Available online at www.elixirpublishers.com (Elixir International Journal)

Agriculture

Elixir Agriculture 47 (2012) 8946-8949

ISSN: 2229-712X

# Variation and correlation analysis of growth parameters in D x P oil palm (*Elaeis guineensis* J.) seedlings

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**ARTICLE INFO**

**Article history:**

Received: 25 April 2012;

Received in revised form: 2 June 2012;

Accepted: 14 June 2012;

**Keywords**

Elaeis guineensis Jacq..
Co-efficient of variation,
Growth parameters,
Genotypic variance,
Phenotypic variance,
Heritability,
Correlation,
Selection.

**ABSTRACT**

Phenotypic and genotypic variability, heritability and correlation among growth parameters were examined in Dura x Pisifera (DxP) oil palm seedlings at the Oil Palm Research Institute Kade between July 2008-Feb 2010. All the characters studied were significantly and positively correlated with each other except leaf area ratio (LAR) in which the correlations were negative with 7 other traits. The highest correlations were between total plant dry weight and crop growth rate (CGR) and between leaf area and plant height. Net assimilation rate (NAR) and (CGR) had the highest phenotypic and genotypic coefficient of variation. For plant biomass the highest variation was observed in total plant dry weight. Broad sense heritability estimates (for growth parameters) were highest for LAR, NAR, LAI and CGR while for plant biomass the highest was for total plant dry weight. The implications of these findings in oil palm nursery management and seedlings selection are discussed.



## Introduction

The oil palm (*Elaeis guineensis*) is of African origin (Jacquemard, 1998) and is the most important member of the genus *Elaeis* in terms of production and economic yields (Jones and Hughes, 1989). The oil palm provides approximately 17% of the world's supply of vegetable oils in the form of palm oil (Paranjothy, 1989).

The oil palm can produce up to six tonnes of oil per hectare per year for up to 25 years under good plantation management and favourable conditions.

In Ghana, the oil palm ranks second to cocoa in importance as a cash crop and is the only cash crop that can be handled from establishment to processing at the rural level.

Yield is a quantitative character that is largely influenced by the environment and hence has a low heritability (Johnson, 1989). As a result, the response to direct selection for yield may be unpredictable unless there is a good control of environmental variation.

Plant breeders are seldom interested in one character and therefore; there is the need to examine the relationship among various characters, especially yield and other characters.

Hardon *et al* (1969) observed a positive correlation between leaf area and bunch yield in oil palm. Numerous different parameters have been used to measure oil palm growth. In general a parameter with some obvious physiological significance should be chosen, for example, leaf area provides an estimate of photosynthetic potential, while the rate of leaf production will be related to the activity of the apical meristem.

For seedling selection purposes however, it is necessary to demonstrate that heritable variation in these parameters occur that could result in genetic improvements.

The main objective of this study was to assess the phenotypic and genotypic variability as well as heritability and correlation of growth parameters in DxP oil palm seedlings as an aid to early (indirect) selection of seedlings for high yield.

## Materials and methods

The experiment was conducted between July 2008 and February 2010 at the Plant Breeding Nursery of the Oil Palm Research Institute (OPRI), Kusi (0.6.00 N, 001.45 W).

Seeds from three Dura x Pisifera (DxP) oil palm progenies obtained from the Plant Breeding Division of OPRI were germinated using the dry heat method (Hartley, 1988). Germinated seeds were sown singly in black polybags (35.6 cm x 45.7 cm layflat) filled with a mixture of topsoil and sand in the ratio 2: 1. The topsoil used in filling the bags belonged to the Kokofu series (Ferri-Plinthic Acrisol – FAO/UNESCO). The lower third of the bags were perforated to enhance drainage of excess water. Bags were arranged at 90 cm triangular pattern.

A randomized complete block design in four replications involving three treatments (progenies) with a plot size of 30 plants was used.

Hand watering was done every other day. Sulphate of ammonia was applied at 25g dissolved in 9 litres of water to 200 seedlings weekly for the first four month. The seedlings were also mulched with sawdust. Routine weed control was carried out by hand picking weeds from the polybags as and when necessary and by spraying with roundup herbicide at a rate of

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200 mls per 15 litres of water to the area between subplots at three months intervals.

Disease control was carried out by weekly spraying of plants with 14g Dithane M45 (Mancozeb 800g/kg) in 9 litres of water. Insect pests were controlled by spraying with "Dursban 4E" (480 g/l Chlorpyrifos) insecticide at a rate of 100 mls to 15 litres of water on weekly basis.

