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# Genotype × Environment Interaction for Bunch Yield and Its Components in the Oil Palm (*Elaeis guineensis*, Jacq.)

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**Summary.** There were significant differences between hybrids for number of bunches (NB), mean bunch weight (MBW) and fresh fruit bunch yield (FFB). For the hybrid population as a whole, significant hybrid × year (environment) effects were also observed for the two yield components and for yield per se. The linear component of the hybrid × year effect was also significant. There were highly significant and positive correlations between FFB, NB and MBW hybrid means and the regression co-efficients of the hybrid means on the environmental index. There were no significant associations between these means and mean square deviations from regression ($s^2d$) for these traits.

**Key words:** Stability – Adaptation – Fitness trait – Bunch yield – Oil palm – *Elaeis guineensis*

## Introduction

Breeding for stable genotypes has received much attention and several methods have been proposed to quantify the differential responses of varieties to environments. The approach to quantify stability of individual genotypes using a regression techniques was first proposed by Yates and Cochran (1938). This was rediscovered and modified by Finlay and Wilkinson (1963), who regressed mean yields of all cultivars in a series of environments and used the regression indices (b-values) of each of the cultivars as a measure of their adaptation or stability to these environments. Eberhart and Russel (1966) regressed mean yieds of individual genotypes on environmental indices, which were calculated by subtracting the grand mean from the mean yield of all genotypes in each environment. The regression provides two stability parameters, the regression coefficients (b-values) and the mean square deviation from regression (a measure of departure of individual genotype from its linear response to the environment). Information on stability analysis of production in tree crops is scanty.

The objectives of this study were to evaluate FFB potential of hybrid families to determine the nature of their genotype × environment interaction over a number of years, and to use their adaptation/stability indices to group the 49 hybrid families.

## Materials and Methods

Forty nine *dura* × *pisifera* hybrid families of oil palm. (*Elaeis guineensis*, Jacq.) planted on Field 4–1 at the Nigerian Institute of Oil Palm Research (NIFOR) in Benin were used for this study. *Dura* and *pisifera* are different fruit forms of oil palm. Dura palms produce thick shells while pisifera palms lack shells. The hybrid is referred to as *tenera* and has thin shells. The *pisifera* palms are generally incapable of producing bunches and are therefore used as males. Nursery and field plantings were carried out in May 1951 and May 1952 respectively. Field spacing was 8.8 meters triangular. A 7×7 quadruple lattice design with four replicates was used. There were 16 plants per plot. Palms came into bearing in 1956, when harvesting also started. Data were taken on individual plams (3,056 palms) for NB, FFB and MBW from 1956 to 1969.

The experiment was analysed as a quadruple lattice (Goulden 1960). Stability analyses were subsequently performed for each of the three traits.

The model given below was used to estimate stability indexes, linear regression and deviations from regression (Eberhart and Russell 1966).

$Y_{ij} = U_i + b_i I_j + D_{ij}$

where $Y_{ij}$ = mean of the $i^{th}$ hybrid in the $j^{th}$ environment (year)

$i = 1 \ldots\ldots\ldots 49$ (v)
$j = 1 \ldots\ldots\ldots 14$ (n)

$U_i$ = mean of the $i^{th}$ hybrid family across all environments.

$b_i$ = regression coefficient that measures the response of the $i^{th}$ hybrid at the $j^{th}$ environment.

$D_{ij}$ = deviation from regression of the $i^{th}$ hybrid.

$I_j$ = environmental index, calculated as the mean of all hybrids at the $j^{th}$ environment minus the overall mean i.e.

$I_j = (\sum_i Y_{ij}/49) - (\sum_i \sum_j Y_{ij}/686)$

$\sum_j I_j = 0.$

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**Table 1.** Stability analyses for number of bunches (NB) fresh fruit bunch yield (FFB) and mean bunch weight (MBW)

| Source | df | Mean | Squares | |
|---|---|---|---|---|
| | | NB | FFB (kg/plot) | MBW (kg/plot) |
| Hybrids (H) | 48 | 13,987** | 1,006,352** | 112.5** |
| Year (E) | 13 | 240,709** | 22,104,528** | 3,987.6** |
| H×E | 624 | 1,552** | 94,924** | 28.5** |
| E Linear | 1 | 781,864** | 71,504,287** | 12,115.7** |
| H×E Linear | 48 | 65,828** | 5,443,370** | 872.6** |
| Pooled deviations | 588 | 266** | 23,479** | 1.1** |
| Pooled error[a] | 1,719 | 86 | 8,661 | 0.44 |

