

**PHYSIOLOGICAL COMPONENTS of OIL PALM**  
**YIELD ELABORATION**

*PROGRESS REPORT 2, period October 94-April 95*

IOPRI-CIRAD Joint Research Project

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Mai 95

## INTRODUCTION

*A joint research project have been conducted since december 93 between IOPRI (Indonesian Oil Palm Research Institute, Medan) and CIRAD about the main physiological trends of oil palm trees in Indonesia. The general aim of these studies is to obtain usefull parameters to test a carbon balance model, simulating the yield at the agrosystem scale, established by DUFRENE (1989) in Ivory Coast conditions for the control family L2T x D10D. These parameters involving mainly the potential photosynthetic response to the light in Indonesian conditions, respiration rates of different organs, theirs relations with some environnmental factors as the vapour pressure deficit of air, the air temperature and the daily variation of the light. A complete description of this research programm can be found in the first progress report in the first part.*

*Already a first data campaign - from December to June 94 - was conducted in Marihat and brought out interesting features as the possibility to show a very hight value for the photosynthetic potential on specific clonal material, never measured elsewhere, but also an unexpectable limitation, in this potential agroecological zone for this crop, for the daily photosynthesis already in the morning. Both stomatal regulation and photoinhibition may be involved.*

## **Part 1. Briefing on previous proposals**

(for more details see "Planned operations for the period October 94 -April 95")

### **1. The test of Dufrêne's model in Indonesian conditions**

To test this model, several specific parameters are needed as the photosynthetic potential, respiration of the organs, LAI, extinction coefficient...

As far as these parameters are concerned the main goal of this present period was to finish the complete estimation of all of them which requiring both collecting some informations in the field and processing data already obtained. Working on two kinds of planting material , one is clonal material of 6 years old, second are sexual adult families of 9 years old, already some of usefull parameters were obtained from the previous campaign 93-94 as

- the photosynthetic potential (clonal material)
- LAI
- leaf respiration
- light efficiency

Others usefull inputs as daily radiation records were started in May 94 in the Marihat meteorological station with a Li-Cor sensor connected to the data logger LI-1000.

Proposals on that gathering for the present campaign were to get :

on clonal material

- extinction coefficient
- leaf rank variation for maximal photosynthesis
- leaflet position effect for maximal photosynthesis
- photosynthetic efficiency
- compensation point for light

on sexual material

- phenological studies
- standing biomass
- soil respiration
- LAI
- light interception

and several data processing ...

## 2. Others proposals

In way to develop also the knowledge on some aspects of the physiological functioning of oil palm, other experimental programm were planned to determine the **carbon allocation to the roots** which are a very important sink not yet well known. Indirect methods will be use as to measure first the total release of the CO<sub>2</sub> from the soil *in situ* and after compare with the release from a free-roots soil in way to get estimation of the roots respiration. From last point , by applying the principle of Raich and Nadelhorfer (1989), it will be possible to get evaluation of the overall carbon allocation to roots in equivalent of C02 in Mg per year at the ha scale.

For **photosynthesis** studies, last proposals were to test the respective **compensation points** for the light for studied material, also to look for new methods to measure the photosynthesis of young plants (at nursery stage and young trials in the field). Other point deals with the variation of the assimilation rate along the **leaf ranks** in way to be able to make a good estimation of the overall canopy photosynthesis.

Some **LAI estimation** started already during last campaign on the clonal material (MK04, MK10, MK22, plot BJ27 , planting 1989, see first progress report) on the basis of the estimation of the LA with Tailliez' method (1992). Present target is to compare last results with the direct measuring of the LAI by the Plant Canopy Analyzer from Li-Cor. Light interception recording has to be completed on the same basis of the last experimental design with just a new a restriction on the daily period recording each time : from 11h-15h (local time).

Evaluation of the total **standing biomass** has to be done precisely especially for the roots and the fronds for adult planting material (n°4, plot MA07S; n°8, plot MA08S, planting 1986).