Data were recorded from 10-bordered plants randomly selected from each plot. Data collection commenced when seedlings were four months old and continued on a monthly basis for seven months. Plant dry weight was determined twice during the experiment, at 4 months after planting and at the end of the experiment (11 months after planting).

The following data were collected:

**Number of leaves per plant:** This was determined by counting the number of leaves on a seedling on a monthly basis and information obtained used in calculating the rate of leaf production**.**

**Plant height (cm):** This was measured as height from the soil level in the bag to the tip of the longest leaf using a meter rule at monthly intervals from four to eleven months.

**Butt circumference:** Butt circumference was determined monthly by using a vernier caliper to measure the diameter at two places on the butt 0.5 cm from the soil level. The circumference was determined by the formula πd where π was taken as 3.14 and d is the average diameter calculated.

**Leaf area:** A non-destructive method was used. The length and greatest width of each leaf were measured with a ruler on each of the record plants sampled per plot and the true leaf area determined by multiplying the product by appropriate correction factor as described by Corley (1976).

**Plant dry weight:** Plant dry weight was determined twice during the experiment, at 4 months after planting and at the end of the experiment (11 months). Five plants were sampled for this measurement. The plants were dug out and the soil in the bags loosened and carefully washed off the root. The plants were split separated into roots, leaves and stem portions, the last including leaf bases as well as true stem material.

The dry weight of plant parts and total plant dry weight was determined by drying to constant weight at 65 $^0$C in an oven).

The following growth parameters were calculated using the appropriate formulae.

$$\text{Net Assimilation Rate (EA)} = \frac{(W_2 - W_1)(\text{Log}_e A_2 - \text{Log}_e A_1)}{(t_2 - t_1)(A_2 - A_1)} \quad \text{g/dm/wk}$$

$$\text{Relative Growth Rate (Rw)} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{t_2 - t_1} \quad \text{\%/day}$$

$$\text{Leaf Area Ratio (F)} = \frac{(A_2 - A_1)(\text{Log}_e W_2 - \text{Log}_e W_1)}{(\text{Log}_e A_2 - \text{Log}_e A_1)(W_2 - W_1)} \quad \text{cm}^2/\text{g}$$

$$\text{Relative Leaf Area Growth Rate (RA)} = \frac{\text{Log}_e A_2 - \text{Log}_e A_1}{t_2 - t_1} \quad \text{cm2/g}$$

$$\text{Leaf Area Index (L)} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Crop Growth Rate (C) = Net Assimilation Rate x Leaf Area Index

= EA x L

Where $W_1$ and $W_2$ and $A_1$ and $A_2$ are total dry weights and leaf areas respectively at times $t_1$ and $t_2$.

An analysis of variance was performed on the data and phenotypic correlation among growth parameters and other traits determined. Genotypic and phenotypic coefficients of variation were determined using the method of Burton (1952) as follows:

$$PCV = \frac{\sigma_p x100}{\overline{X}}$$

Where σ is the standard deviation and $\overline{X}$ the general mean of the trait being investigated. The genotypic coefficient of variation is therefore as follows:

$$GCV = \frac{\sigma_g x100}{\overline{X}}$$

Heritability ($h^2$) in the broad sense was estimated as $h^2 = \frac{\sigma_g^2}{\sigma_p^2}$

Where $\sigma_g^2$ and $\sigma_p^2$ refer to genotypic and phenotypic variance respectively (Allard 1960).

**Results**

Phenotypic and genotypic coefficients of variation for the various growth parameters and for plant biomass are shown in Table 1. A wide range of variation in plant growth parameters was observed.

For plant growth parameters, phenotypic coefficient of variation ranged from 9.46% for leaf number to 81.57% for NAR while genotypic coefficient of variation ranged from 3.44% for leaf number to 75.51% for NAR. NAR and CGR had the highest phenotypic and genotypic coefficients of variation.

For plant biomass, phenotypic coefficient of variation ranged from 40.99% for both root dry weight and leaf dry weight to 67.66% for total plant dry weight, while genotypic coefficient of variation ranged from 11.98% for leaf dry weight to 54.91% for total plant dry weight. Plant biomass generally had low to medium genotypic coefficient of variation values.

Table 2 shows phenotypic and genotypic variances of the various parameters studied and their associated broad sense heritability estimates. A large proportion of the phenotypic variance of LAR (91.36%), NAR (85.68%), RGR (80.38%), LAI and CGR (68.03%) and total dry weight (65.86) was attributable to genotypic differences among the progenies, however only 7.7% and 8.5% of the differences in plant height and leaf dry weight respectively could be accounted for by genotypic differences.

