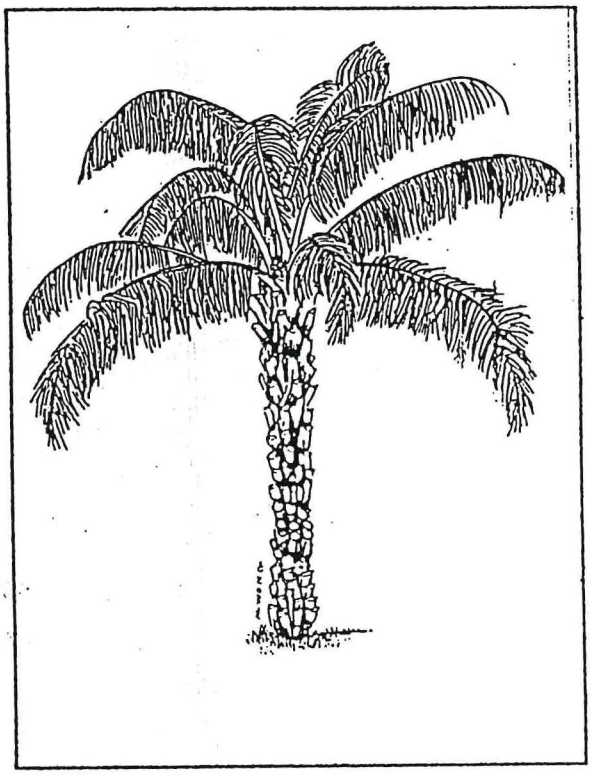
PHYSIOLOGICAL COMPONENTS OF OIL PALM YIELD ELABORATION

Planned operations



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1996

Planned operations

IOPRI*-CIRAD** joint project

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Schedule 1996

Introduction

Two campaigns of field study in ecophysiology of the oil palm have been realized since 1994 in Marihat Research Station (North Sumatra, Indonesia). They have been undertaken in an important research programm involving IOPRI (Indonesian Oil Palm Research Institute) and CIRAD-CP which the general aim is to get usefull physiological parameters to test a simulation model of production established by Dufrêne in 1989 in Ivory Coast on the control family L2T x D10D (Lamade,1994, 1995). Already, a lot of interesting results were produced and valorized through publications[1] specially concerning the hight level of the maximal photosynthesis in Indonesia around 31 µmol.m-2.s-1 comparing to the rate, 23 µmol.m-2.s-1 found in Ivory Coast. The apparent quantum yield at low radiation for all tested material is much higher (from 0.06 to 0.08 mol.mol-1) than the value of 0.053 mol.mol-1 established in Ivory Coast on the control family L2T x D10D.

An other highlighted point has been the differential sensitivity in the photosynthetic response of young clonal material to the vapour pressure deficit of the atmosphere. This observation needs to be checked on other material and under different ecological conditions. After testing by comparing this "sensitivity" of certain clones and correlating this with their respective yield it could be applied as a possible selection criteria at young stage.

The actual research proposals contains new investigations particularly focused on the physiological properties of the oil palm canopy including the variation of the maximal photosynthesis among leaf rank and depending of leaflet position related to leaf nitrogen content and chlorophyll content. Recent development in modelling photosynthesis and stomatal conductance by Ball et al. (1987) or Llyod (1991) leads to new investigations in the field for

[1] See Annexe 1

getting usefull parameters. The variation of the stomatal conductance with the environnemental factors as the VPD (Vapour Pressure Deficit) or the radiation and the air temperature as the leaf and at the canopy level will be will be measured in the field with a new accurate apparatus : the steady state porometer of Il-Cor.

From the last two data campaigns in Marihat, it have been observed sometimes a daily closure before midday and some periods, which have to be identify, when the stomatal conductance is very far from the optimum. This closure may have two origins : the moisture conditions (external factors) or a feed-back (internal factor) action from the photosynthetic products. Daily and seasonnal variation of the stomatal conductance has to be investigated in relation with the soil moisture content and the night temperature.

The simulation model of production established by Dufrêne (1989), with a new computing version "SIMPALM" in C++ (Bonnot, 1995) , have been tested on two contrasting families with a new set of 14 parameters (physiological one and biometrical one) directly measured in the field. Differences between simulation production and observed yield pointed possible new research investigations

as the depressive effect on production of the waterlogging especially in the North Sumatra.

From soil respirations measurements it is possible to get an estimation of the total photosynthetic carbon allocated to the root system during a period of one year (Lamade et al., 1996). A good test of this simple method is to make a carbon balance at the plant scale involving standing biomass measurements, estimation of the carbon gain by photosynthesis and total respiration cost (maintenance and growth). Furthermore, an approach of the annual variation of the total gas exchange balance at the plant scale may represents a good way to clarify rules of carbon allocations.

Phenological observations routines have been undertaken on two adult families belonging to *different origins (one to the "Lamé group", second to the "Rispa" one). From precise observations concerning the*

rhythm of leaf emission, the date of each rank 1, the date of each prunning , of each anthesis and harvesting, it is possible to try to lock models involving sexualisation aspect. To be able to be use such data, several years of observations routines are needed.

Concerning the sexualisation of the oil palm, a general hypothesis is currently admitted bases on several observations: the sex differentiation is related to the avalaibable assimilate at the tree scale (Breure & Corley, 1992; Corley & Breure, 1992). To be able to appreciate precisely the interconnection between "source" organs and "sink" one phenological and growth routines observations will be undertaken on different genetic material under differential prunning conditions.

Chap. 1. Gas exchange

Photosynthesis

☛ METHODOLOGY : few points

1. LCA4 : new QPRO software

Some mistakes have been identified in the formula and in the internal software of the LCA4 package especially concerning the transpiration, the stomatal conductance and the leaf temperature. On the basis of the Dufrêne's work, a new software specially adapted to the LCA4 technology will be built up to avoid this problem.

Identification of the problems →

✗ The air flow formula :

LCA4 original equation

: W = Flow * 293 / (24.387 * 1000 * 60 * (273 + T°a)*p(atm)

LCA4 corrected

: W = Flow * 273 / (22.4 * 1000 * 60 * (273 + T°a) * p(atm)

✗ The C'an (ppm) formula :

LCA4 original equation

: C'an = CO2 out * (1 - Wref) / (1 - Wan)

LCA4 corrected

: C'an = CO2 out * (100 * p(atm) * (273 + T°a) - Rhin * es(T°a)* 273)/ (100 * p(atm) * (273 + T°a) - RH'out * es(T°a) * 273

These differences in W and C'an leads to different results in TR, A and T° leaf estimations.

The T°leaf formula

LCA4 corrected :

$$T°\,leaf = T°a + (PAR * 0.168 / 0;88 - (45064, 3 - T°a * 42.9) * TR) / (2*(0.93*28.97*1.012/0.4) + (4*5.67*(T°a + 273.16)^3/10^8$$

For the calculation of the leaf temperature there is another alternative : to use the Energy Balance Equation established by Dufrêne and Saugier (1993) already use in the LCA2 software. :

T°leaf (energy balance equation corrected)

$$T°leaf = T°a + (698 * (0.8*0.92*0.94+0.2*0.85*1.06) * PAR/3190 - (2454 + (20 - T°a) * 2.4) * 18 * TR) / (2 * (0.93 *28.97 * 1.012 / 0.35) + (4 * 5.7 * (T°a + 273)^3/ 10^8$$

2. Calibration test of the physiology equipment

* The LCA4

sensors

- **PAR sensor**

  calibrated with the Quantum sensor Il-Cor model IL-190S-1, newly calibrated in 1996 (sensor of the Porometer LI-1600)

- **temperature thermistor**

  comparison test with one of the LCA2 and of the Il-Cor Porometer IL-1600.

IRGA Cells

- **CO2 concentration in ppm**

  It will be tested by comparison with the LCA2 results newly calibrated in University of Paris XI, Orsay (France).