Last point of the previous proposals was concerning **new modelling development** especially to add new levels, in sense of de Wit (1965) at the actual Dufrêne's model with boh the water balance compartiment and the nutrient one.

## Part. 2. Realisations

### 1. Photosynthesis

1.a. Technical aspects of the use of the LCA4 from ADC (Analytical Development Company Limited, UK).

Compared with the oldest LCA2, the new analyzer from ADC is requiring much care. A lot of tests have yet done on it to get the best accurency for measuring.

To get start with it (important points)

1. Before press the red bootom "start",

\* verification of the batterie 12 v (recharging every day, after use with ADC charger) and the current status of the columms :

a- drier column fill with blue drierite (renew content when the total is turned to pink. At the top of the column, it must be add molecular sieve, to avoid interaction with CO<sub>2</sub>. If the molecular sieve is missing, the drierite column must be "purge", with an internal flow equal to 600 ml.mm-1 at list more than 15', before starting measuring. Don't forget this point when a recalibration for CO<sub>2</sub> is needed.

b- soda lime column fill with it (renew when 3/4 is brown). Completely renew when a recalibration is needed.

\* connect both the volume to the air supply, and the portable leaf chamber without mixing the two inlets.

2. Start, press the red bottom.

Most of the time next indication will raize up the screen :

Cref low, check  
absorber !

Until now, reasonnable cause for this phenomena is just in the domain of hypothesis. ADC will be contacted for such a fact. The most probable cause is at the beginning an interaction of both infrared cells supposed to determine the CO<sub>2</sub> concentration and the moisture of the air the system (for this new version of analyzer it's a quite different system which is fonctionning with "2 cells" (page 33 in the ADC manuel) ) when there is still some condensed vapour in the system from previous work in the field.

To avoid such a case, it was empirically test the accurency to put a drier before the all system fill with magnesium perchlorate similar to the older system with the LCA2 (described in the technical notes in the first progress report). With this the relative humidity ). Logger file must be chozen. Zero must be check. for CO<sub>2</sub> and H<sub>2</sub>O.

3. Check configuration :

- leaf area : 5.68 cm<sup>2</sup>
- flow (internal): 126 µmol.s<sup>-1</sup>

- Cr (set) :           ambient
- Wr (set) :           ambient
- rb                   0.40 m<sup>2</sup>.s.mol<sup>-1</sup>
- Tleaf                (calc)
- Tleaf mtd           (calc)
- Hfactor             0.168
- Trw                 0.88

#### 4. Check logger file

Here is one example of a logger file already use . It, at least, must contained :

A: date  
 B: comment  
 C: record label text  
 D: time of the day  
 E: leaf chamber volume flow ml.min<sup>-1</sup>  
 F: CO<sub>2</sub> reference in vpm  
 G: CO<sub>2</sub> anl, dilution corrected vpm  
 H: H<sub>2</sub>O reference in %RH  
 I : H<sub>2</sub>O dilution corrected %RH  
 J : leaf chamber temp in °C  
 K: leaf chamber temp in °C  
 L: P.A.R at leaf surface, μmol.m<sup>-2</sup>.s<sup>-1</sup>  
 M: transpiration rate mmol.m<sup>-2</sup>.s<sup>-1</sup>  
 N: photosynthetic rate μmol.m<sup>-2</sup>.s<sup>-1</sup>  
 P : CO<sub>2</sub> substomatal concentration in vpm

#### 5. Check screen file

First part :

V.....mol.min-1	Wan.....%RH
Can.....vpm	Wref.....%RH
Cref.....vpm 2.s-1	Q.....μmol.m- 2.s-1
time.....	Tch.....°C

second part :

A..... $\mu\text{mol.m}^{-2}.\text{s}^{-1}$	date.....
E..... $\text{mmol.m}^{-2}.\text{s}^{-1}$	ci.....vpm
gs..... $\text{mol.m}^{-2}.\text{s}^{-1}$	Power
$\rho$ .....mbar	rs..... $\text{m}^2.\text{s.mol}^{-1}$

Of course, this screen may be changed, but at least, it must be sure to be able to follow correctly the dynamic of the photosynthesis with good parameters.

