

- [3] BREURE C. J. and CORLEY R. H. V. (1983). — Selection of oil palms for high density planting. *Euphytica*, **32**, p. 177-186.
- [4] CORLEY R. H. V., HARDON J. J., WOOD B. J. (1976). — *Oil palm research*. Elsevier scientific publishing company, Amsterdam, 532 p.
- [5] FREMOND (1950). — Hauteur des arbres-mères et sélection. *IRHO, Note intérieure*.
- [6] HARTLEY C. S. W. (1967). — The oil palm. *Tropical agriculture series*, Longman, Bristol, 750 p.
- [7] HENRY P. (1957). — Recherches sur la croissance et le développement chez *Elaeis guineensis* Jacq. et chez *Cocos nucifera* L. Comparaison avec quelques autres palmiers. Thèse d'Etat, Université de Paris, 154 p.
- [8] IRHO (1957). — *Rapport annuel 1957*.
- [9] JACQUEMARD J. C. (1979). — Contribution à l'étude de la croissance du stipe d'*Elaeis guineensis* Jacq. Etude du croisement L2T × D10D (bilingue fr.-angl.). *Oléagineux*, **34**, N° 11, p. 492-497.
- [10] JACQUEMARD J. C. (1980). — Croissance de la lignée témoin : L2T × D10D. *IRHO, note intérieure*.
- [11] MEUNIER J. and HARDON J. J. (1976). — Interspecific hybrids between *Elaeis guineensis* and *Elaeis oleifera*. In: *Oil Palm Research* (R. H. V. CORLEY, J. J. HARDON and B. J. WOOD, eds.) Elsevier, Amsterdam.
- [12] NOIRET J. M. et GASCON J. P. (1967). — Contribution à l'étude de la hauteur et de la croissance du stipe d'*Elaeis guineensis* (Jacq.). Application à la sélection du palmier à huile. *Oléagineux*, **22**, N° 11, p. 661-664.
- [13] SURRE C. (1968). — Les besoins en eau du palmier à huile. Calcul du bilan de l'eau et ses applications pratiques (Conseils de l'IRHO N° 71). *Oléagineux*, **23**, N° 3, p. 165-167.
- [14] SURRE C. (1979). — Croissance en hauteur du palmier à huile (bilingue fr.-angl.). *Oléagineux*, **34**, N° 11, p. 491.

## SUMMARY

**Contribution to the study of oil palm vertical growth. A descriptive model.**

J. C. JACQUEMARD, L. BAUDOUIN, *Oléagineux*, 1987, **42**, N° 10, p. 343-351.

The economic life of an oil palm plantation is directly linked to its rate of growth. Oil palm growth has thus been the subject of much research, which has led to a better knowledge of this character. Previous studies concluded that growth was practically linear between 6 and 25 years. New observations now make it possible to see a gradual increase in the rate of growth, reaching a maximum at around 10 years, followed by a gradual reduction. A descriptive model has been created to take these variations into account. The effect of rainfall is discussed, along with the problem of plantation replanting.

## RESUMEN

**Contribución en el estudio del crecimiento de la palma africana. Presentación de un modelo de descripción.**

J. C. JACQUEMARD, L. BAUDOUIN, *Oléagineux*, 1987, **42**, N° 10, p. 343-351.

La vida económicamente útil de una plantación de palma africana se relaciona directamente con su velocidad de crecimiento. Por tal motivo el estudio del crecimiento de la palma fué objeto de numerosas investigaciones que permitieron mejorar el conocimiento de este carácter. De los estudios anteriores se había llegado a la conclusión de que el crecimiento era casi lineal entre los 6 y los 25 años. Nuevas observaciones permiten evidenciar ahora un aumento progresivo de la velocidad de crecimiento, que alcanza un nivel máximo hacia los 10 años, y luego disminuye poco a poco. Se ha elaborado un modelo de descripción a fin de dar cuenta de estas variaciones. Se discute la influencia de la pluviometría, como también el problema de la renovación de los palmerales.

# Contribution to the study of oil palm vertical growth

## A descriptive model (1)

J. C. JACQUEMARD (2) and L. BAUDOUIN (3)

## INTRODUCTION

From an economic point of view, vertical growth is one of the most important biological characters of the oil palm, after oil yield. As the oil palm grows in height, harvesting becomes more and more difficult and an increasing number of crowns escape the usual harvesting methods. Production losses increase and replanting becomes necessary.

This led breeders to seek planting material which combines high yields and slow vertical growth [Surre, 1979]. In addition, the people in charge of plantations wish to be able to determine the most suitable period for replanting, bearing in mind two factors : production losses on harvesting and the maintenance of a sufficient production level to keep the oil mill going.