- **Relative humidity**

  Taking into account that all "testers" like the thermohygrometer Vaisala and one which is included in the IL-1600 Steady State Porometer are not based on the same principle for the measurement of the relative humidity than in LCA4, a direct calibration is not possible but just a control.

EXPERIMENTS

Experiment 1

General aim : empirical relations at the canopy scale for mineral nutrition modelling (level 3 in sense of de Wit)

Variation of the maximal net photosynthetic rate with the leaf rank, the leaflet position and the leaf nitrogen content.

Justification : Maximal net photosynthesis have been determined in Sumatra conditions for 3 clones (MK04, MK22, MK10) on the leaf n° 9 in way to compare local rates to the rate established by Dufrêne in Ivory Cost conditions (Dufrêne, 1989; Dufrêne and Saugier 1993). We know already throught previous works (Corley, 1986; Dufrêne 1989; Henson, 1991) that there is a decrease of this rate throught the leaf rank. To be able in the futur to give a correct estimation of the total canopy photosynthesis, a complete evaluation of the rules of variation of this rate among rank and leaflet positions are required. Futher modelling development may be undertaken on this basis (Babeck, 1995). It is also well none that the level of nitrogen content in leaf affect the leaf photosynthesis (Evans, 1983; Evans, 1989; Evans & Terashima, 1988). A classical gradient of nitrogen content in leaf have been highlighted for the oil palm from the leaf rank 1 to 49 (Ollagnier and Ochs, 1981; Corley, 1976).

Material : MK04, MK10, MK22 ; plot BJ 27 S

Methods : Precise measurements of the photosynthesis will be undertaken with LCA2/LCA4 at saturated light. Response to light variation will be obtained with additionnal filters on the screen of the leaf chamber. For rank variation analysis, five leaflets around B will be selected for measurements for each studied rank. These leaflets will be furthermore submitted to nitrogen analysis. On leaf n° 9, divided in 10 segments, 5 representative leaflets per segment will be chozen . Response to light variation will be obtained at saturated light with additionnal filter.

Experiment 2

(Only if there is time...)

General aim : identification of local constraint factors on photosynthesis

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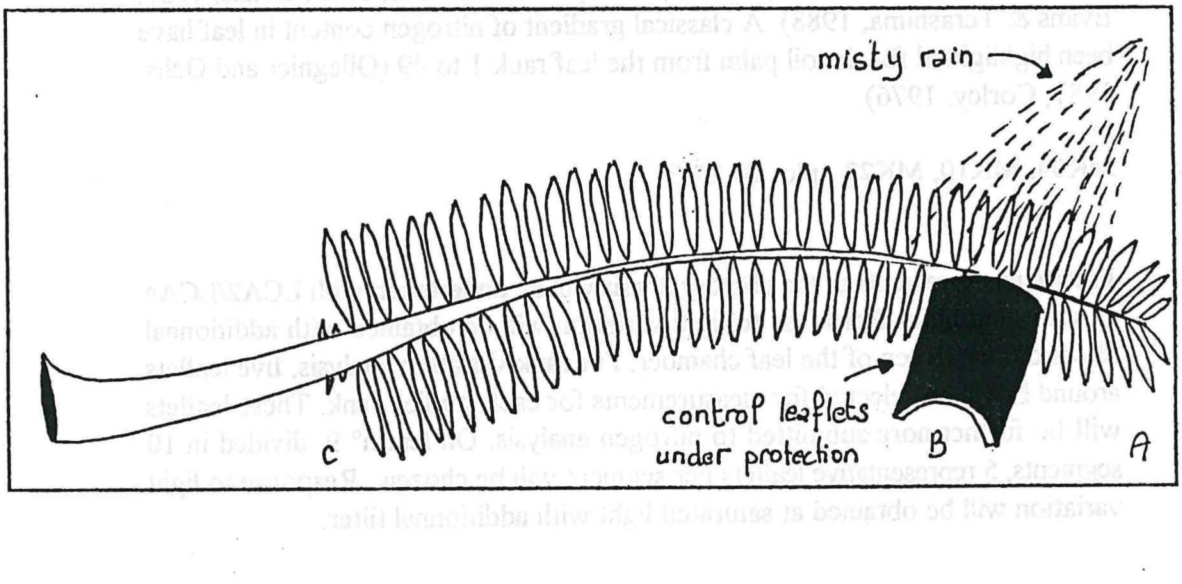
Effect of continuous leaf wetness on photosynthesis

Justification : New experiment (Ishibashi &Terashima, 1995) have clearly indicated that leaf wetness causes not only instantaneous suppression of photosynthesis but also chronic damage to the photosynthetic apparatus. Marihat Research Station is located in a very rainfall place (from 3000 mm per year up to 6000 mm sometimes) and most of the time it is an intensive rain during a very short period. Since diffusion of the CO2 is 10 000 times slower in water than in air (Nobel, 1991), leaf wetness can greatly reduce the rate of photosynthesis gas exchange. This effect on oil palm leaves remains still unknown...

Material : MK04, MK22, MK10, plot BJ 7 S.

Methods : Leaflets on the leaf n° 9 around the B point will be submitted at 3 different treatments respectively to 2h, 4h and 6h of misty rain. At 11 a.m. the dynamic of photosynthesis and stomatal conductance will be followed under saturated light. Response of the photosynthetic assimilation rate to C02 concentration in the intercellular spaces of leaves of both control leaflets and those submitted to treatments will be compared.



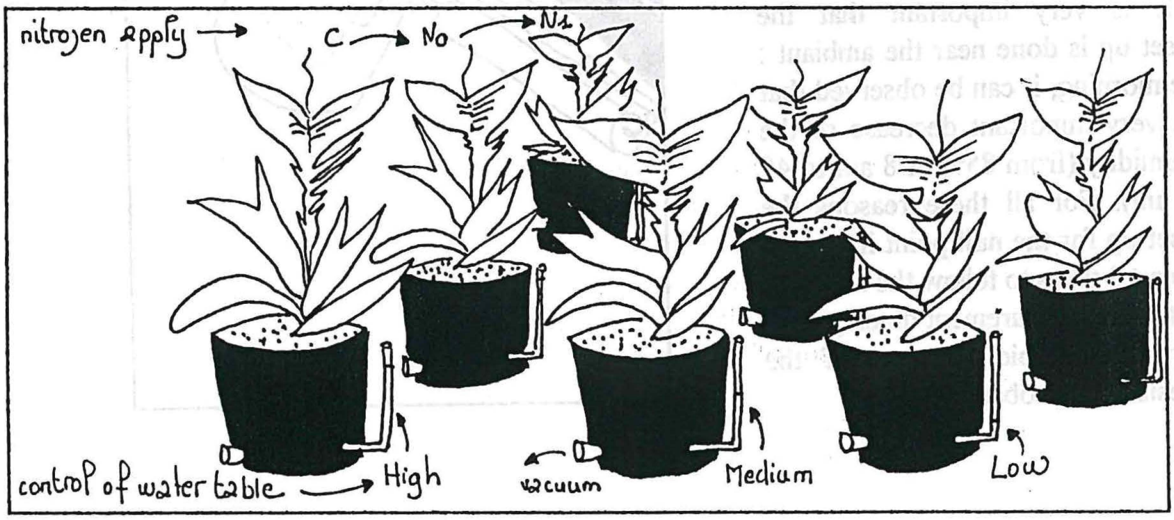
Experiment 3

effect of the waterlogging on leaf gas exchange, on growth and on biomass allocations, interaction with fertilizer application

Justification : It had been observed in Marihat location , temporary water-logging in oil palm plantation after a strong rain. The question is to determine if the oil palm is water logging tolerant .Waterlogging induces generally soil hypoxia and it can be observed a big decrease of the root biomass. From last works (Dreyer, 1994), it have been clearly shown that waterlogging leads to dysfonctions in the carbon metabolism of plant with a decrease of the net assimilation rate, to partial stomatal closure and in consequence on the general growth pattern of the plant.