#### 5. Measurements :

At the beginning  $C_{ref}$  must be equal to  $C_{an}$ , the same for the humidity. To get a correct measurement, basic principles remain the same : PAR stable, chamber well closed, flow stable, waiting  **$C_{an}$  at the equilibrium.**

For all other, the notice of the apparatus is quite well done and easy to understand.

#### 6. Maintenance

The apparatus has to be stored in AC room with a relative humidity less than 65 %, in a cool box, for example, with a glass fill with new silicagel.

#### 7. About the PLCA4 portable leaf chamber

Normally, for the leaf temperature, a sensor is provided (miniature thermistor) with the chamber. It was not apparently (?) the case. Requiring information about it from ADC may be useful in the future in spite of a good estimation of this parameter via the energy balance equation.

## 1. b Calibration

CO<sub>2</sub> calibration have been realized for both LCA4 and LCA2 with a pressure bottle of this gas at 800 ppm (Euro-gas management services ltd, Bramley, Surrey. GU5 OEG, UK).

The PAR sensor of the chamber have been compared with one from Orsay (Pontailler, France). RAS. .

The flow was also compared with the flowmeter Fisher-Houdec. RAS. Relative humidity and temperature in the chamber weren't in contradiction with those obtained with the LCA2 system.

## 1. c Measurements

### \* Photosynthetic potential

In way to finish the study undertaken during the previous campaign, further measurements of leaf photosynthesis were done on the clones MK10, MK04, MK22, on the leaves 8 to 10 around the B point from December 94 to March 95. Comparison between both system LCA4 and LCA2 have realized at the same time properly. It is quite obvious that if the both system give aproximatively the same value for the photosynthetic rate in  $\mu\text{mol}(\text{CO}_2).\text{m}^{-2}.\text{s}^{-1}$ , it is not the same for the transpiration and the stomatal conductance which seem overestimated with the LCA4 system. Calculations and test ar still in process with the collaboration of E. Dufrêne (University of Paris XI). May be some bug will be founded in the LCA4 software. In that case a technical note will be published soon.

LCA4      PN (mean, 67 pts) = 7.31 (e.s. 3.42)

LCA2      PN (mean, 67 pts) = 8.34 (e.s. 3.06)

### \* Daily variation of the leaf photosynthesis

From last campaign, an important observation have been pointed out from daily following of photosynthesis : some unexpectable limitations seem appeared around 10.30 am for the assimilation rate which can be explained by both stomatal conductance limitation and photoinhibition.

### \* Leaf rank variation

As it was described in the planned operations, it is quite pertinent to understand what is going on at the different leaf rank as far as the maximal rate of photosynthesis is concerned. Many works (Corley,



1983; Dufrêne, 1989, 1993) have highlighted a decrease of the maximal photosynthetic rate after the leaves rank 20. Studies in the same sense have been undertaken with the LCA4 on clonal material in way to be able to predict what will be the photosynthesis at the canopy scale. All observations have to be made at saturated light with  $PAR > 1100 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ , on equivalent leaflets, numbered from the point B.

Such measuring may be related to the chlorophyll content of the different leaves and also to nitrogen content.