Table 3 shows the estimates of phenotypic correlation among the traits studied.

All the characters were significantly and positively correlated with each other ($P<0.001$) except with LAR which though significant ($P<0.05$-$P<0.001$) was negatively correlated with the other traits. The correlation between LAR and LAI was however not significant.

The highest significant correlations ($P<0.001$) were found between total plant weight and crop growth rate ($r^2 = 0.90$) and between leaf area and plant height ($r^2 = 0.82$).

**Discussion**

A wide range of variation was found in the plant growth parameters studied as indicated by their phenotypic and genotypic coefficient of variation. This range of overall variation in the parameters studied is quite encouraging since for any improvement and selection in any desired character to be possible, there should be the existence of wide variability in the population for that character.

The low levels of variation in some of the characters (root, leaf and stem dry weight, leaf number, leaf area, plant height, butt circumference and RLAGR) suggest little potential for their improvement through selection. An examination of their broad sense heritability estimates reveal that generally for those characters with low variability, their heritability estimates were also low. In particular, leaf number per plant; plant height, RLAGR, stem and leaf dry weights had heritability estimates below 20% suggesting large environmental influence on these characters. It also suggests difficulty in controlling the environmental influences and reducing them so that genetic effects can be effectively isolated.

The parameters with high heritability estimates indicate high genetic control over their expression (CGR, LAI, LAR, RGR, NAR and Total Plant Dry Weight) and the opportunity to select for desired levels of expression.

Hardon *et al*, (1972) however observed a low genetic component of variation in NAR in oil palm and suggested that improvement in yield through selection for high NAR may not be very rewarding because in mature palms, NAR is affected by many factors. During seedling growth in the relatively uniform nursery environment however, it appears probable that differences in NAR will indicate real differences in photosynthetic rate. Thus NAR could be considered as a seedling selection criterion.

LAR had the highest heritability estimate but it was significantly and negatively correlated with all other important growth parameters including Crop Growth Rate. Hardon *et al* (1972) made similar observations and showed that selection for LAR in oil palm might not be very successful. Breure and Corley (1983) also reported that selection for high LAR in giving palms capable of yielding well at high density was not effective.

Several workers have found significant correlation between vegetative characters of oil palm in the nursery and yield. Subronto *et al* (1989) in a study on nursery seedlings of oil palm showed that on several crosses the butt diameter and leaf area could be used as selection criteria in 9-month-old seedlings as each was highly correlated with yield.

Tan and Hardon (1976) reported that leaf area in the nursery was positively correlated with crop growth rate, mean leaf area and total plant dry weight. It was also significantly correlated with leaf area index, bunch yield and bunch number. Lucas (1980) observed leaf number, seedling height and girth to be highly and positively correlated with one another and with the dry weight of seedlings in a polybag nursery in Nigeria.

The results of this work support most of these findings. Leaf area was observed to be strongly correlated with plant height and agrees with the observations of Hardon *et al* (1969). This may be due to the fact that taller plants are not mutually shaded by other plants and receive maximum sunlight and hence benefit more from the effect of light in leaf expansion through increased cell differentiation and extension and the stimulation of differentiation of vegetative primordia in apical meristems.

Corley (1973) observed that NAR was negatively correlated with LAI. In this present work even though the association was not negative, it was low and not significant. Increasing leaf area index results in mutual shading, which ultimately reduces NAR.

Leaf Area Ratio (LAR), gives an estimate of the proportion of photosynthetic to non-photosynthetic tissue and a probable explanation for the observed negative correlation between LAR and almost all the other parameters may be due to the fact that an increase in any of the other parameters is associated with increased plant dry weight which far exceeds the proportionate increase in accompanying leaf area, hence causing the ratio to reduce. Selection for high LAR therefore may result in a reduction in all the other characters.

Tan and Hardon (1976) observed that leaf characters measured at the later main nursery stage were found to be significantly correlated with many characters of the mature palm and concluded that nursery selection based on leaf characters could therefore result in higher growth rates in the field and higher yields in the oil palm.

**Conclusion**

Based on the observations made in this work and the findings of other workers, it could be concluded that for purposes of nursery selection, where high growth rate is required, leaf area per plant, leaf area index (LAI), total plant dry weight and crop growth rate (CGR) may be better nursery selection indices for predicting field performance and subsequent yield in oil palm. The use of NAR may be important in identifying palms that have some advantages in growth, which results in more rapid early development in the field.