Material : nursery plants, commercial material. 45 seedlings

Methods: The seedling will be first submitted to 3 different traitments. (C) is the control, (PF) will be the pots partially flooded, (F) completely flooded. In each "water" treatment, if possible, it will apply two level of nitrogen fertilizer (N0, N1 and N2). The control of the watertable, by the mean of an external plastic tube connected to the botom of each pot, will be controlled every day. Measurements will start 4 weeks after the begining of the experiment. Photosynthesis and stomatal conductance will be measured on the leaf n° 1 and n°4. The growth of each plant will be followed simply (diameter of the collar, height of the plant at the leaf n°1). At the end of the experiment the total MS allocation will be measured, the leaf area and eventually the chlorophyll content and the leaf nitrogen content.

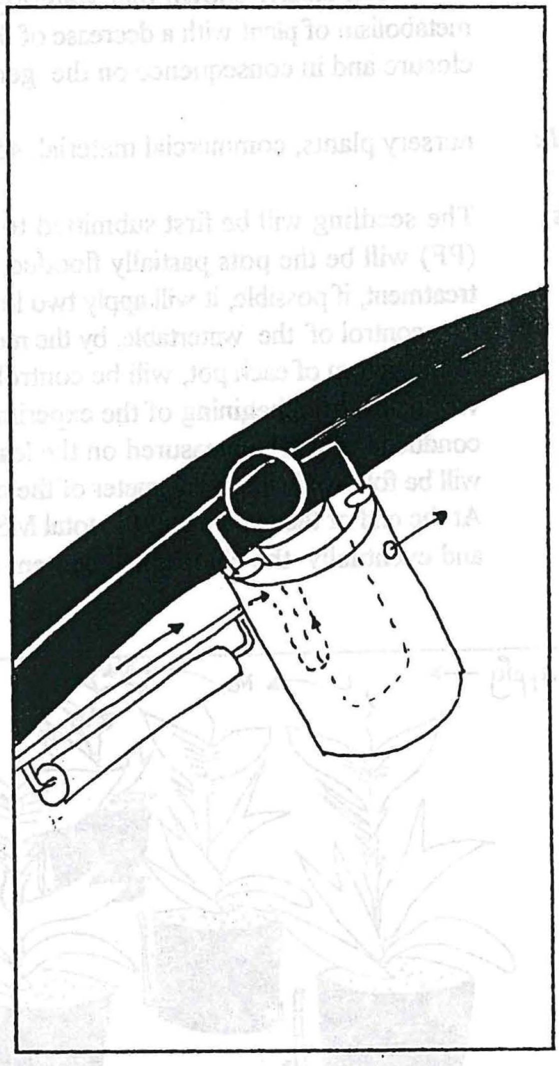


Stomatal conductance and transpiration

☛ *Methodology*

1. Preliminary test on the Steady State Porometer Il-Cor 1600

The principle of the measurement (see notice) of the transpiration flux by maintaining a constant vapour pressure in the cuvette is easy to undestand but leads to a quite difficult realization of good measurements because they are strongly susceptible to the variations of the outside wind speed and difference of temperature between the studied leaflet and the cuvette. Firstly, an appropriate timing has to be found between the moment when the limb is introduced under the clap and the moment when the measurement is done. The oil palm is very sensitive to the dry air and it is possible to observe a quite immediate stomatal closure when the limb is on the cuvette. It is very important that the humidity set up is done near the ambiant : during the morning, it can be observed that there is a very important decrease of the ambiant humidity (from 85% at 8 am to 45 % at 11 am). For all these reasons the humidity set up for the null point has to be change at least 3 times to follow the ambiant. It is better to take measurement quickly after 10s otherwise a rapid increase of the stomatal resistance is observed.



2. Comparison Analyzers (LCA4/LCA2) Porometer for the stomatal conductance

It is possible with the IRGA LCA4(LCA2) to measure the transpiration of the portion of the limb which is inside the chamber at the same time that photosynthesis. Also with adapted mathematical formula it is possible to get an estimation of the stomatal conductance and the temperature of the leaf. Because stomatal conductance seems to be an important key in the regulation of the photosynthesis, even in potential ecological conditions like in North Sumatra, it's of prime importance to get a good estimation of it. Already priliminary results have been published concerning relation between photosynthetic rate and stomatal conductance : a cross test with both apparatus types (analyzer and porometer) appears urgent.

For this reason, during the first two months, all *in situ* measurements should involve both apparatus. But in this comparison, one detail have to be taken into account : the photosynthesis measurements are taken in full light which is not the best conditions to use the porometer.

3. Calibration of the Thermohygrometer Vaisala HMP 35 A*

The Thermohygrometer Vaisala HMP 35 A is a probe used to get instant ambiant values of the relative humidity and the temperature. Both the humidity and temperature sensors are located at the tip of the probes and protected by a menbrane filter. The probe can be connected to several measurements systems and device. To receive the ouput signal in mV (RH%) and in ohms (T°C) given by the probe, a precise multimeter will be used assuming that the output cable wires are well connected.

With that, it is possible to calculate the VPD between the atmosphere and the leaf surface if we know the the leaf temperature with following formula :

$$VPD(Tleaf) = 100 * es(Tleaf) - Rha * es(Ta)$$

with Tleaf :temperature of the leaf
es(Tleaf) : saturated vapour pressure at T°leaf
Rha : ambiant relative humidity
es(Ta) : saturated vapour pressure at T°a

The calibration of the thermohygrometer may be done with the HME 32 Humidity Checker. The operation of the calibration checker is based on the humidity equilibrium of the air surrounding a saturated salt solution. The value of the relative humidity in the air depends on the salt solution used. For that, we used chemical cartridges (see figure) first one for 33 % : magnesium chloride, the other at 75 % : sodium chloride.

*(*VAISALA sensor system, Vaisala Oy, PL 26, SF - 00421 Helsinki, Finland, fax : 358 0 894 927)*

Experiment 1

Identification of stomatal limitation and non-limitation of the photosynthesis in relation with factors as soil moisture, VPD, night temperature and assimilats.

Justification : From last results, it appears that limitations in photosynthesis are strongly related to the stomatal conductance. Decrease in stomatal conductance may be due to several factors as the outside VPD between the leaf and the atmosphere or the soil moisture. In such area as the Marihat Research Station it may be also a question of night temperatures which are sometimes quite low (19°C) and may decrease the respiration rate. The consequence can lead to an accumulation of assimilats in the leaf which provoq a feed back control on photosynthesis via the stomatal control (Chaves, 1991). In way to undestand underground mechanisms short investigations will be undertaken to identify key limitation factors.

Material On plot BJ27, clone MK10, MK04 and MK22.

Method Stomatal conductance will be followed the morning (7h-12h) in relation with the night temperature (22h). VPD will be measured with the Thermohygrometer Vaisala HMP 35A (7h-12h). Soil moisture will be evaluated (but not precisely) from tensiometer system ***STM 2150*** Specific leaf mass will be followed each hour : limb samples will be collected regularly. Specially on leaf 9 on leaflets around B point.

Experiment 2

general aim : investigation of the relation between gas exchange and water balance for modelling.

Estimation of the photosynthesis and the canopy conductance in relation with the seasonnal evolution of the soil water balance in North Sumatra

Justification The development of a water balance model for oil palm has been undertaken this year in IOPRI-Marihat Research Station throught a Thesis subject to complete the carbon one and reach the level 2 in sense of de Wit . The effect of the variation of soil moisture on photosynthesis is well known on several species and also the drastic effect of water stress on the production of oil palm like in Benin (Adjahossou, 1983; Carvalho, 1991; Cornaire et al. 1993) for example. At a smaller scale, short period of decrease in soil water avaibality may affect quickly stomata pattern. Dufrêne (1989) noticed that stomata are very sensitive to rainfall in Ivory Coast. Throught Sumatra Island and Malaysia somes works (Purba and Lubis, 1991, Chow Chee Sing, 1992; Caliman, 1992) have highlighted possible correlation between the existence of period of soil water deficit and the production.

