which is a measure of stability. Therefore, as noted by LANGER et al. (1979) stability of a variety is a measure of how well its actual yields in a set of environments are predicted by linear regression.

Although G x E interaction occurs in both annual and perennial or tree crops, the joint regression method have been applied more to annual and information on stability analysis in permanent crops is scanty. The objectives of this study were to (i) determine the stability and adaptation responses of some progenies of the African oil palm (Elaeis guineensis Jacq.) in early and later years of production and (ii) use the adaptation and stability indices...
to determine whether there was consistency of performance throughout the period of production.

MATERIALS AND METHODS

Progenies resulting from nine crosses of oil palm planted on Field 31-3 at the Nigerian Institute for Oil Palm Research (NIFOR), near Benin-City, were used for this study. Six of the progenies were dura x tenera crosses and the remaining three were Deli dura x tenera crosses. Dura and tenera are different fruit forms of the oil palm. Nursery and field plantings were carried out in 1959 and 1960, respectively. The experiment covered an area of 3.8 ha and spacing was 8.84 m triangular. The experiment was laid out as a randomized complete-block design with four replicates and 12 palms per plot. Palms came into bearing in 1963 at which time yield recording started and continued until 1982, a total of 20 years. Data were taken on individual palms (432 palms) for number of bunches (NB), fresh fruit bunch yield (FFB) and mean bunch weight (MBW) for the 20-year period.

The experiment was first analysed as randomized complete-block design with years as random environments. The 20-year period was arbitrarily divided into three sets: years 1 to 10, 11 to 20 and 1 to 20, and analysis of variance (AOV) was performed on each set. Subsequent to the conventional AOV, the three sets of data were subjected to stability analysis, using the model of EBERHART and RUSSELL (1966), i.e.

\[
Y_{ij} = \bar{x}_i + B_i + d_{ij}
\]

where \(Y_{ij}\) = mean of the \(i^{th}\) progeny at the \(j^{th}\) environment

\(i = 1, ..., 9; j = 1, ..., 10\) or 20.

\(B_i\) = regression coefficient that measures the response of the \(i^{th}\) progeny to varying environments.

\(d_{ij}\) = environment index calculated as the mean of all progenies at the \(j^{th}\) environment minus the overall mean, i.e.

\[
I_j = \frac{\left(\sum Y_{ij}/g\right) - \left(\sum Y_{ij}/gn\right)}{g - 1}
\]

\[
\sum I_j = 0, g = 9, n = 10\) or 20.

\(d_{ij}\) = deviation from regression of the \(i^{th}\) progeny in the \(j^{th}\) environment.

The proportion of total variation explained by regression \(r^2\) was obtained as

\[
r^2 = \frac{\left(\sum Y_{ij} I_j\right)^2}{\sum Y_{ij}^2 / n}
\]

The hypothesis that a regression coefficient did not differ significantly from unity was tested by approximate t-test as follows:

\[
t-test = \frac{r_{00} \sqrt{df}}{\sqrt{\frac{\sum d_{ij}^2 / \frac{n}{2}}{\sum I_j^2}}}
\]

The error used in the regression analysis of variance was obtained by dividing the pooled error from the AOV by number of replications, since stability was performed on progeny means across replications (SINGH and CHAUDHARY, 1977). Similarly to BILBRO and RAY (1976), \(b\) and \(s_d^2\) values were used as measures of environmental response or adaption and stability, respectively. A progeny with \(b = 1.0\) was considered adapted to all environments. A progeny with \(b > 1.0\) was adapted to high yielding environments and that with \(b < 1.0\) was adapted to low yielding environments. A stable genotype has \(s_d^2 = 0\) and high \(r^2\) value. An ideal progeny therefore had \(b = 1.0\), \(s_d^2 = 0\), high \(r^2\) and relatively high mean yield (i.e., high NB, FFB and MBW).

Simple correlation coefficients were computed among progeny mean (\(X\)) and the \(b\), \(s_d^2\) and \(r^2\) values for each set of data and each of the yield components NB, FFB and MBW.

RESULTS

Stability analysis partitioned the environment plus the progeny x environment interaction variance into three components (i) mean squares due to factors which were common to all environments, i.e. E-linear; (ii) mean squares due to regression of the traits (NB, FFB or MBW) for each progeny on the environmental indices, i.e. Prog. x E-linear; and (iii) mean squares due to deviation from regression (pooled deviations). For the first 10 years of production, all sources of variation, except the pooled deviations, were significant (Table 1). Non-significant pooled deviations indicated that the progenies did not differ for stability of performance during this period. Significant E-linear indicated linear response to changes in environmental factors, while significant Progeny x E-linear indicated that the progenies differed for linear response to the environments during this period.