\* photosynthesis on nursery plant

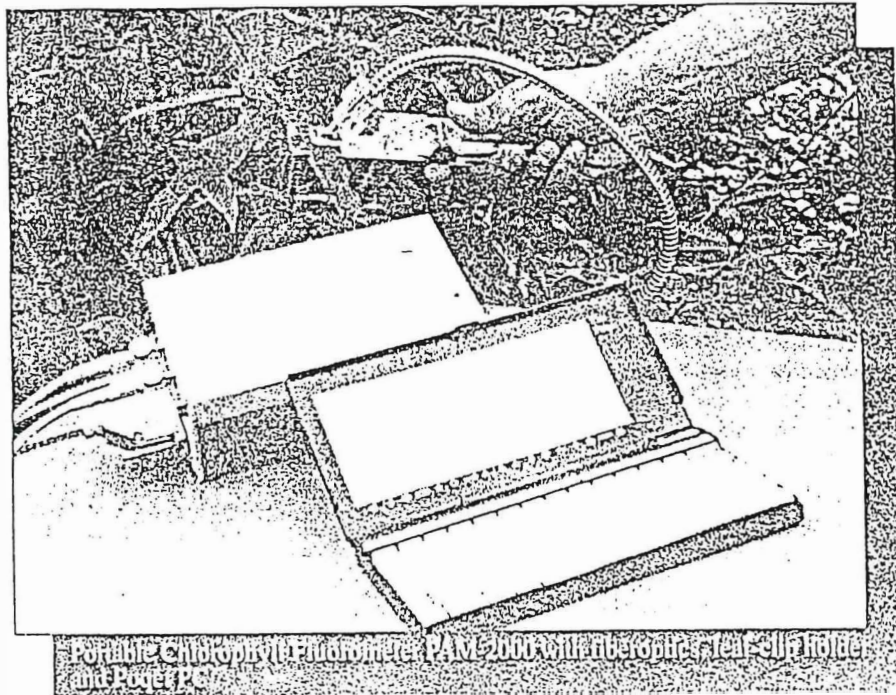
To start with the study of the effect of nutrients on photosynthesis, an experimental design have been built to measure the photosynthesis of all a plant at nursery stage. For that purpose, a chamber have been built with aluminium and polypropylen plastic film. Two fans connected to a 12v batterie ensure a good air homogenization. A thermistance 10 kohms measures the temperature inside. The plant is put inside and fully isolated. Especially soil of the polybag is isolated to avoid contamination in the chamber. The principle of the measurement belongs to that of closed system. A PAR sensor is put at the top of the chamber for radiation recording during the measurement.

At this stage, only the technical aspects have been investigated. Further development will follow during next campaign.

Other point : at the same time , nursery plants are registrated with different vegetative parameters as the number of fronds, number of leaflets, the height and the total leaf area (estimated from the number of leaflets and the lenght and the width of five representative one)

## 2. Fluorescence

In way to get a better undstanding of the factors which can limit the photosynthetic assimilation in the conditions of Sumatra-North fluorescence measurements have been done on clonal material (MK22, MK10, MK04) with the PAM-2000 (Walz GmbH, Effeltrich,



**THE NEW  
PORTABLE  
CHLOROPHYLL  
FLUOROMETER  
PAM-2000**

fig.1PAM-2000

Germany<sup>1</sup>, see fig.). Main significance of the chlorophyll fluorescence is based on the responses of the leaf receiving actinic light. There is, 3 main ways of dissipation of this energy : photochemic, thermic and by fluorescence.

The study was done with Dr. E. Dufrêne in the same time with leaf gaz exchange from 19 february to 4 march 95. Data are still in process. But due to the lack of good and stable radiation during that time, results may still remain without significance.

### 3. Chlorophyll

Simultaneously with fluorescence; measurements of radiation absorbance have been realized with the SPAD-502<sup>2</sup> (see fig.) from the frond rank °1 to the 49, even 56 when it was still present on the tree, for the three clones MK04, MK10, MK22 (with 6 trees per clones, 5 leaflets per fronds and 20 measurements on each leaflets). Nitrogen content analyses on dry leaflets were also undertaken on same material.

The value given by the SPAD-502 express only the relative content of chlorophyll. To known exactly the absolute value, calibration is necessary by the classic method of extraction with acetone, follow by spectrophotometry evaluation.