Material MK60, BJ 26 S

Methods To follow what was done in Ivory cost conditions (Dufrêne et al., 1994), a similar methodology to get the fully canopy conductance will be apply. With one tree per day, 3 level in the canopy will be investigated : level 7-9-10, level 16-17-18 and level 24-25-26. On the middle zone of each leaf, ten leaflets will be sampled both side of the rachis. Each leaflet will be cut and immediatly process with the Il-Cor porometer. Along each cut leaflet 10 measurements will be taken.Transpiration and stomatal conductance will be known each day of measurements.
The photosynthesis will be also follow at the same tree levels as the stomatal conductance but the measurements will be done in situ on non cut leaflet. Easier procedure with quite tall tree and when a towel is used to reach correctly the palm leaves is to work around th B point (This reference was already used in previous work, see abstract in annexe 1). Amax will be estimated at saturated light when the stomatal conductance is up to 9 mm.s-1.

Respiration

Roots, leaves respiration have been measured partially on MK10, MK04, MK22 and also on adult families in Andarasi. The main objective, this year is to try to get simultaneously the respiration of different organs as the roots, the trunk, the petiole/rachis and the leaves in way to be able to realize a balance of the gaz exchange at the plant scale. Some methodologies are used now for roots and leaves but for others organs like the rachis and petiole experimental designs has to be realized.

Experimental design for the respiration of the trunk and bunches had been realized by Dufrêne (1989) in Ivory Coast with a plastic bag including a part of the trunk or the bunch. With a compressor the air is pushing inside the volume, the flow and the concentration of C02 are measured at the entrance and when the air goes out the plastic bag.
For the trunk an empirical relation was found in relation with the temperature :

$$MTR = 0.0417 * T°C\ (trunk) - 0.5409 \quad (g_{CH20}\ kg_{ms}^{-1}\ d^{-1})$$

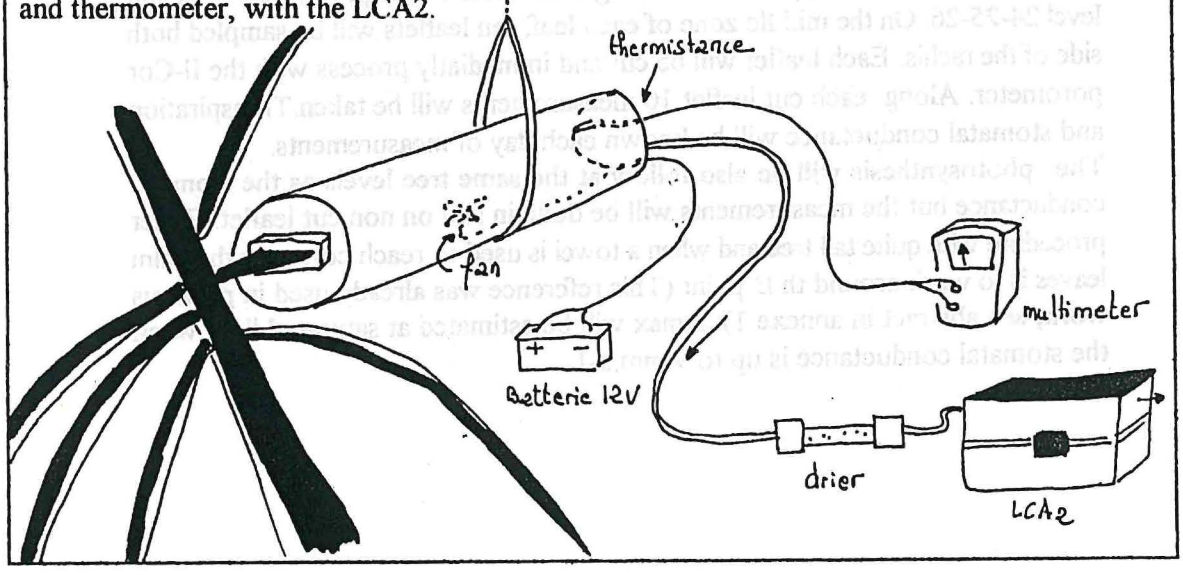
MRT : maintenance transpiration of the trunk (measuring at 1m height assuming that there is not growth at this level)
For the bunches, an empirical respiration coefficient was found at 36 °C at rank n° 36 : 0.0063 $g_{CH20}\ g_{ms}^{-1}\ d^{-1}$.

☛ Experimental proposals

*LEAF**

Material : MK04, MK10, MK22, plot BJ27

Method : "semi-closed system"(Lamade, 1996) with a long PVC chamber including fans and thermometer, with the LCA2.



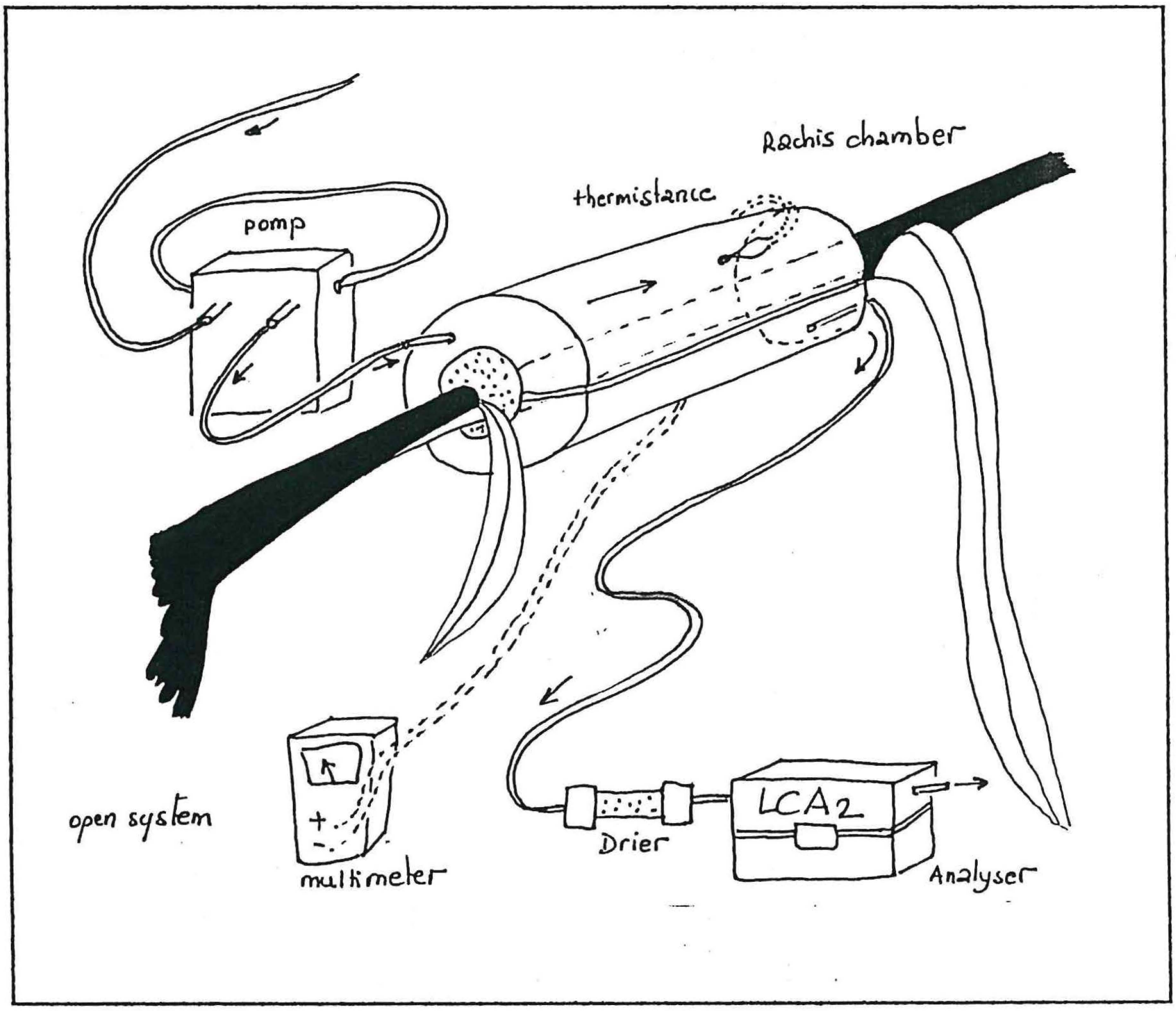
(* still remain the leaf rank variation study for MK04 and MK22)

ROOTS

Material : MK04, MK10, MK22, plot BJ27 Method : "semi-closed system" (Lamade et al., 1996) with an aluminium chamber including fans and thermometer with the LCA2.The same methods than for adults trees in Andarasi will be used on clones.