For the 11 to 20-year period of production, all sources of variation, except Progeny x E-linear and pooled deviations, were significant (Table 1). In the combined analysis (i.e. the 20 year period) all sources of variation, except the pooled deviations for the three traits and Progeny x E-linear for FFB, were significant.
<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>NB</th>
<th>MWB</th>
<th>FFP</th>
<th>MWB</th>
<th>FFP</th>
<th>MWB</th>
<th>FFP</th>
<th>MWB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-10 Year Periods</td>
<td>1-20 Year Period</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean Squares</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant F-test at 0.05 and 0.01 levels of probability, respectively.

Degrees of Freedom for 1-20 Year Period:

<table>
<thead>
<tr>
<th>MWB</th>
<th>FFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>

Skin yields and analysis for number of bunches (NB), fresh fruit bunch yield (FFP), and mean bunch weight (MWB) for

TABLE I
Grouping of the progenies on the basis of adaptation and stability indices revealed that for NB, two progenies had \( b < 1.0 \) and were therefore below average in environmental response for the 1-10 and 1-20 year periods (Table 2). Four of the progenies were of average response (\( b = 1.0 \)) while the remaining three were above average in environmental response (\( b > 1.0 \)) for the 1-10 and 1-20 year periods. Generally, all progenies had average environmental response in the 11-20 year period for all traits except for one progeny when NB is considered. For FFB, all progenies had consistent average response to the environment in the 1-20 year period, while in the 1-10 year period only seven progenies were of average response, while one progeny each had below and above average environmental response. There was no consistent pattern for MBW. Although for this trait, three progenies were adapted to each of the environments in year 1-10 and 1-20, they were not the same progenies.

Simple linear correlations among mean yield (\( \bar{X} \)), environmental response index (\( b \)) and stability parameters (\( S_d^2 \) and \( r^2 \)) are presented in Table 3. In most cases, \( \bar{X} \) was positively correlated with \( b \), \( r^2 \) and \( S_d^2 \). The few exceptions occurred during the 11-20 year period and these involved NB and FFB. As expected, \( r^2 \) and \( S_d^2 \) consistently showed negative correlation, while \( b \) and \( r^2 \) were positively correlated. For MBW, \( b \) and \( S_d^2 \) were positively correlated for all the production periods, while they were generally negatively correlated for NB and FFB, for the 1-10 and 11-20 year production periods. The 1-20 year period showed positive correlation between \( b \) and \( S_d^2 \) for NB, but negative correlations for FFB.

### TABLE 2

<table>
<thead>
<tr>
<th>Adaptation Parameters</th>
<th>Production period (yrs.)</th>
<th>NB</th>
<th>FFB</th>
<th>MBW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-10</td>
<td>11-20</td>
<td>1-20</td>
<td>1-10</td>
</tr>
<tr>
<td>( b )-values ( b &gt; 1.0 )</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>( b = 1.0 )</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>( b &lt; 1.0 )</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>( S_d^2 )-values ( S_d^2 = 0 )</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>( S_d^2 = 0 )</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( b ) and ( S_d^2 )-values ( b = 1.0, S_d^2 = 0 )</td>
<td>4</td>
<td>8</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>( b &gt; 1.0, S_d^2 = 0 )</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
**TABLE 3**

Correlation coefficient among mean yield (\( \bar{X} \)), adaptation index (b) and stability parameters (\( S_d^2 \) & \( r^2 \)).

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Correlated</th>
<th>1-10 year Period</th>
<th>11-20 year Period</th>
<th>1-20 year Period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NB</td>
<td>FFB</td>
<td>MBW</td>
</tr>
<tr>
<td>1 ( \bar{X} ) with 2 b</td>
<td>0.801**</td>
<td>0.859**</td>
<td>0.850**</td>
<td>0.543</td>
</tr>
<tr>
<td>( \bar{X} ) ( r^2 )</td>
<td>0.431</td>
<td>0.433</td>
<td>0.858**</td>
<td>-0.304</td>
</tr>
<tr>
<td>( \bar{X} ) ( S_d^2 )</td>
<td>0.305</td>
<td>0.004</td>
<td>-0.151</td>
<td>0.075</td>
</tr>
<tr>
<td>b ( r^2 )</td>
<td>0.764*</td>
<td>0.740*</td>
<td>0.672*</td>
<td>0.704*</td>
</tr>
<tr>
<td>b ( S_d^2 )</td>
<td>-0.021</td>
<td>-0.223</td>
<td>0.244</td>
<td>-0.255</td>
</tr>
<tr>
<td>( r^2 ) ( S_d^2 )</td>
<td>-0.608</td>
<td>-0.787</td>
<td>-0.487</td>
<td>-0.887**</td>
</tr>
</tbody>
</table>

* ** Significant at 0.05 and 0.01 levels of probability, respectively.