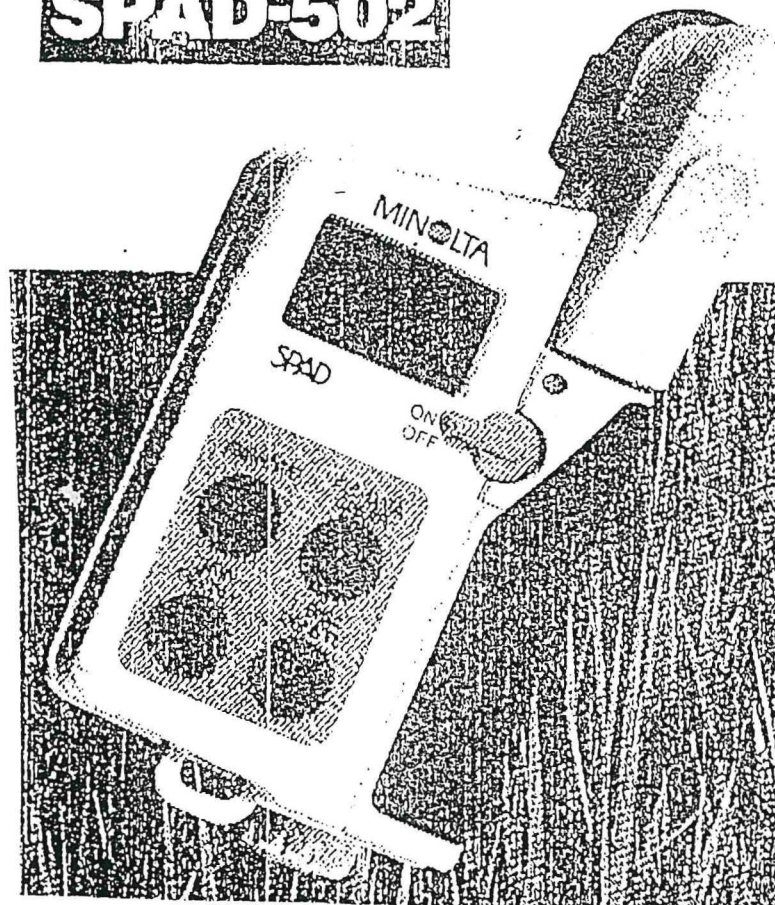
Results :

clones	mean	significance
MK10	68.88	A
MK04	67.27	B
MK22	66.34	C

<sup>1</sup>Portable Chlorophyll Fluorometer PAM-2000 : WALZ Mess -und Regeltechnik, Heinz Walz GmbH, Eichenring 6, D-8521 Effeltrich, Germany, Phone 09133/871, Fax :09133/5395.

<sup>2</sup>Chlorophyll meter SPAD-502 : Minolta Singapore (Pte) Ltd. 10, Toban Gardens , Singapore 2260, phone : 563 5533.

**SPAD-502**



**CHLOROPHYLL METER**

fig.2 SPAD-502.



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Leaf rank

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33	73.92	A
25	72.40	B
17	69.92	C
9	68.01	D
1	53.24	E

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(A, B, C .....: NewMann Keuls test with < 5 %)

Already, from results above it's possible to see that there are significant difference within clones and within leaf rank with rough data. But to be able to give a good interpretation of the results, the respective specific leaf weight of the studied material has to be evaluated. It was done exactly on same studied trees.

As far as the nitrogen content of the leaf is concerned clear relation had been pointed out with the chlorophyll content ( see fig. from Peng et al, 1993). It may be interesting to see such a relation on oil palm, in that way the chlorophyll content of leaves may be a good tool to get idea about nitrogen status.

## 4. Respiration

### 4.1 Leaflet respiration

This type of measurement was already undertaken last data campaign with the idea to follow during night and day the leaflet respiration with a simple closed system. The experimental design is composed by a PVC chamber (volume : 15 027 cm<sup>3</sup>) with inside, two fans (Micronel) connected to a 12 v portable batterie for homogenization, a thermistance 10 kOhms (Sagimeca) for air temperature measurement. At one top of the chamber there is an inlet to uptake sample of air . An IRGA analyzer is connected to this inlet via a specific rubber tube of 5 mm with diameter. One leaflet is introduced in the chamber with a piece of polysthyren. Then mastic is applied around to avoid as much as possible air lost. This design has permit to see that respiration is partially dependant to the temperature but also (see fig.3 ) to the level of carbohydrate pools which are present in the leaflet.