RACHIS/PETIOLE

The rachis and the petiole may be assimilated as leaves because they contains chlorophyll tissu. They can assimilates carbon during the day as leaves and they have also a respiration cost. Rachis and petiole are an important part of the total biomass of the canopy. It may be interesting, in a first step, to realise an experimental design - a chamber - which permit to follow gas exchange and gas balance.



Chap. 2.

Carbon allocation and sexualisation

Focuse

As far as carbon balance models are concerned, especially on "fruit" trees it quickly appears indispensable to investigate rules of carbon allocations to the reprodutive parts and explore what factors, both internal and external one, contribute to the determinism of reproductive organogenesis. On oil palm, all concerning sexualisation, abortion and the development, the maturation of the bunches still remains more or less in a black box. Of course, several hypothesis have been already proposed (Breure , 1987; Corley, 1976; Breure & Corley, 1992) and modelling exploration have been elaborated (Gerristma, 1988; Kraalingen, 1985). It is currently admitted that a lack of photosynthetic assimilates due to any kind of reason as pest damage on leaves, water stress, lack of radiations and so one may leads to abortion or male cycle increasing compared to the female one. Several indirect proofs of that can be found throught prunning experiments which aims were to compensate water stress effect in Benin (Benard & Daniel, 1971; Ochs & Daniel, 1976).

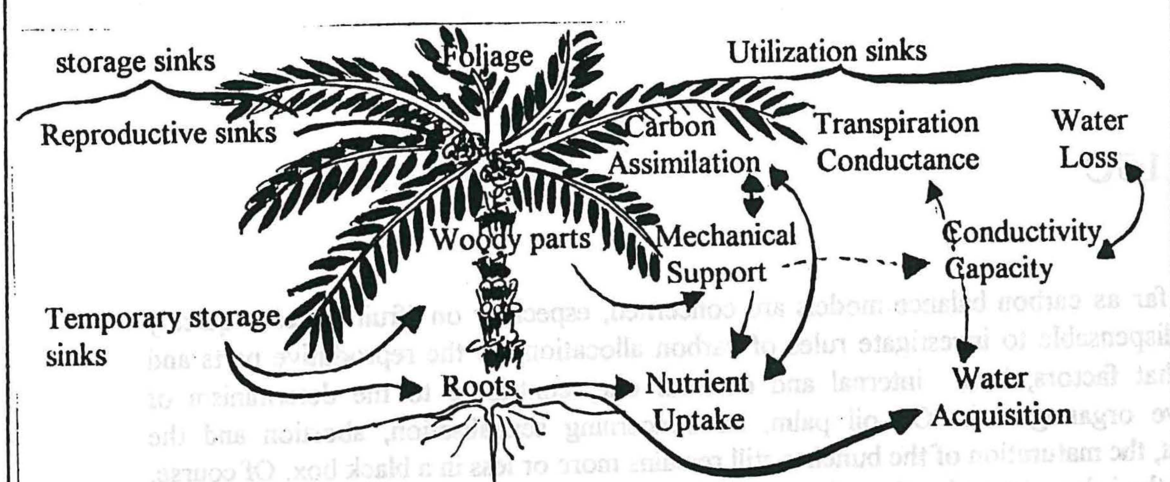
Carbon allocation

In the Dufrêne 's model (Dufrêne et al. 1990) , the carbon coming from photosynthesis is simply allocated in fonction of the needs of each organs. These needs are also simply evaluated from the annual increasing of the standing biomass per organs plus the respiration cost related the standing (maintenance respiration) and the increasing biomass (growth respiration). It is assumed that the carbon is allocated first to the vegetative development. After one year of daily allocation, a carbon blance is made to estimate from the total photosynthetic gain which proportion is devoted to the bunches and indirectly how much bunches it is possible to produce.

Furthers informations are needed to determine more exactly the sink/source relations.

The carbon allocation is difficult to study directly : there are much information on the distribution of dry matter in plants, but very little on the undestanding of the mechanisms that govern carbon allocation (Wardlaw, 1990). The transport, the storage and the utilization of assimilates are reduce by modellers as allocations coefficients or sink priorities. Allocation (better than partionning) is the outcome of many processes rather than a process in its own right (Cannell & Dewar, 1994)

In the review of Cannell and Dewar (1994) it is possible to found a framework with a diagramm of the relationship between five part of a plant (see figure)



(From Cannell & Dewar, 1994)

An oil palm tree may be divided into five parts :

1. Reproductive sinks (fruits and seeds)
2. Temporary storage sinks (carbohydrate and nutrient reserves)
3. Foliage
4. Woody parts (rachis, petiole, I and II roots)
5. Fine roots (III and IV roots)

Following Cannell and Dewar (for example) six separate functional relationships have been identified among these 5 plant parts :

. Reproductive and "utilization" (vegetative) sinks
2. "Utilization" and storage sinks
3. Foliage and fine roots (carbon assimilation and nutrient uptake)
;. Foliage and fine roots (carbon assimilation and water uptake)
5. Foliage and woody parts concerning water loss and water conducting capacity
6. Tree parts providing structural support and parts being supported.

To start to study in detail the carbon allocation rules for the oil palm in potential conditions as in Indonesia a prunning experiment will start this year on clonal material as MK04, MK22, MK10. This prunning experiment will include both ablation of inflorescences and prunning of palm leaves. The possibility to instaure phenological routines as in Andarasi during at least 3 years will be discussed.

Sexualisation

Phenological observations routines have been install on two adult families in Andarasi (plot MA07S, n°4; plot MA09S, n°8) with 24 trees for each family from 1994. From observations routines (weeckly) it is possible to get a good idea about the vegetative and the reproductive organogenesis during one year. It is also a great matter of interest to follow male and female cycle exactly and also abortion rate per family in relation with some environment factors as dry period or low radiations.

It is sure that sexualisation can't be determine only from avalaible carbon in the plant but some assumptions can be done and from previous works we can built a functionning diagram as below.

What we can suggest : a possible "scenario" (Leterme, 1993, see diagramm behind) :

* *Potential growth rate evolution of an inflorescence from differentiation to maturation :*

From Dufrêne 's thesis, there is a set of value from which it is possible to know the weight of female and male inflorescence from the rank N° 12 to 26 and to estimate that the growth requirement is 17g of DM per day and per bunches in Ivory Coast conditions. From that, it must added the respiration cost (also in g of DM) and the cost of oleosynthesis during the last three months of the bunches maturation.