**DISCUSSION**

Substantial genetic variability among progenies was indicated by the highly significant progeny mean squares. Analysis of variance performed on individual palm basis showed significant mean squares for the palm/progeny source of variation. This may be due to the various fruit forms (\( dura \) and \( tenera \) present within a progeny. However, palm/progeny \( x \) environment mean squares was not significant for all traits. This indicates that the relative performance of palms (regardless of their fruit form) in a progeny was maintained from year to year. Therefore any residual environmental effects from previous years affected all the palms within a progeny relatively equally. This is desirable since the breeder can expect consistent performance from any of the palm within the selected progenies in a breeding programme.

Highly significant E-linear mean square suggested that climatic factors, soil fertility levels and other factors common to all environments accounted for a large proportion of the variation in the environment. The progenies in this study differed in their response to environments (b-values) as indicated by significant Progeny \( x \) E-linear mean squares in five of nine comparisons. The statistical significance of this source of variation occurred during the 1-10 and 1-20 year periods but not during the 11-20 year period. Moreover, grouping of progenies are shown in Table 2 suggested that the pattern of distribution in the 1-10 year period was identical to that of the 1-20 year period. It would seem, therefore, that the pattern of genotype \( x \) environment interaction in the oil palm, as shown by the joint regression approach, is determined in the early year of production and remains more or less the same in later years. It was further observed that there were no remarkable differences between Deli \( dura \) x \( tenera \) and \( dura \) x \( tenera \) crosses for stability and adaptation parameters. Thus neither of these crosses could be said to be better adapted to a particular environment.

Generally, mean \( (\bar{X}) \) was positively correlated with b-value for the three traits. Similar pattern of correlation was observed by EBERHART and RUSSELL (1966) in maize (\( Zea mays \) L.) and OBISANJU and FATUNLA (1983) in oil palm. During the period involving years 11-20, mean yield and b-values for NB and FFB were negatively correlated. Relating the pattern of correlation in later years of production to the nonsignificant differences in environmental response of progenies for the same period suggests that poor yielding genotypes at earlier stages of production became adapted to high yielding environments during the 11-20 year period. The inconsistency in the grouping of progenies according to their b-values for MBW suggests that this trait is highly variable, perhaps because it is obtained from two traits; NB and FFB. Thus MBW was not predictable and would not be a good selection criterion for yield improvement in the oil palm. FFB was the least variable of the three traits. By the eleventh year of production, the progenies were not only stable \( (S_d^2 = 0) \) in the expression of this trait, but were also adapted to all production environments.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


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**ABSTRACT**

The construction of cultivars that are high yielding and stable in performance over a wide range of environments is an important objective in the breeding of oil palm (*Elaeis guineensis*). Properties related to production of oil from whole oil palms were evaluated at the young and mature stages to determine the potential for high yield and stability. Parameters of production for bunch yield were determined at 25 and 50 years of age, as well as at their respective growth stages. Parameters such as stability, adaptation, and yield were significantly different between the young and mature stages. The results suggest that the young stages are more important for yield and stability than the mature stages.

**EXPERIMENT**

Crop variation was examined in terms of its susceptibility to variable environments. This is achieved through the evaluation of adaptation to specific environments, which reduces the predictability of genotype performance in other environments. The study was conducted at the young and mature stages to evaluate potential variation in a sample of genotypes for which there are few developed. The objective was to understand the effect of genotype-environment interaction on the performance of all genotypes in each environment. The regression was analyzed for the stability parameters of the regression model, which is used to evaluate the impact of environmental factors on the mean square deviation from the regression line. The measure of stability is therefore, as noted by LAMONTE (1975), a measure of the stability of the regression model. The measure of stability is a useful tool for predicting the performance of cultivars.

Although several methods for evaluating the stability of genotypes have been developed, the regression method has been shown to be reliable and informative. The stability concept is a measure of variability and adaptation. The objectives of the study were to determine the stability and adaptation of genotypes of some propensities of the young oil palm (*Elaeis guineensis*).