OIL PALM BREEDING AND SEED PRODUCTION.

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I. Introduction

The oil palm was first introduced into Malaysia during the early part of this century and since then it has become a major agricultural crop in this country. In fact, it is the second most important crop after rubber and in 1975, became the second largest earner of foreign exchange.

If we examine the rate of increase in the oil palm acreage, one finds that the biggest expansion occurred during the sixties and early seventies, during which period, between 100,000 to 200,000 acres of oil palms were planted annually. On the basis of 100 seeds per planted acreage, this would mean a quantity of 10 to 20 million seeds being used up annually. The expansion of the oil palm acreage is expected to continue at the same rate over the next 10 to 20 years and hence is expected to consume a similar quantity of seeds.

It is therefore very easy to visualise the importance of an effective breeding programme to produce sufficient quantity of high quality seeds to meet the needs of an expanding oil palm industry.

II. Taxonomic position

The oil palm, Elaeis guineensis, (Jacquin) with chromosome number 2n = 32, is grouped with the familiar coconut, Cocos nucifera under the tribe Cocoineae in the family Palmae. (Hutchinson, 1934; Tomlinson, 1961). The oil palm is the only recognised species in the genus Elaeis. Two other species have at times been included in the genus, namely Elaeis melanococca (Gaertner) and Elaeis madagascariensis (Bec). The former species is now generally placed ~~in a different genus~~ as, E. oleifera ~~(HBK~~ Bailey while the latter is considered primarily as a variant of the E. guineensis.

A number of types, forms, or varieties have been recognised within the species, based largely on the different characteristics of the fruit. (Sparnaaij, 1969).

A. <u>External fruit pigmentation</u>

1. "nigrescens" - common type, anthocynin present, fruit colour deep violet or black when unripe
2. "virescence" - less common type, anthocynin absent, fruit colour green when unripe

B. <u>Pigmentation of the fruit pulp</u>

1. "normal" - carotenoids present (600ppm) in pulp, giving it a deep orange colour
2. "albescens" - carotenoids absent (less than 100ppm) from pulp resulting in a very pale yellow colour

C. <u>Fruit characteristics</u>

1. "normal" single fruit
2. "mantled", Poisonii - presence of additional carpels around fruit

D. <u>Shell characteristics</u>

1. "dura" - thick shelled, 2 - 8mm, no fibre ring around the nut
2. "pisifera" - shell absent, only fibre ring around the nut
3. "tenera" - thin shelled, less than 3 mm, fibre ring around the nut

The different characteristics are inherited in a more or less independent manner so that various combinations of the above characteristics are possible in a single palm giving rise to types such as albo-nigrescens dura, mantled virescence tenera etc.

A rare form also exists, namely "idolatrica" in which the leaflets are completely or partially fused.

III. Origin and distribution in the world

The oil palm, Elaeis guineensis, (Jacq) is native to tropical Africa where it still exists fairly extensively as wild and semi wild groves along the western coast in a narrow belt from Guinea to Angola and towards the central regions in Congo, Southern Sudan, Uganda and Tanzania (Zevens, 1964b).

The oil palm has ~~become~~ been an important source of edible oil for the local population in Africa since ancient times. In Africa, the spread and distribution of the species has been closely associated with human activity. At the present time, the oil palm has spread to other parts of tropical Africa, namely Zanzibar and Madagascar, the Far East and South America.

The oil palm was first introduced to the Far East at Bogor, Java in 1848. Four palms were introduced from West Africa (via Maurities or Reunion) and established at the Bogor Botanical Gardens. Two of these palms are still standing today.

Materials derived from this introduction were used to establish the first plantations in Indonesia and Malaysia. Since then it has also become the most important source of dura parents in most of the oil palm breeding programmes and is commonly referred to as "Deli" dura (Hardon and Thomas, 1968).

IV. Economic Importance

Two main economic products are produced from the oil palm, namely "palm oil" and "palm kernel oil". The former is derived from the pulp of the fruit while the latter is derived from the kernel. The residue from the kernel after extraction of the oil is also an important source of animal feed.

Palm oil and palm kernel oil is used largely for edible purposes eg. manufacture of margarine, cooking oil and shortenings. It also forms an important componenets in salad dressings and spreads eg. mayonaise and peanut butter.

Palm kernel oil and, also to a lesser extent, palm oil, is used for soap making.

Small quantities of palm oil are used as a flux for tin plating, making greases, lubricants and candles. One fraction from palm oil is also used as a cocoa butterfat substitute and has application in chocolate manufacture and cosmetics.