* *Variations of requirements with the rank*

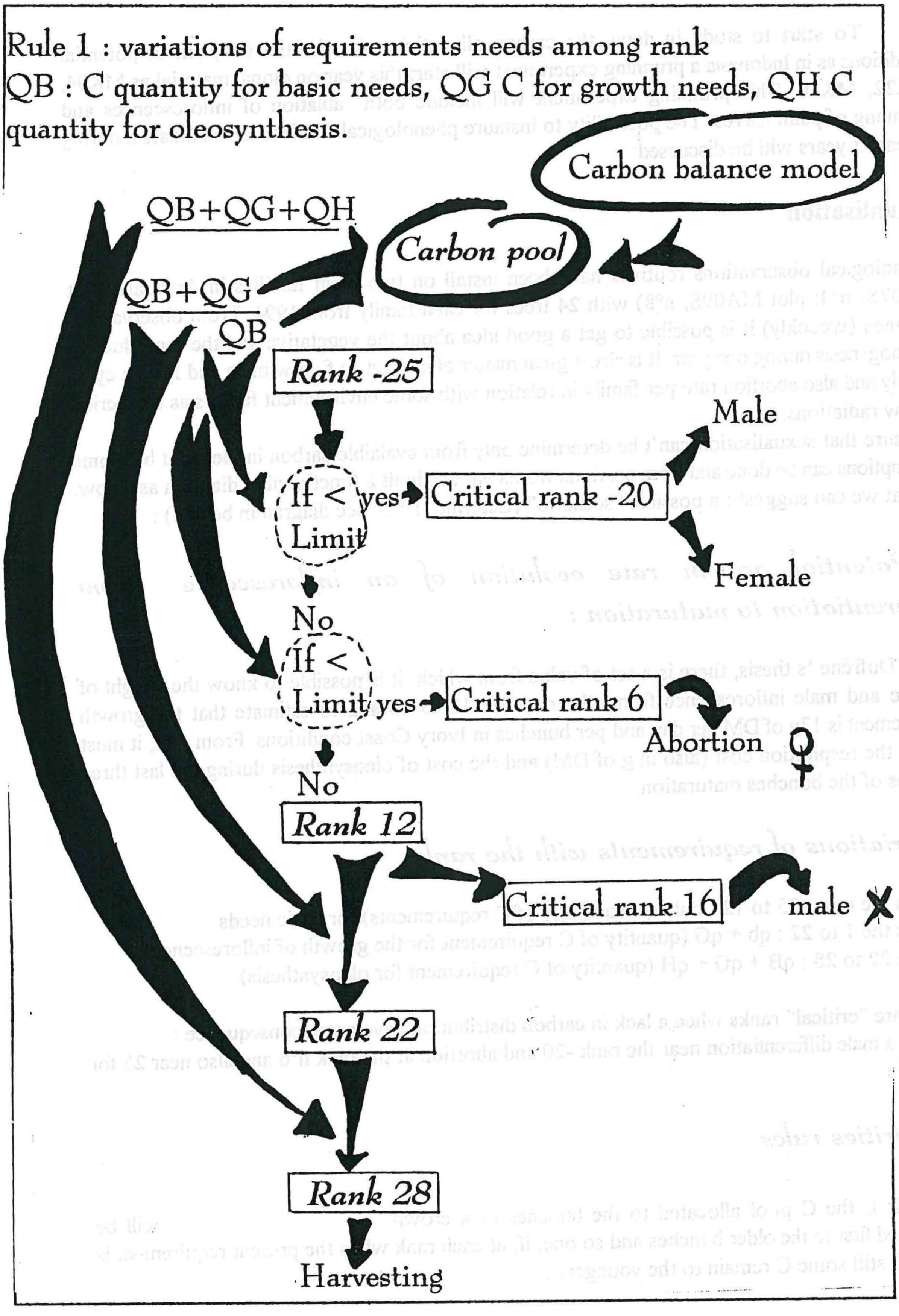
- From the rank -25 to 12 : only qB (quantity of C requirements) for basic needs
- From the 1 to 22 : qb + qG (quantity of C requirement for the growth of inflorescence)
- From 22 to 28 : qB + qG + qH (quantity of C requirement for oleosynthesis)

There are "critical" ranks when a lack in carbon distribution have some consequence :
there is a male differentiation near the rank -20 and abortion at the rank n°6 and also near 25 for example.

* *Priorities rules*

At time t, the C pool allocated to the bunches of a crown will be distributed first to the older bunches and so one, if, at each rank when the present requirement is covered, still some C remain to the youngers .

CARBON ASSUMPTION DIAGRAMM FOR SEXUALISATION



Experiment 1

Effect of the leaf prunning and inflorescences ablation on carbon allocation and on organogenesis

Justification :	This experiment will be undertaken this year is a part of a new research programm in CIRAD, which the main aim is to built a new model about both oil palm and coconut. This model will integrate both architectural and physiological aspects. This programm (Dauzat and Quencez, 1996) is involving the Agronomy Department of CIRAD-CP and Amap. There is a need to know better rules in carbon allocation. Direct methodologies are dealed with radio-isotope (14 C) and are rather expensive. For tall trees they are quite impossible to apply. Some indirect informations may be obtain from the suppression of carbon sources and sinks. A lack in carbon source will increase competition within organs, a lack in sinks will highlighted possible effect on non priority usual organs. Prunning on leaves and inflorescence may influence the general sink/source carbon pathway and also organogenesis. Other effect on some physiological pattern as leaf gas exchange may be also investigated. The root system is also an important sink but still difficulties to study it remains. In the futur it can be undertaken to follow the effect of a removing equal to 1/4 of the root system on the root/shoot ratio development.
Material	MK10, MK04, MK22 plot BJ 27 S with a minimum of 10 trees per clones and 10 trees observed for the control.
Methods	Prunning of leaves from 1 per trees to the total leaves. The possibility to instaure leaf prunning gradiant among trees will be decided with MRS-IOPRI and PTP VII. It will be the same with the ablation of the inflorescences. Some phenological observations will be done on prunning trees completed by the study of the variation of the specific leaf mass and the evolution of the growth of the remained bunches.

Chap. 3.

The Dufrêne s' model

Theoretical and experimental aspects : few points

1. Theoretical headlines

The carbon balance model established by Dufrêne in 1989 on oil palm yield in Yvory Coast conditions, especially on the control family L2T x D10D is a classical determinist one, belonging to the nederland "school" as de Wit's one. The basic principle is supported by the concept of a potential yield of the crop under non limiting environmental conditions. In the Dufrêne 's model the daily photosynthesis will be used for covering respirations and growth needs. At the end of one year , the remaining carbon in the reserve pool will be attribuated to the bunches. In this model the growth is only a genetic component and is not depending on environmental factors.

* *Calculations of the daily photosynthesis*

a) Hourly decomposition of the global incoming radiation

Generaly from meteo station it is possible to get the daily global incoming radiation in kj m-2 day-1. But the relation between the leaf photosynthesis is instantaneous : it cannot be applied like that for a daily radiation. A first decomposition of the incoming daily light to hourly one is necessary. (Following the Brook's calculations, 1981)

$$Ihor = R * I0 * 3600 * 12 /PI ((\sin(L)*\sin(D)*PI/12(T(j+1)-T(j))-\cos(L)\cos(D)(\sin(PI/12*t(J+1))-\sin(PI/12*t(j))))$$

with R a correction factor to the solar constant (R= 1 + (0.033*cos(2*PI*N/365))), I0 the solar constant equal to 1367 W m-2, PI = 3.141593, L : the latitude, D the declination angle equal to D= 23.45 sin(360*(284 + N)/365) with N the number of the day, t(j) the time at the hour j.

b) light interception

Following the Monsi and Saeki (1953) calculation :

The amont of light absorbed dR by a little part of the canopy dF will be equal to

$$dR = k\, I\, dF$$

when dR is the absorbed radiation by the leaves of one strate, proportional to the incoming radiation I and the the leaf area index dF.