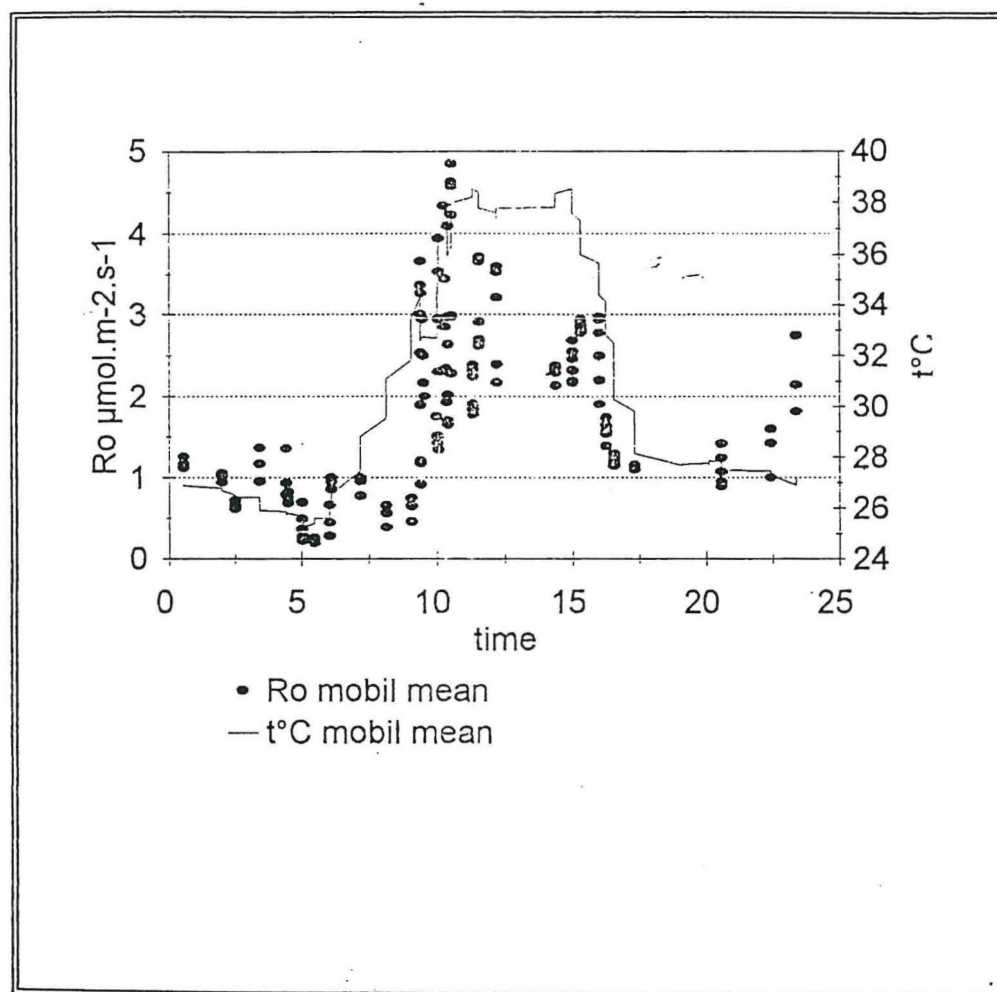


fig.3. Evolution of the dark respiration of the leaflets on frond n° 9 for the clone MK04 (Marihat, Indonesia). Mobil mean , step = 5 . Relation with the air temperature.

present in the leaflet. Comparing the two curves, respiration and temperature, it is possible to see that there is a decrease of the respiration rate after midday even the temperature remains high. Lack of carbohydrates substratum due to a decrease of the photosynthetic rate may be one explanation.