V. Breeding objectives

Oil palm breeding is carried out with the following main objectives.

1. Improvement of oil yield
2. Improvement of the oil characteristics
3. Reduction of palm height
4. Development of resistance to diseases

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The above ranking represents to some extent the relative priorities given to these objectives in the breeding programmes. Obviously, the relative priorities vary from programme to programme. For instance, disease resistant breeding is given a higher priority in West African countries than in Malaysia, as disease occurence causes greater yield losses in the African countries. The objectives will also change with changes in technology related to use of the product and to field agronomic practices. In the oil palm there is new greater interest in obtaining a higher level of unsaturated fatty acids in the oil and this objective is becoming more important and may take precedence over oil yield in some future programme.

VI. Breeding method

1. Improvement of oil yield

As has been mentioned earlier, two main economic products are derived from the oil palm namely, palm oil and palm kernel oil. Both these products are derived from the fruit and are considered simultaneously in the oil palm breeding programmes.

a) Selection criteria

From the point of breeding, oil yield can be regarded as a composite character in that its final expression depends on a number of sub components. These are as follows :

A. Fresh fruit bunch yield
   - mean weight per bunch
   - mean number of bunches per palm

B. Mean weight per bunch
   - mean weight of fruits
   - mean weight of stalk and empty spikelets

C. Mean weight per fruit
   - mean weight of mesocarp
   - mean weight of shell
   - mean weight of kernel

D. Mean weight per mesocarp
   - mean weight of oil
   - mean weight of fibre
   - mean weight of water

E. Mean weight of kernel
   - mean weight of oil
   - mean weight of oil free residue
   - mean weight of water

Data on all these characteristics are collected on all breeding programmes. Individual palms are measured for their fruit bunch yield over the first 5 years. Bunch analysis is carried out during the last 2 years.

In the selection programme, particular attention is focussed on certain of these sub components, the criteria of which depends on :

i) the heritability of the characteristics.

ii) the relationship between the characteristics.

iii) the contribution to increased oil yield.

Estimates of heritability give the following value :

	Malaysia		Africa	
Bunch number	0.18[1]	absent[2]	0.55[4]	0.50[5]
Bunch weight	0.25	absent	0.35	0.13
Fruit to bunch (%)	0.07[ns]		0.45	
Mesocarp to fruit (%)	0 (0.31)		0.88	
Oil to mesocarp (%)	0.48		0.3 - 0.98	
Kernel to fruit (%)	0.07		0.65	

1. Ooi et al (1974); Ooi (1975)
2. Thomas et al (1969)
4. Van der Vossen (1974)
5. Meunier et al (1970)

It is generally agreed that the heritability for fruit bunch yield components is low. Higher levels of heritability are obtained for mesocarp and oil content. Shell thickness is determined by a single gene (Beirnaert and Vanderwayen, 1941) but is is generally believed that modifying genes may also be present due to the observable differences in shell thickness within each shell type.

Studies on correlation between components (Ooi et al 1974; Ooi, 1975) indicate the following relationships :

- strong negative relationship between bunch number and bunch weight
- negative relationship between fruit set (%) and average fruit weight
- positive relationship between fruit weight and mesocarp content
- no relationship between oil content and other components

It should be pointed out that these estimates are valid only for the populations studied and the environments under which the study is carried out.

b) Selection method

As has been mentioned earlier, shell thickness is controlled by a single gene. This fact has been fully exploited in oil palm breeding resulting in a tremendous boost in oil yield. It was established in 1941 by Beirnaert and Vanderwayen that shell thickness is inherited in a simple Mendelian manner. The dura type material is homozygous for thick shell while the pisifera type is homozygous for absence of shell. The hybrid between the two types gives rise to an intermediate shell type known as tenera. Since the 1960's all commercial plantings and breeding efforts have been based on the tenera type. The improvement in oil yield is as shown below :

Average bunch composition of dura and tenera

	Dura	Tenera
Fruit to bunch (%)	60	60
Mesocarp to fruit (%)	60 - 65	75 - 85
Shell to fruit (%)	25 - 30	8 - 15
Oil to mesocarp (%)	50	50
Oil to bunch (%)	18 - 19.5	22.5 - 25.5

Fruit bunch yield is not affected at all and in fact it is probably higher in some tenera progenies.