After the cross of one strate by the radiation , the radiation will be I- dR equal to

$$dI = -k\, I\, dF$$

after integration we found the Beer Lamber 's law

$$I = Io\ e^{-kF}$$

c) Response of the photosynthesis to the light

Dufrêne use a rectangular hyperbola already used by Montheith (1965)

$$A = (a\ Ii\ Ainf\ ) \,/\, (\ a\ Ii + Ainf\ )$$

with a : apparent quantum yield in mol.mol-1, Ainf is the maximal photosynthetic rate when the radiation is infinite and Ii is the intercepted radiation by the foliage

After integration at the total canopy level we get

$$A = (Ainf/k)\ \ln\ ((a^*Io^*k + Ainf)/\ (\ a^*Io^*exp\text{-}k^*LAI + Ainf))$$

Still we have to integrate the instantaneous response of the photosynthesis to the light upon one hour

$$PN = 3600 * (T(j+1) - T(j)) * Amax/kext * Log\ ((\ a * kext* (PAR\text{-}41) + Amax\ ) \,/\, (a * kext * (PAR\text{-}41) * exp(-kext * LAI) + Amax))$$

To get the daily photosynthesis PN will be summed along all the hour of the day. The daily assimilation rate will obtain in gCH2O m-2 d-1

The model is iterative : the day n is depending on the day n-1. PN (n) will be equal to :

$$PN\ (n) = PN\ (n\text{-}1) + PN * 3 / 100000$$

* *The leaf area index*

$$LAI = LA * NL * Dens / 10000$$

with LA : leaf area, NL the number of leaf on a crown and Dens the planting density

* *The maintenance respiration*

(complete calculation can be seen in Dufrêne et al. (1990) and in Penning de Vries, 1972, 1975)

As in the model BACROS developped by de Wit et al. (1978) there is a respiration coefficient specific for each organs from the actual formula

$$MR = turn * prot * (N) + GI * (Mx)$$

(it will calculate how much g of glucose (CH20) is needed to make 1 g of DM).

with (N) as the nitrogen content in g.gDM -1, (Mx) the mineral content in g.gDM-1, "prot" a coefficient equal to 6.25 (how to tranforme nitrogen in protein)," GI" the ionic gradient maintenance , and "turn" the turnover rate of the protein.

All these coefficients (for all organs) will be calculated at 25 °C. In the model, the daily temperature will affect MR following the equation

$$MR(T) = M(T=25°C)\ \exp\ (0.069 * (T\text{-}25))$$

for example for the leaflets

$$Mrleaflet = 0.035 * 6.25 * 0.025 + 0.07 * 0.038$$
$$\text{in g CH20 g DM -1}$$

* *The growth respiration*

The values of the growth respiration coefficient used in the model are coming from Kraalingen (1985) .
The conversion factors are specific for each organs : they were estimated from the synthesis cost for each biochemical composants

as follow :

Glucid : 0.761
Lipid : 0.304
Lignin : 0.435
Organic acid : 1.017
Protein : 0.503
Minerals : 1

for the leaflets the calculations will be

$$Cfleaflets = 0.75 * 0.761 + 0.05 * 0.304 + 0.05 * 0.435 + 0.05 * 1.017 + 0.06 * 0.503 + 0.04 * 1 = 0.728 \text{ kg DM / kg CH20}$$

The total growth respiration for the vegetative part per day will be

$$VRC = (Cfleaflets -1) * IBleaflets + (Cfroots - 1) * Ibroots + (Cftrunk -1) * Ibtrunk$$

with VRC as vegetative respiration coefficient (will be in kg CH20 ha-1 day-1) , Ibx as the daily increasing biomass rate

Every day a respiratory balance is done with both the maintenance and the growth respiration.

* *The vegetative growth*

- the standing biomass

for the trunk

DSTRUNK = 184 kg DM m-3 (trunk density)
RADTRUNK = 0.23 m (trunk radius)
HEIGHT = 4.44 m
DENS = 143 (density planting)

$$BTRUNK = DSTRUNK * PI * RADTRUNK \wedge 2 * HEIGHT * DENS$$

- the growth of the trunk : around 0.48 m per year , 0.48/365 per day

- leaf emission : around 21 leaves per year

- the root system

The annual turnover of the different kind of roots is taken from Ruer (1968) with

- 15 % for the RI (primary roots)
- 31 % for the RII (secondary roots)
- 51 % for the RIII+RIV (fines roots : tertiary and quaternary)

The daily growth of the root will be :

$$DBR = (0.15 * BRI + 0.31 * BRII + 0.1 * BRO) /366$$

On one one year, to maintain the biomass of the root system constant the mortality will be equal to increase of biomass (may be correct for on agrosystem at the equilibrium).

2. Experimental tests

These was done during two years in Marihat Research Station on 5 differents types of material : first clonal material as MK04, MK22 and MK10, second on adult families belonging to two different origins.

Several paramaters has been already check as

1. Determination of Apot and Amax in Indonesian conditions
2. Apparent quantum efficiency (a)
3. Compensation point for the light
4. Extinction coefficient (kext)
5. Standing biomass (roots, trunks and leaves, petiole and rachis)
6. LAI and LA
7. Number of leaves per crown
8. Planting density
9. Specific Leaf Mass

Still few measurements remain for 96 concerning

1. The roots biomass of the clonal material
2. The extinction coefficient of the clones

The test of the model of Dufrêne done on the adults families (see abstract in Annexe 1) highilighted possible constraint on carbon acquisition due to pest damage on leaves or waterlogging effect.

Conclusion

A lot work in perspective : see the daily schedule in following pages !!

Schedule Physiology 96

April 96	Mai 96	June 96	July 96
1.Porometry/Photos MK04 2.Porometry/Photos MK22 3.Porometry/Photos MK10 4.Porometry/Photos MK04 5.////////////////// 6.////////////////// 7.//////////////////	29.Porometry/photos MK04 30.Porometry/photos MK10 1.Porometry/photos MK22 2.Porometry/photos MK10 3.computer/meteo 4.////////////////// 5.//////////////////	3.Porometry/photos MK04 4.Porometry/photos MK22 5.Prunning exp. 6.Computer 7.Computer 8.Night Soil Respiration MK04 9.Night Soil Respiration MK04	1.Porometry/photos MA 008 2.Porometry/photos MA 008 3.Computer 4.Computer 5.Computer 6.Night Soil Respiration MK10 7.Night Soil Respiration MK10
8.Yani/water balance MK15/roots MK04 9.Yani/water balance MK15/roots MK04 10.Yani/water balance MK15/roots MK04 11.Yani/water balance MK15/roots MK04 12. Computer 13.//////////////	6.Yani/water balance/roots MK22 7.Yani/water balance/roots MK22 8.Yani/water balance/roots MK22 9.Yani/water balance/roots MK22 10.laboratory 11.//////////////////	10.Yani/water balance/roots MK10 11.Yani/water balance/roots MK10. 12.Yani/water balance/roots MK10 .13.laboratory. 14.laboratory	8. Yani/water balance/light inter 04. 9.Yani/water balance/light inter 22. 10.Yani/water balance/light interc 10. 11.lYani/water balance/light interc 04 12.computer 13.////////////////
15.Porometry/Photos MK04 16.Porometry/Photos MK22 17.Porometry/Photos MK10 18.Porometry/Photos MK22 19.Computer/meteo/LAI pheno 20.////////////////	13.Porometry/photos MK22 14.Porometry/photos MK10 15.Prunning exp. (Clones) 16.////////////////// 17.Computer/meteo/LAI pheno 18.Night Respiration (MK22) 19.Nigt Respiration (MK22)	17. VPD test (BJ 30 S) 18. VPD test (BJ 30 S) 19. VPD test (BJ 30 S) 20. Soil resp MK04 21. Computer/LAI pheno	15.Porometry/photos MA 008 16.Porometry/photos MA 008 17.Porometry/photos MA 008 18.prunning exp. 19. Computer/LAI Pheno 20.//////////////// 21.//////////////// Libour
22.Waterlogging (nursery) 23.Waterlogging (nursery) 24.Waterlogging (nursery) 25.Respiration (leaf, MK10) 26.Respiration (leaf, MK04) 27.////////////	20.Waterlogging (nursery) 21.Waterlogging (nursery) 22. Prunning experiment 23.Respiration (leaf MK22) 24.Computer/meteo 25.////////////////	24.Waterlogging PS 25.Waterlogging PS 26.Soil Resp MK10 PS 27.Soil Resp MK22 PS 28.computer S 29.////////////////	22.waterlogging PS 23.waterlogging PS 24.respiration PS (trunk) 25.respiration PS (trunk) 26.computer S.
	27.Respiration (rachis,petiole) MK04 28.Respiration (rachis, petiole) MK04 29.Prunning experiment 30.Respiration (rachis, petiole) 31.Computer		