#### Leaf rank variation

(File : LEAFRANK.WQ1)

In way to be able to predict what will be the respiration of all the canopy, the effect of leaf rank on dark respiration rate has been investigated on the spirale n° 1. As it can be expected there is a net decrease of the respiration rate from the younger leaves to old one. The respiration rate of the older leaves is very small. This point has highlight some bottlenecks in the actual experimental design : the volume of the chamber doesn't allow in that case very precise measurement. The only point which brings some variability within measurements is the difference within leaflets as far as their specific leaf weights are concerned. To get better precision, a new chamber has to be built with smaller dimension.

#### 4.2. Soil respiration

(File : BJ.WQ1 ; LAME.WQ1)

##### *In situ*

The comparaisn of two sites corresponding to two families already studied with phenological observations was done in october 94 after finishing test on experimental design. The closed system have been chozen essentially because it gave good estimation before in Benin. It is possible to see on fig.4 the design for the in situ measurements.

More then 300 measurements have been done for each family. In way to highlight possible variation with the planting design and the influence of the roots density on CO<sub>2</sub> release, four locations have been distinguish between trees : 1. near the trunk ; 2. in the middle of the frond pile; 3. in the middle of the harvestpath ; 4. in the middle of

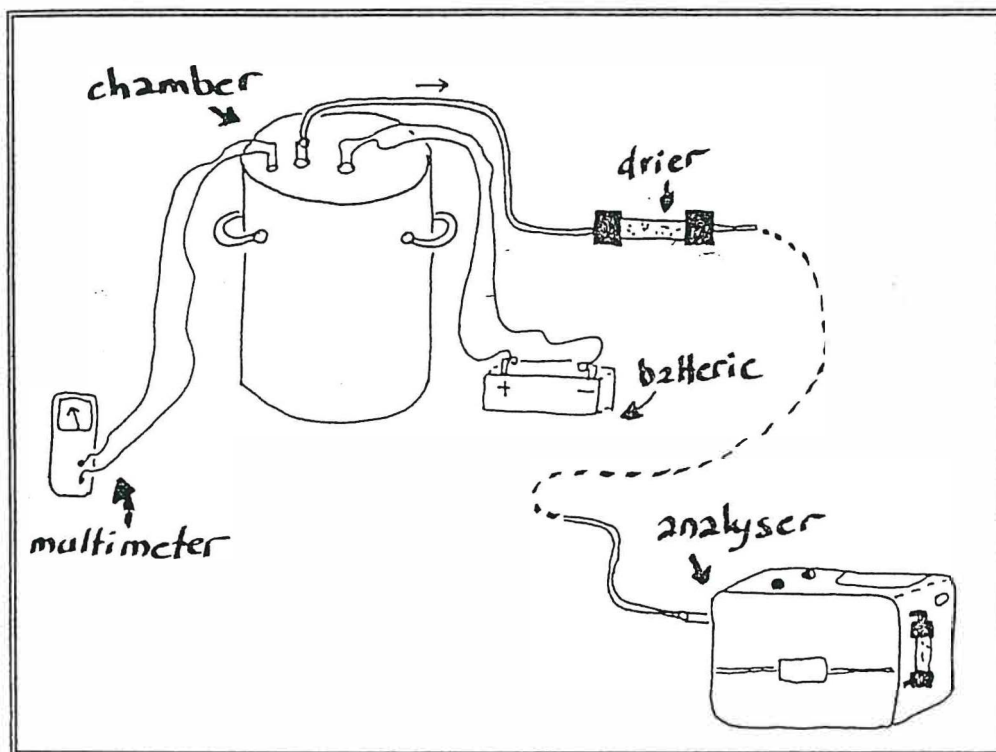


fig.4. Experimental design for soil respiration measurements with a closed system.



interligne. Each measurements have been repeated two time. Clear distinctions within locations were pointed out very quickly, with quite a important release from the frond pile and very few from the harvestpath.

To get a better understanding of these measurements, samples of studied soil were collected for carbon analyses, moisture content and roots density content determination. Analyses were done in the soil laboratory of Marihat Research Station.