To solve these problems, it is essential to know how to measure the basic characteristics of oil palm growth and to describe and forecast its evolution over time, depending on environmental variations.

The first part of this paper will describe a certain amount of previous research work on oil palm vertical growth, along with the factors which modify it. A simple descriptive model of oil palm growth will then be proposed. Finally, a few examples will be given of how this model is used.

## I. — PREVIOUS STUDIES

## 1. — Biology of growth.

Henry [1957] describes the growth of the oil palm stem and compares it to that of climbing palms and other plants. The originality of arborescent palms lies in the existence of a vast meristematic zone around the growing point ; this zone ensures stem thickening. This thickening meristem, which gives the oil

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palm apex its characteristic basin-like form, develops in the initial years of the oil palm's life. Hence, there exist two distinct periods in stem growth. In the early years, growth is limited to stem thickening and it is only when the meristematic depression has reached its maximum diameter that vertical growth begins. The same author also notes the existence of growth variations between different environments (Benin and Lower Côte d'Ivoire), as well as between individuals in the same environment.

The factors affecting growth rate have been studied by numerous authors :

#### a) Genetic factors.

Beirnaert and Vanderweyen [1941] note that there is no difference in stem growth between the *dura* and *tenera* varieties. However, aborting *pisifera* oil palms grow more rapidly. In addition, a certain number of slow growing varieties are known : such as the « Dumpy » which is characterized by both its slow vertical growth and its thick stem. The progenies of the Pobé 1-2 T oil palm also show a marked tendency towards Dwarfism. It is also worth mentioning another source of variability : the American oil palm *Elaeis oleifera*, whose extremely low vertical growth partially dominates that of *Elaeis guineensis* in the interspecific hybrid [Meunier and Hardon, 1976].

Fremont [1950] observes no correlation between growth and yield. However, certain observations indicate that there is probably a relationship with precocity [RHÖ, 1957 ; Breure and Corley, 1983].

#### b) Edaphic factors.

The factors affecting photosynthesis have a direct effect on growth : temperature, light and humidity in particular. Jacquemard [1979], along with other authors, observes considerable differences in growth between planting sites for the same planting material. The main cause of these differences lies in the rainfall level prevalent in the various sites.

A high planting density, leading to competition for light, results in growth acceleration [Breure, 1982]. This acceleration is accompanied by a reduction in the number of fronds produced and thus a lengthening of internodes. However, intense shading slows down growth considerably [Hartley, 1967].

Other research work has concentrated on the effect of environmental variations on the rate of leaf emission. Worth mentioning are the effects of rainfall and soil fertility (though Breure [1982] observes no effect on growth in this latter case), castration (to be compared with the case of sterile *pisifera* palms) and heavy defoliation [Corley *et al.*, 1976]. However, few studies deal with internode length.

## 2. — Kinetics of vertical growth.

Oil palm vertical growth is usually measured through direct observations, taking a predetermined leaf as a reference point. Leaf 33 proves to be the most practical one to use [Jacquemard, 1980]. However, Noiret and Gascon [1967] proposed an indirect method using the ratio :

$$V = \frac{100 \times \text{number of leaves emitted in one year}}{\text{number of petiole bases on one metre of stem}}$$

with the petiole bases counted from 0.5 to 1.5 m. Within a cross, the correlation between calculated vertical growth and observed growth rate is excellent. The correlation between the calculated rate and the height reached at a given age (around 0.8 as previously) is found both within each cross and between crosses. Nonetheless, it should be noted that the calculated values are always much lower than shown by observations made around 13 years. This difference is due to the lengthening of internodes with age.

Jacquemard [1979] has produced a detailed study of the height of the cross L2T × D10D, which has been planted as a control in numerous trials at the La Mé station. He observes 3 phases : from 0 to 3 years the oil palm is acaulescent and growth is limited to increase in diameter ; from 3 to 6 years, vertical growth rate takes off and gradually increases ; finally, from 6 to 25 years, vertical growth rate seems to be stabilized.

When a second set of measurements was made on the same trees [Jacquemard, 1980], it was possible to determine the evolution of the vertical growth rate : the acceleration phase is followed by a phase starting at around 10 years when growth gradually slows down. This observation is confirmed by the study

of old oil palms, whose height is distinctly lower than that calculated from the vertical growth rate at around 10 years old.

It has thus been possible to show, through repeated observations, that the kinetics of oil palm vertical growth is much more complex than originally believed. It therefore becomes necessary to find a model which is likely to take precisely into account the evolution observed with age, so that valid comparisons can be made between different families or environments and so that reliable forecasts can be made far enough in advance.