** Significant at 0.01 level of probability
[a] Pooled error from the quadruple lattice analysis of variance

The hypothesis that each regression coefficient does not differ from unity was tested using the appropriate t-test (Eberhart and Russell 1966; Gamma and Hallauer 1980). A 95% confidence limit was placed on each regression coefficient, based on a two-tailed test. When the deviation mean square for each hybrid is not significant at the 0.05 probability level, it was assumed to be due to chance and that $S^2d = 0$. Pooled errors used in the regression analysis of variance were obtained by dividing the appropriate pooled error from a quadruple lattice test by the number of replications, since stability analyses were performed on hybrid family means over replications (Singh and Chaudhary 1977).

In this study, b and $S^2d$ values were used as measures of general adaptation and stability respectively (Eberhart and Russell 1966; Fatunla and Frey 1974). A hybrid family with $b = 1.0$ is considered to be adapted to all environments, whereas one with $b > 1.0$ is better adapted to high yield environments and those with $b < 1.0$ are better adapted to low yield environments. A stable variety has an $S^2d$ that is not significantly different from zero. An ideal variety is one with $b = 1.0$, $S^2d = 0$ and has a high yield.

Simple product-moment correlation coefficients were determined among hybrid means and the b and $S^2d$ values for each of the three traits using the raw data and transformed data (logarithmic and square root).

**Table 2.** Grouping of 49 hybrids on the basis of stability and adaptation indexes for each trait

| Adaptation parameters | Traits | | |
|---|---|---|---|
| | NB | FFB | MBW |
| $b < 1.0$ | 17 | 6 | 14 |
| $b \approx 1.0$ | 21 | 38 | 21 |
| $b > 1.0$ | 11 | 5 | 14 |
| Total | 49 | 49 | 49 |
| Values of b and $S^2d$ | | | |
| $b \approx 1.0$, $S^2d \approx 0.0$ | 1 | 8 | 2 |
| $b > 1.0$, $S^2 \approx 0.0$ | – | 3 | 4 |

## Results

Mean square for hybrid (H), year (E), hybrid×year, E linear and pooled deviations were highly significant for all traits (Table 1). The regression coefficient of the hybrids included values from +0.31 to +1.84, +0.66 to +1.29 and +0.62 to +1.24 for NB, MBW and FFB, respectively. For each of the three traits, the 49 hybrids were placed in one of three groups on the basis of the magnitude of their b-values (Table 2). The range of the

**Table 3.** Subsets of 49 hybrids grouped on the basis of possible simultaneous selection of traits for stability and adaptation reactions

| Adaptation parameters | Different combinations of traits | | | |
|---|---|---|---|---|
| | NB, MBW, FFB | NB & MBW | NB & FFB | MBW & FFB |
| $b > 1.0$[a] | 0 | 2 | 1 | 2 |
| $b \approx 1.0$[a] | 4 | 6 | 14 | 8 |
| $b < 1.0$[a] | 1 | 5 | 2 | 3 |
| $S^2d \approx 0.0$[b] | 8 | 11 | 10 | 11 |
| $b \approx 1.0$ $S^2d \approx 0.0$ | 0 | 0 | 4 | 0 |

[a] Based 95% confidence limit on a two tailed test (df = 1,719)
[b] When the deviation mean square for each hybrid is not significant at 0.05 level of probability, it is assumed to be due to chance and that $S^2d \approx 0$)

**Table 4.** Correlation coefficients among mean yield ($\bar{x}$), adaptation index (b) and stability parameters ($S^2d$) for FFB and its components

| Statistics correlation | | | FFb and its components | | |
|---|---|---|---|---|---|
| Stat 1 | Stat 2 | | NB | MBW | FFB |
| $\bar{x}$ | b | i. | 0.62** | 0.66** | 0.56** |
| | | ii. | 0.60** | 0.67** | 0.55** |
| | | iii. | 0.62** | 0.67** | 0.56** |
| $\bar{x}$ | $S^2d$ | i. | 0.19 | 0.20 | 0.15 |
| | | ii. | 0.19 | 0.20 | 0.22 |
| | | iii. | 0.19 | 0.20 | 0.18 |
| b | $S^2d$ | i. | 0.25* | 0.27* | −0.17 |
| | | ii. | 0.13 | 0.23 | −0.06 |
| | | iii. | 0.19 | 0.24 | −0.12 |

i, ii and iii = estimates from raw, logarithmic transformed and square-root transformed data, respectively
**,* Significantly different from 0.0 at 0.01 and 0.05 levels of probability, respectively

central group (b≈1.0) was +0.84 to 1.19 for NB, +0.79 to +1.14 for MBW and +0.89 to 1.13 for FFB.