Instead of breeding for thinner shell in the tenera, it would seem logical to use the pisifera since this 'type' is completely shell-less. The pisifera is however, generally sterile, in that the bunches do not develop beyond the stage of anthesis, or is only partially fertile. Even in the latter case where the bunch may reach to full maturity, the level of fruit set is usually very low and therefore the oil to bunch seldom exceeds that for a tenera bunch. Some attempts, however, have been made to breed for improved fertility in the pisifera (Tang, 1971).

While all the breeding programmes are aimed at the production of tenera type materials, the exact method of breeding differs for the different breeding programme.

In the programmes generally adopted in Malaysia, the procedure is as follows :

The selection of dura parents is based on family and individual phenotypic values. Superior families are selected on the basis of bunch yield characteristics i.e. total bunch yield, bunch number and bunch weight, the assumption being that these characteristics have low heritability values and thus can be more effectively selected on this basis. Individuals are then selected from these superior families on the basis of the mesocarp to fruit, oil to fruit and kernel to fruit content. Attention is also given to the other characteristics eg. fruit to bunch and shell to fruit but this is largely to ensure that they are at reasonable levels. Although these latter characteristics have low heritability values, they are correlated with the other characteristics eg. fruit to bunch with mesocarp to fruit, and thus would effect the phenotypic values of the characteristics of interest. For instance, care is taken to ensure that the individuals selected do not have a fruit to bunch lower than 65% and shell to fruit higher than 30%.

The pisifera parents are derived from selfing or intermating between selected tenera individuals. The selection of tenera individuals follows that adopted for dura selection. However, selection of pisifera individuals is not possible, because as mentioned earlier, these are generally sterile or only partially fertile. It is thus necessary to evaluate the pisifera on the basis of actual test crosses with selected duras, a procedure normally referred to as progeny testing. The progeny testing is normally carried out by the top cross selection method i.e. one pisifera is crossed to several duras and the mean performance over all the crosses is taken as a measure of the breeding value of the pisifera. This method is clearly intended to exploit general combining ability and one which fits into the present method of production of commercial seed. At present, all oil palms are produced from seed and because of the large demand for seeds it is not possible to confine seed production only to those crosses between dura and pisifera that have been progeny tested. The normal procedure would be to select dura and pisifera parents independently and any selected dura would be used in combination with any selected pisifera.

The dura lines and tenera lines (which is used to generate the pisifera parents) are largely maintained and selected in independent lines. This procedure has been adopted largely to avoid inbreeding effects. The oil palm is natural out-breeder and it is known that inbreeding results in depression of yield (Gascon et al 1969; Hardon, 1970). This procedure also allows some characteristics to be selected in the dura lines and others in the tenera lines to overcome problems of negatively correlated characteristics. For instance, it is known that bunch number and mean weight per bunch is highly negatively correlated. When two characteristics are highly correlated, it is clearly not possible to maximise for both in the same palm except through high selection pressure over a long period of time. On the basis of the present knowledge of the relationship between characteristics, average bunch weight, fruit to bunch, kernel size and shell thickness is emphasised in the selection of dura parents while bunch number, average fruit size and mesocarp content is emphasised in the tenera lines. Selection for oil content is emphasised in both lines.

A modified breeding programme, developed and adopted in West Africa (Meunier and Gascon, 1971) is the reciprocal recurrent selection. The procedure for this is as shown below :

Dura parents ⟶ DT ⟵ Tenera parents

Selection based on test crossed performance — Selection based on test crossed performance

selfed ⟶ DP ⟵ selfed

D x D — Seed production — T x T

Dura parents ⟶ DT ⟵ Tenera parents

repeat cycle — repeat cycle

In that programme, the selection of dura and tenera parents are based on actual test cross performance. The objective of this breeding procedure appears to be largely to exploit specific combining ability. Criticisms (Hardon & Ooi, 1971) however, have been raised against this programme centred around these points.

i) the limited number of individuals that can be tested

ii) no reason to assume that the selfed individuals will combine in the same manner as the parents since this is based on specific combining ability

iii) to exploit hybrid effects, the lines need to be highly inbred and thus the introduction of new materials into the system would not be convenient

iv) long generation intervals in oil palms of at least 10 years

v) will not be able to produce adequate amount of seed

2. <u>Improvement in oil characteristics</u>

Palm oil is a semi solid liquid at room temperature. For this reason it is not favoured for use directly as liquid cooking oils which requires the oil uniformly liquid at room temperature. With introduction of fractionation techniques, it is now possible to separate palm oil into several fractions, the two main, being :

- liquid, olein fraction with a low cloud point
- solid, stearin fraction with a high melting point

It is normally possible to recover up to 70% of the palm oil as liquid olein fraction and 30% as solid stearin fraction. The liquid olein fraction can be directly marketed for blending in liquid cooking oils and fetches a price higher than crude palm oil. The stearin fraction, ~~however~~ on the other hand, is far more difficult to market and fetches a lower price than crude palm oil. It should also be noted that the liquid fraction is more highly unsaturated, and with the present concern of the health hazards of saturated fats, it may be easier to market.