## II. — OBSERVATION METHODS AND PLANTING MATERIAL

The method used for measuring stem height is described by Jacquemard [1980]. The measuring apparatus consists of an angle iron attached to a sufficiently long pole, along with a 20 metre tape measure. The zero of the tape measure is placed to coincide with the bottom edge of the horizontal arm of the angle iron.

This arm is slid into the axil of leaf 33 and the height is read off at ground level, to the nearest centimetre. Leaf 33 is on the same spiral as the last leaf to open (leaf 1), in 5<sup>th</sup> position. The choice of this leaf as a reference point results from practical considerations, as it is approximately located at the level of the ripe bunches.

The initial measurements made on the crosses planted at La Mé between 1959 and 1963 were taken using leaf 57, before leaf 33 was adopted as the reference point. It has been decided to correct the age to this measurement in accordance with the leaf emission (LE) rate measured in 1970 :

$$\text{Corrected age} = \text{Actual age} - \frac{(57-33)}{\text{LE}}$$

Which amounts to adopting a date when the leaf measured would have been leaf 33.

Around 50 trees from each family were measured.

To study the kinetics of vertical growth, two sets of measurements were taken, in 1979 and 1981, on 13 replications of the cross L2T × D10D planted in 12 different years at La Mé.

Finally, measurements were taken at different stations in Africa (Pobé-Bénin, Mondoni-Cameroon) and in Southeast Asia (Aek Kwasan-Indonesia and Johore-Labis-Malaysia) to estimate the effects of the environment on growth. The mean water deficit at each of these stations was calculated using the simplified method of calculating the water balance proposed by Surre [1968].

## III. — RESULTS

### 1. — Evolution of vertical growth rate.

Table I summarizes the observations made on cross L2T × D10D. For all planting years, the vertical growth rate of this cross was measured over the same period — March 1979 to December 1981. The main cause of variation is therefore the age of the trees : it is seen that vertical growth, which is slow at 5 years, accelerates up to 10 years, then slows down gradually : at around 30 years it reaches approximately 70 p. 100 of the maximum.

An analysis of growth rate evolution according to age clearly brings out these variations. The oil palm growth curve thus takes the form of a very erect sigmoid rather than a straight line. This type of curve is very often seen when studying growth processes. The slowdown observed can be explained through the greater difficulty in exploiting the environment as the organism grows, or through the appearance of senescence phenomena which can occur very early.

A particularly well-known case of a growth curve is the logistic function. It makes it possible to describe the evolution of certain micro-organism populations. It is also capable of describing the growth of organisms or organs with defined growth.

### 2. — Modelling of growth.

#### a) The model.

The model chosen to represent the oil palm growth curve is based on the following relation between height and age :

$$H = c \exp(-bt^{-k})$$

where H is the height of the stem, t is the time and c, b and k are parameters.

The significance of parameters b and c becomes clear if their effect on the position of the growth curve's point of inflection is examined. This point corresponds to the moment when vertical growth rate is maximum (Table II, Fig. 1) :

— the greater the value of c, the higher the height reached at the point of inflection and the greater the maximum vertical growth rate (Rmax). However, c has no effect on the age at which this point is reached. The theoretical height limit is also represented by c when t tends towards infinity ;

— the greater the value of b, the later the point of inflection is reached, and the lower the maximum growth rate. The height reached at the point of inflection is not affected by b.

The curves in figure 1 show that the role of parameter b is particularly evident at the start of vertical growth : curves B and D take off later.

Parameter k is involved in both the position of the point of inflection and in the form of the curve. It mainly influences the slope of the tangent at the point of inflection. High k values correspond to considerable variations in growth rate (S shaped curve) ; on the other hand, k values around 0.5 or under lead to almost linear growth (Table II, Fig. 2).

The characteristics of a growth curve for a given type of planting material are estimated as follows, based on the observations made : a k value is fixed beforehand, c and b are determined by linear regression using the following logarithmic transformation :

$$\text{Log } H = \text{Log } c - bt^{-k}$$

This process is repeated for different k values and the k value which minimizes the residual mean square is chosen. It is then possible to calculate maximum growth rate and the length of the plantation's economic life (e.g. age corresponding to a height of 12 m).

#### b) Applying the model to the control cross at La Mé.

The observations carried out at La Mé on L2T × D10D in 1979 and 1981 underwent two separate adjustments (Table III, Fig. 3). The two curves calculated virtually merge and tally with the data. The gradual start of vertical growth and its inflection beyond 20 years can be seen.

Variations in the growth rate are much more pronounced, as can be seen from the curves which are representative of growth rate plotted on the same graph (Fig. 3). They are simply derivatives of the growth curves. They therefore integrate total growth from planting up to 1979 or 1981. The growth rates observed only concern the period 1979-1981. Despite this difference, the calculated curves faithfully reproduce the evolution of growth rate observed (with a slight shift indicating that growth was significantly faster between 1979 and 1981 than during the previous period, perhaps because of more favorable climatic conditions).