When all three traits were considered simultaneously, no hybrid had above average response in all three, four hybrids had average response (b≈1.0) while one hybrid had below average response to improving environmental indexes for all three traits (Table 3). Only eight hybrids were stable for all traits i.e. having $S^2d$ not significantly different from the error variance ($S^2d \approx 0$).

The range of hybrid means ($\bar{x}$) for NB, MBW, FFB included values between 75–143, 8.2–12.1 kg and 635–1,359.2 kg per plot, respectively. There were highly significant and positive correlations between means and regression coefficients for each of the three traits (Table 4). These associations were not substantially changed by logarithmic and square-root transformations. There were no significant association between $\bar{x}$ and $S^2d$ for any of the traits. The positive and significant association: between b and $S_2d$ for NB and MBW were reduced to nonsignificant levels in both transformations (Table 4).

## Discussion

Stability analysis of tree crops at a single location is complicated by biasing covariances arising from growing the same trees on the same plot throughout the evaluation period. We judge that the yearly variations in environmental factors such as rainfall, sunshine hours, number of dry days, temperature, humidity and heat units in this location were large enough (Obisesan and Fatunla in press) to allow us to screen for stable hybrid families. The parents of the 49 hybrid families reported herein are also diversified enough in their origin and yield characteristics to allow inferences bearing on oil palm populations.

Stability analysis permitted the partition of the year and hybrid × year mean squares into E linear and H × E linear. In another paper, it was demonstrated that while FFB, MBW and NB had a curvilinear response with age, transformation of the data eliminated this association (Obisesan and Fatunla in press). In the present paper, the overall linear response of all the hybrids with age is reflected in the E linear, while the individual linear response to age is contained in the H × E linear mean square.

Stability analyses were run for yield and two of its direct components, NB and MBW. None of the tested hybrids can be described as being ideal for the three traits, i.e. having $S^2d$ 0.0, b≈1.0 and high yields. The eight hybrids with b≈1.0 and $S^2d \approx 0$ for yield have near-average yields (102% of mean yield) while the three hybrids with b > 1.0, $S^2d \approx 0.0$ had yields of 104% of the mean. Only one of the three (hybrid 42) was substantially above average (117% of the mean). This hybrid is still only 87% of hybrid 44, the highest-yielding hybrid. This result is noteworthy, in that there was no significant correlation between $S^2d$ and mean values, yet the hybrid families with $S^2d \approx 0.0$ were generally low yielding.

Fatunla and Frey (1974) and Langer et al. (1979) reported highly positive correlations between means and b-values for grain yield, seed number, bundle weight and plant height of radiated and nonradiated oats.

Eberhart and Russell (1966) also found that these two statistics for grain yield in corn were positively correlated. Fatunla and Frey (1974) further observed that, for grain yield components, a positive association between means and b-values may be a rather general phenomenon for fitness traits. This association was not affected by logarithmic and square root transformation.

The parents of the 49 hybrids were sufficiently diverse to represent a random sample of the oil palm population. While the variation observed for yield, mean bunch weight and number of fruits were satisfactory, there is no hybrid that corresponds to an ideal variety. All high-yielding varieties had $S^2d > 0.0$. This may mean that in the oil palm, a simultaneous selection for high yield and stability as defined in this paper is not realizable. It may also suggest that the population under study needs to be enlarged considerably to recover such recombinants. It should also be noted that the parents are relatively unimproved populations and that several cycles of selection may be needed to bring together a combination of high-yielding and stable varieties. Since this is hardly realisable in tree crops, individual-plant selection may offer the opportunity to recover such rare combinations. The use of tissue culture in oil palm will allow the mass propagation of such selected individual palms.

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