The present method used in breeding for a higher level of unsaturated fatty acids involves intercrossing between two species namely Elaeis guineensis the present oil palm and E ~~Corozo~~ oleifera or melanococca. The oil composition of the two species is as given below :

Fatty acids	E. guineensis	Hybrids	E. ~~Corozo~~ oleifera
Myristic	1.7	0.9	0.3
Palmitic	44.0	32.5	25.0
Palmitoleic	0.2	0.2	1.4
Stearic	7.4	3.4	1.2
Oleic	32.5	48.0	68.6
Linoleic	11.0	13.8	2.1
Linolenic	0.5	0.4	0.8
Arachidic	0.2	0.1	0.1
Iodine value	54.5	62.0	80.3

(Source Hardon, 1969)

Although Elaeis ~~Corozo~~ oleifera would have the desired oil composition, the oil yield of the materials currently available is extremely low. The fruit bunch yield per acre is less than 5 tons and the oil to bunch is less than 15%.

The hybrids has intermediate levels of unsaturated fatty acids, but although the fruit bunch yield is comparable to E. guineensis, the oil per bunch is still low between 18 - 20% as compared to good tenera materials with 23 - 25% oil to bunch. This deficit is gradually being overcome in the present breeding programmes and it is not unlikely that in the near future, such materials will be planted commercially.

For the present, in all breeding programmes, the breeding method adopted is based on the evaluation of F_1 hybrids between the two species.

Apart from the above desired property, the hybrids also possess other advantages eg. reduction in stem height and disease resistant. In fact in South America, the presence of a wilt disease "machetes" makes it not possible to plant E. guineensis and commercial plantings are at present based on the hybrids.

3. <u>Reduction in stem height</u>

Although the oil palm can grow and produce crop up to 150 years or more, its economic life span is only 30 years. Part of the reason for this, is the rapid increase in height of the palms, making harvesting difficult and thus more costly.

Breeding for reduced stem height has been made possible by the availability of a mutant type which posses extremely reduced stem height increment. This mutant type, however, has poorer oil yields due largely to poorer fruit characteristics, and the hybrids with normal type, although resulting in reduced stem height increment still does not posses sufficiently good oil yields. Efforts are continuing to improve the yield characteristics but at present, with relatively low labour cost, height is still a relatively less important characteristics.

4. <u>Breeding for disease resistance</u>

In Malaysia, the only disease of some economic importance is <u>Ganoderma</u> spp or basal stem rot. However, this problem can be minimised to a great extent by proper cultural practices. Furthermore, oil palm breeding is a very long term process with at least 10 years between generation. For these and other reasons, breeding efforts for disease resistance in this country is non existant.

In Africa and South American countries, however, the situation is completely different.

Fusarium wilt caused by <u>Fusarium oxysporium</u> is a major problem in West Africa. Nursery screening techniques have been developed (Predergast, 1963) which allow for resistant individuals to be identified and used in breeding programmes. Incoporation of such materials in the general breeding populations is currently in progress in Africa with some success. Breeding for resistance to other oil palm diseases in W. Africa e.g. blast disease and crown disease have also be reported (Blaak 1969, Blaak 1970).

VII. Practical Aspects

1. Data collection

Each individuals palm in a breeding programme is recorded for its fruit bunch yield characteristics, namely total weight of fruit bunches, bunch number and bunch weight. This is carried out at regular rounds of 7 - 10 days during harvesting. Yield recording normally commences from the 3rd to 4th year after planting in the field and is continued for 5 years thereafter. The oil palm will continue to produce crop for the next 25 years and the question of the validity of this partial recording would arise. This has been examined and under Malaysian conditions the correlation between the first 5 years of yield and the total yield during its full economic life span is fairly good. Obviously, the precision would improve if a longer period of recording is carried out, but this would also lengthen the generation interval.