The growth rate variations observed therefore prove to be due to differences in age and are not caused by uncontrolled factors.

#### c) Wider application of the model.

In order to determine the number of observations necessary for estimating the curve parameters, a study was carried out on the control cross L2T × D10D using the same data. It appears essential to have at least four observations appropriately distributed around the point of inflection.

For the time being, there are few sets of data available which satisfy these conditions. Nonetheless, numerous observations show that the conclusions drawn for the L2T × D10D are of general value as far as the oil palm is concerned :

— an overall estimation of parameter k was calculated on 13 Déli × La Mé crosses planted at La Mé between 1959 and 1963. A mean value of 0.685 was obtained. The calculated growth curves are compatible with observations. However, studies made per cross come up with considerable variability for parameter k. These variations can be attributed to the genetic differences between crosses, or to inaccuracy due to an insufficient number of measurements, particularly on young trees. For the moment, it is difficult to say which is the major factor of the two ;

— table IV summarizes the results of three series of measurements taken on 24 Déli × La Mé crosses planted at La Mé. It confirms that after 9-10 years the growth rate slows down : the growth rate observed between the last two sets of measurements (Rbc) is always lower than that measured between the first two sets of measurements (Rab).

Table V gives the growth observations carried out at the Aek Kwasan station (Sumatra, Indonesia) on the control cross L2T × D10D and on 3 Déli × La Mé reproductions, each represented by 8 crosses. There is a different growth curve for each planting material. The control cross has relatively low vertical growth up to 6 years. Its growth rate then accelerates : at 10 years, its height is significantly greater than that of the reproduction L2T Self × D115D Self. The control cross is characterized by a later take-off point. A good approximation of this point can be given by the intersection of the straight line joining the heights at 6 and 10 years to the age axis.

With the help of these few examples, we see that it is impossible to take into account all the oil palm's growth characteristics using a single measurement.

However, based on 3-4 measurements, the model proposed makes it possible to take into account the reduction in the growth rate of adult palms and the fact that the growth take-off date varies depending on the type of planting material.

### 3. — Environmental effects.

Table VI gives the height measurements taken on the cross L2T × D10D at four plantations. These measurements are compared to the height of the same cross at the same age at the La Mé station (as per the curve adjusted to 1979 data, Fig. 3). This comparison brings out important differences between stations (Table VI) which are related to the size of the water deficit.

There are also variations in vertical growth at the same station. Thus, the value given for Aek Kwasan at 6 years is the mean of 10 replications, for which the results vary from 1.16 m at the least favorable sites to 1.57 on the best soils.

The vertical growth of the oil palm is therefore greatly influenced by environmental effects, especially rainfall. In this respect, the model proposed, which only takes into account age as a factor of variation, could be completed by allocating to annual growth a correcting coefficient characterizing rainfall and the other environmental factors. However, this implies having prior good knowledge of the growth characteristics of several types of planting material in different environments.

## IV. — DISCUSSION

Interest has been shown in the study of oil palm growth and its use as a breeding and selection criterion for a long time now, but it was only a few years ago that it became possible to have a general overview of its evolution with age. Numerous observations carried out on the IRHO control family (L2T × D10D) reveal a gradual reduction in vertical growth rate with age.

A simple growth model has been created to describe this evolution. It takes observations appropriately into account, whether considering the relations between height and age or those between vertical growth rate and age. It has been possible to apply it to the cross L2T × D10D and to twenty or so others. However, in many cases, too few measurements, or their poor distribution over time lead to inaccuracy in the parameters. In fact, to obtain an accurate adjustment, an adequate number of measurements have to be available (at least 4).

In its current form, this model does not take into account external factors such as rainfall. Nonetheless, it would be possible to introduce them as corrective factors, once better knowledge of them has been acquired.

As far as the geneticist is concerned, the first selection criterion remains the maximum vertical growth rate, which can be estimated through measurements made around 10 years. It is also worth taking an interest in the growth rate reduction phase. The quicker it is, the longer the economic life of the plantation is extended. A third factor has to be taken into account — the homogeneity of the planting material : with identical average growth characteristics, non-harvestable trees will appear more quickly in a heterogeneous cross than in a homogeneous cross.

The programming of replantings requires that the same factors be taken into account. This can be achieved by taking measurements several times on the same sample of trees appropriately distributed throughout the block involved. This will make it possible to determine on what date a certain proportion of trees (e.g. 30 p. 100) will have reached the maximum acceptable height. It will be possible to improve the accuracy of this estimation through subsequent measurements, taken once again on the same sample. ■