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**Table 1: Phenotypic and genotypic coefficient of variation for plant growth parameters and biomass**

| Character | Pcv (%) | Gcv (%) |
|---|---|---|
| Leaf Number | 9.46 | 3.44 |
| Leaf Area ($cm^2$) | 33.46 | 19.35 |
| Plant Height (cm) | 13.59 | 3.77 |
| Butt Circumference (cm) | 17.28 | 8.97 |
| Root Dry Weight (g) | 40.99 | 25.01 |
| Stem Dry Weight (g) | 49.20 | 17.24 |
| Leaf Dry Weight (g) | 40.99 | 11.98 |
| Total Plant Dry Weight (g) | 67.66 | 54.91 |
| NAR (EA) | 81.57 | 75.51 |
| RGR (RW) | 34.79 | 31.19 |
| RLAGR (RA) | 23.00 | 7.00 |
| LAR (F) | 65.77 | 62.86 |
| LAI (L) | 60.28 | 49.72 |
| CGR (C) | 80.43 | 64.86 |

NAR-Net Assimilation Rate, RGR-Relative Growth Rate, RLAGR-Relative Leaf Area Growth Rate, LAR-Leaf Area Ratio, LAI- Leaf Area Index, CGR-Crop Growth Rate.

**Table 2: Phenotypic and genotypic variances and heritability of plant growth parameters and dry weight (g) of plant parts**

| Character | Phenotypic variance | Genotypic variance | Heritability (%) |
|---|---|---|---|
| Leaf number | 0.542425 | 0.07180 | 13.24 |
| Leaf area ($cm^2$) | 363,175.60 | 121,438.0 | 33.44 |
| Plant height (cm) | 87.50 | 6.74 | 7.70 |
| Butt circumference (cm) | 3.881 | 1.041 | 26.82 |
| Root dry weight (g) | 548.2 | 204.00 | 37.21 |
| Stem dry weight (g) | 258.88 | 31.80 | 12.28 |
| Leaf dry weight (g) | 193.64 | 16.55 | 8.50 |
| Total plant dry weight (g) | 3,782.27 | 2,491.0 | 65.86 |
| NAR | 0.08766 | 0.07511 | 85.68 |
| RGR | $1.2565 \times 10^{-5}$ | $1.101 \times 10^{-5}$ | 80.38 |
| RLAGR | $3.228 \times 10^{-6}$ | $2.99 \times 10^{-7}$ | 9.26 |
| LAR | 427.31 | 390.37 | 91.36 |
| LAI | 2.4975 | 1.6945 | 68.03 |
| CGR | 0.5182 | 0.3370 | 68.03 |

NAR-Net Assimilation Rate, RGR-Relative Growth Rate, RLAGR-Relative Leaf Area Growth Rate, LAR-Leaf Area Ratio, LAI- Leaf Area Index, CGR-Crop Growth Rate.

**Table 3: Phenotypic correlation coefficients for association among traits**

| Trait | Leaf Number | Leaf area | Plant *Height* | Butt Circum. | Total plant dry weight | NAR | RGR | LAR | LAI | CGR |
|---|---|---|---|---|---|---|---|---|---|---|
| Leaf Number | - | 0.76*** | 0.73*** | 0.88*** | 0.70*** | 0.48*** | 0.63*** | - 0.38*** | 0.62*** | 0.69*** |
| Leaf area | | - | 0.90*** | 0.79*** | 0.70*** | 0.33*** | 0.49*** | - 0.24* | 0.74*** | 0.64*** |
| Plant Height | | | - | 0.80*** | 0.71*** | 0.37*** | 0.46*** | - 0.28** | 0.76*** | 0.65*** |
| Butt Circum. | | | | - | 0.71*** | 0.46*** | 0.56*** | - 0.39*** | 0.62*** | 0.69*** |
| Total plant dry weight | | | | | - | 0.77*** | 0.65*** | - 0.53*** | 0.57*** | 0.95*** |
| NAR | | | | | | - | 0.74*** | - 0.74*** | 0.12* | 0.79*** |
| RGR | | | | | | | - | - 0.57*** | 0.35*** | 0.72*** |
| LAR | | | | | | | | - | 0.07 | -0.51*** |
| LAI | | | | | | | | | - | 0.58*** |
| CGR | | | | | | | | | | - |

*, **, ***: Significant at 5%, 1% and 0.1% levels respectively.

NAR-Net Assimilation Rate, RGR-Relative Growth Rate, RLAGR-Relative Leaf Area Growth Rate, LAR-Leaf Area Ratio, LAI- Leaf Area Index, CGR-Crop Growth Rate.