For determination of the other components of oil yield, a procedure termed as "bunch analysis" is carried. Normally, 3 bunches per palm per year is sampled and 2 years records are kept. The sampled bunches are chopped up to separate the spikelets from the stalk. A 2.5 kilogram sub sample is taken for determination of the proportion of fruits in the bunch. From this sub sample, a 250 grm sample of fruits is again taken for determination of the mesocarp, shell and kernel content. 5 grms of the dried mesocarp sample is then taken for determination of the oil content, usually by solvent extraction.

2. Pollination

The oil palm is monoecious, bearing separate male and female inflorescence on the same palm. Occassionally, both male and female flowers may occur on the same inflorescence. These are avoided in the crossing programmes.

The inflorescence which is a spadix, is borne in the leaf axils. The female inflorescence bears some 5,000 to 6,000 female flowers but only 1,000 to 2,000 eventually develop into fruit. For the crossing programmes, the female inflorescence is isolated in a bag either made of paper or terylene fibre but sufficiently porous to allow moisture to be evaporated off. The female inflorescence is bagged at about 1 week before it is due to be anthesised or receptive. Precaution is taken to minimise contamination of foreign pollen. No emasculation is necessary in the oil palm as distinct male and female flowers are formed.

The male inflorescence is also isolated in the same manner. When the pollen is released, the inflorescence is harvested and the pollen collected. Oil palm pollen, after suitable drying, can be kept under low temperature for a period of 6 months to 1 year. If it is necessary to keep the pollen for longer periods, freeze drying techniques may be used and the pollen will remain viable for 2 to 5 years.

When the female flowers become receptive, pollen is introduced into bags and the crossed bunch is ready for harvesting in 6 months.

3. Seed production

The crossed bunches, after harvesting, are chopped up to separate the fruits from the other tissues. Each fruit is then cleaned until only the nut is remaining.

To induce flush germination, the seeds are subjected to heat treatment at 40°C for 60 days and at controlled moisture content of 18%. When the moisture content of the seed is raised to 22%, good germination of up to 90% can be expected.

VIII. Further prospects

The oil palm yields, at present, in Malaysia are in excess of 2 tons of oil per acre. This makes the oil palm, the highest producer of vegetable oil as compared to soya beans, coconuts and ground nuts etc.

The high yield in the oil palm is due in part to improve agronomic practices and to breeding efforts, the biggest impact was brought about by the switch from dura type materials to tenera type materials.

What, then, are the future prospects of raising the oil yield of the palm further ?

The oil palm breeders are optimistic that the yield potential can be raised even further.