August 96	September 96	October 96
29..Porometer/photos MK04 30..Porometer/photos MK22 31..Porometer/photos MK10 1. Prunning experiment 2. Computer	2. Porometry/photos MK04 3. Porometry/photos MK22 4. Porometry/photos MK10 5.computer 6.computer	1.Report 2.Report 3.Prunning expreriment 4.Computer 5.Computer
5. Yani/water balance/light inter MKO4 6. Yani/water balance/light inter MK22 7.Yani/water balance/light inter MK10 8. Yani /water balance 9.computer	9. Yani/water balance 10. Yani/water balance 11. Yani/water balance 12. Yani/water balance 13. Yani /water balance	7. Yani/water balance 8.Yani/water balance 9.Yani/water balance 10.Yani/water balance 11.Computer
12.VPD test (BJ 30 S) 13.VPD test (BJ 30 S) 14.VPD test (BJ 30 S) 15.LAI pheno 16.Computer	16. VPD test (BJ 30 S) 17. VPD test (BJ 30 S) 18. VPD test (J 30 S) 19. LAI pheno 20. Prunning experiment	14.VPD test (BJ 30 S) 15.VPD test (BJ 30 S) 16.VPD test (BJ 30 S) 17.LAI pheno 18.computer
19.waterlogging (nursery) 20. Waterlogging (nursery) 21. Waterlogging (nursery) 22. Prunning experiment 23. Computer	23.PIPOC . Biomass MK10 24.PIPOC . Biomass MK10 25.PIPOC . Biomass MK10 26.PIPOC 27.PIPOC	21. Report 22. Report 23. Report 24. Report 25. Report
26. Computer; Biomass MK04 27. Computer; Biomass MK04 28.Computer; Biomass MK22 29. Computer Biomass MK22 30. Computer	28.//////////// 29./////////// 30.///////////	//////////////////////// ///////////////////////

ANNEXE .1

Publications from the two last data campaigns

"Photosynthetic potential of three clones of oil palm in North Sumatra. Preliminary results."

Lamade E & E Setiyo

1994. IOPRI-SOCFINDO Symposium "Fourth technical Meeting on the progress of Oil Palm Tissus Culture". June 27-30.

Abstract

To get potential Net Assimilation rate at the leaf level have been measured on three clones over a range of incoming radiation. ential values of the leaf photosynthesis, data had been selected by taking into account the maximum stomatal conductance limit and also environmental conditions as the VPD. Results give a new value for the photosynthetic potential established by Dufrêne in Ivory Coast on the control family L2T x D10D and highlight differences within clones especially for high radiation. Consequently photosynthetic potential may be used for selection criteria.

"Photosynthetic rate of D x P crosses : sensivity to VPD in North Sumatra."

Setiyo, E ; Subronto, & E Lamade

1996. PIPOC Colloquium sept. 96.

Abstract

*The main objective was to know the photosynthetic characteristic for three clones of different origin at four years old. Photosynthesis was measured in situ with a portable analyzer (IRGA) LCA2 (ADC) in Bah Jambi Estate, PT Perkebunan VII, North Sumatera. During the experiment, water and nutrients were assumed to be not limiting factors. It was observed at saturated light (PAR > 1100 µmol.m-2.s-1) that stomatal conductance (gsmax in mm.s-1) tends to decrease with the increasing of VPD (Vapour Pressure Deficit, in kPa, atmospheric drought) which is well illustrated with an exponential curve equal to, respectively for MK04, MK10 and MK22 gsmax = 37.69 *exp(-0.675 * VPD) (r = 0.92, df 111), gsmax = 58.88 * exp(-0.785 * VPD) (r = 0.96, dF= 81), gsmax = 94.38 * exp(-1.15 * VPD) (r = 0.95, df = 83). The sensitivity of gsmax to VPD , highlighted by a ln transformation (linear regression) show significant differences between the three clones (P<0.001). Net maximal photosynthesis (Amax) shows a negative linear regression with the increasing VPD. The Amax-sensitivity is well related with the gsmax-sensitity to VPD. For Amax (MK04) = 34.85 - 6.82 * VPD (r = 0.85 df = 111), Amax (MK10) = 36.30 - 6.96 * VPD (r = 0.94 df = 81) and Amax (MK22) = 43.51 -11.22 *VPD (r = 0.94 df = 83). To increase oil palm productivity in breeding programm, it may be usefull to select genotype with a low gsmax-sensitivity.*

"Test of the Dufrêne's production model on two contrasting families of oil palm in North Sumatra"

Lamade E & E Setiyo

PIPOC 96. Symposium

Abstract

A simulation model of production has been established by Dufrêne (1990) on the control family L2T x D10D In Ivory Coast conditions. The results of the simulation in the african ecological environments shows a hig compatibility with the observations in the field when the oil palm are in potential conditions without water or nutrient constraint. It was highlighted that a lack of radiation may be at the origin of the relative low yield observed in Africa. To test the validity of the model in indonesian conditions, a large set of parameters (at least 14 with both physiological parameters such as the maximal photosynthesis, the quantum yield, or biometrical one such as the leaf area, the number of leaves per crown, the specific leaf weight, the trunk hieght, the root biomass and so one...) have been studied on two contrasting families (one belonging genetically to the "Lamé group", the other to a local material). At the same time, a precise recording of daily radiation was undertaken to get an appropriate "meteo input file" for the model. A first comparison between both ecological situation "Lamé" and "Marihat" taking into account only the difference of radiation (around 2 MJ ha-1 day-1 more for indonesian conditions) shows a "theoretical" increase of annual photosynthetic assimilates of 4 %, a general decrease of respiration cost of % due to lower daily temperatures in Marihat, an increase of 18 % of the annual production of the dry matter at the plantation level and an important increase of FFB of around 80 % (from 18t.ha-1 to 30 t.ha-1). The test of the model on the two families with an "indonesian meteo file" based on theirs respectives biometrical and physiological patterns shows differences in their respective yield, giving an advantages of 8 t of FFB for the Lamé group (theoretical production : 38 t FFB.ha-1) compared to the local material (30 t FFB.ha-1). This is due essentially to different carbon allocation between the upper to the below plant part. The observed yield was around 24 t FFB for the Lamé group and 17 t for the local material. Thsi difference between estimations and the observations in the field may be due to a lack of photosynthetic assimilates, consequence of pest damage to foliage and/or negative effect on root system due to frequent tempory flooding.

A rapid method for estimating Leaf Area Index with the Il-Cor "Lai 2000" PCA for Oil Palm"

Lamade E & E Setiyo

PIPOC 96 - Symposium

Abstract

A new method to obtain a rapide estimation of the Leaf Area Index (LAI) in an oil palm stand with the Il-Cor LAI-2000 PCA (Plant Canopy Analyzer) has been tested at the Marihat Research Station (North Sumatra). This method was also compared with the conventional direct method commonly used by CIRAD-CP. With the direct method, the chosen material, both clonal and sexual plants, revealed quite a wide LAI range from 3.4 to 7 while LA(leaf area) values were between 5.6 m2 and 11.7 m. Regression lines were established between the indirect and the direct methods. With the direct method used as a reference, it can be clearly shown that the PCA, without any kind of correction and when the 5 optical sectors are taken into account in the calculation, underestimates the LAI by nearly 40 %. Nevertheless, a very significant correlation (r2 = 0.93, df = 8) can be found between the methods. The best apparatus accurancy (nearly 100 %) was obtained when only the first three central rings corresponding to a complete sky optical sector of 43 ° was used. In that case, a highly significant correlation (r2 = 0.96, df = 8) with the direct method was observed. These preliminary results indicate the remarkable suitability of the PCA LAI - 2000 in tropical humid conditions, since all measurements have to be carried out under constant cloudy conditions. The only constraint for using the LAI-2000 in a tall crop such as oil palm will be to purchase two optical sensors and two data loggers : this will ensure a complete fit between both A reading (above the canopy) and B reading (below the canopy).

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