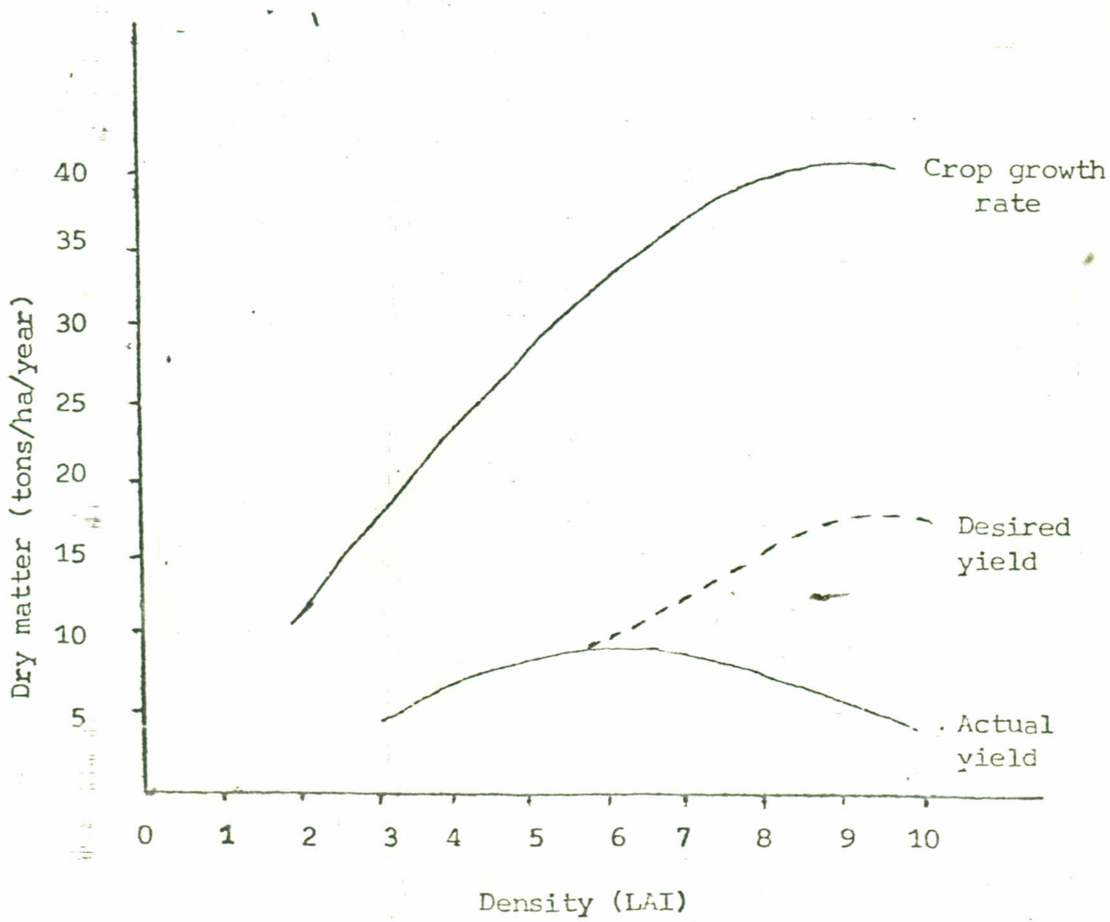
Firstly, it is clear in all breeding programmes that one of the constraints to further improvement is the fact that the level of heritable variation is very low. (Thomas et al 1969; Ooi et al 1974, loc cit.; Ooi 1975 loc. cit). This is largely because the breeding populations currently in use have a very narrow genetic base, i.e. derived from a very small number of individuals. As a result of inbreeding and selection under restricted population size, most of the heritable variation has been exhausted. Steps to rectify this situation have already been taken. For example, MARDI has completed a large prospection effort in the natural oil palm grooves in Nigeria and several hundred thousand seeds have been introduced in this country (Arasu & Rajanaidu, 1975). These materials will then be able to extend the genetic base of the existing breeding materials. The extent to which the genetic variability is enhanced in the Deli dura population throughout crossing is apparent from one such study (Ooi, 1976).

Secondly, at present, all oil palm plantings are established from seed. If we examine any progeny or family, the variation in yield between the individuals is very large, from 300 lbs per year to 800 lbs per year. Part of the variation is clearly environmental but it is not unlikely that genetic differences also account for a large part of this variation. Clearly if vegetative methods of propagation are available and if the palm with 800 lbs may be reproduced exactly, the improvement in yield from the present materials would be 100 per cent or 4 tons of oil per acre. Research is currently at hand, to develop methods of tissue culture and the result obtained so far holds good promise (Corley et al 1976).

Thirdly, the present selection criteria for improvement of oil yield is being reexamined in the light of our present knowledge of the physiological basis of oil palm growth and productivity. So far, all the breeding efforts have been concerned with raising the yield potential of the individual palms (Corley, et al 1971). Clearly, yield can be improved by increasing the number of palms per unit area. However, if this is to be achieved, then the approach and selection criteria will need to be different i.e. to deliberately select palms which tolerate a higher density of planting without reduction in yield of individual palms.

Studies have been carried out to examine the effects of density on oil palm total dry matter production and yield (Corley 1972). The relationship is as shown below :

The Relationship Between Dry Matter Production and Density



For the present materials, the fruit bunch yield reaches maximum levels at LAI of 6 (leaf area index). However, total dry matter production as measured by Crop Growth rate reaches maximum levels at LAI of 8 - 10. At this level, the total dry matter produced is 40 tons per hectare per year while yield accounts for less than 25% of the total dry matter. Clearly if the total dry matter for yield production can be raised to 50% at that level of density, it would be easier to predict the extent to which the yield would be increased. Assuming a moisture content of 50%, it may be expected that the bunch yield would reach 40 tons per hectare on fresh weight basis or equivalent 10 tons of oil per hectare (4 tons per acre).

The question remains, however, of the type of selection criteria required to breed for such a palm. One possibility which is currently being examined is to select for small but efficient palms on the basis of partioning of the dry matter i.e. harvest index or bunch index, rather than merely on absolute yields of the palm. (Harvest index or bunch index refers to the ratio of total yield to total dry matter production). Genetic studies (Hardon et. al. 1972) suggest that it should be possible to breed and select for these characteristics.

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