To be able to determine in the total release of carbon dioxide the part belonging to the roots respiration, samples of studied soil were collected and the roots carefully removed.

### *In laboratory*

(FILE : SOILLAB.WQ1)

These free-roots soil samples were put in a closed content (~~see~~ fig.), maintain in a thermostat bath at 28 °C. With the same procedure as before for closed system, the respiration of each free-soil samples have been determined.

## 5. LAI

### 5.1 technical aspects of the use of the LI-2000 Plant Canopy Analyzer

The estimation of the LAI by the LI-2000 Plant Canopy Analyzer of Li-Cor is based on the comparison of two readings (for better information, see notice) , the "A" reading , which are recording from above the studied canopy, and the "B" reading which is are below. Quite difficult task is to get very good "A" reading. With two data logger and two sensors, the only task is to choose a good area free from tall trees. For "B" reading sampling was adapted to row crop. View caps from 45° to 180 ° may be reccommended.

\* Instruction for cable :

To collect data from the LI-2000 from a computer, specific cable may be used. It must follow reccomendations below

LI-2000 side

Computer side

25 pins female

9 pins female

2-----3  
3-----2  
20-----4  
6-----6  
7-----5

With the communication from LI-COR : "comm" on the 1000-90 and the cable with previous specification, it's possible to get good data collecting.

## 5.2 Accuracy of the LI-2000

Simultaneously with the measurement of the LAI on clonal material, leaf area have been determined with the Tailliez' methodology (see previous report) in way to evaluate the LAI directly with standard method.

What was found is a complete assimilation of both results when the evaluation from LI-2000 are submitted to specific process with the software C2000 available in Li-Cor company on request. Ring 4 and 5 have to be remove and also some "B" recording when they are quite out normal scale within the others.

	LAI	LAI-(ring 4,5)	measured
MK22	2.98	4.57	4.47
MK10	5.04	7.09	7.09
MK04	3.21	4.06	4.02

## 6. Light interception

With exactly same experimental design (see previous report) some light interception measurements have been conducted on both families, with few changes. Recording are done from 10h to 14h (local time). Horizontality was check each time when sensors were moved from place to place.

## 7. Phenology

Following the technical note 3 (progress report n°1), phenological observations on both studied families (plot MA07S, n°4 "DA128Dself x LM7T self; plot MA08S, n°8 BJ13D self x BJ221P) have done already during one year.

Several remarks can be done on previous results.

"LAME" family n°4 (results until 10/04/95)

tree	yield/year gFM	nb bunches	Lpet cm	Lrach cm	ab.%	SR %
plot a						
4/13	214000	14	119	678	18	66
4/14	150900	11	113	501	8	67
4/15	218900	14	99	640	6	81
4/16	68600	3	98	516	56	25
5/13	182900	13	121	683	7	69
5/14	222500	14	124	618	7	82
5/15	103200	4	111	546	15	32
5/16	175800	9	114	684	0	74
6/13	201100	15	105	640	23	70
6/14	184800	13	117	687	4	81
6/15	183800	14	101	487	20	61
6/16	221300	17	108	639	14	77
mean : 12 bunches/year/tree, 177.3 kg FB/tree.						

plot b

19/5	243800	13	108	639	27	59
19/6	135600	8	108	674	11	74
19/7	227100	11	122	711	22	55
19/8	247200	12	121	694	9	66
20/5	105200	4	115	555	34	40
20/6	271700	16	120	651	10	81
20/7	218600	13	120	673	23	71
20/8	217400	11	110	646	3	66
21/5	225800	10	130	722	7	57
21/6	180400	9	123	494	8	43
21/7	140600	8	111	631	12	42
21/7	140600	8	111	630	12	42
21/8	226380	15	103	599	18	70
mean : 10 bunches/year/tree; 184.47 kg/tree						

Some comments can be done about problem of legitimacy especially for 4/16, 5/15, and eventually 6/15. For 4/16 it may be a problem of abortion.

"BJ" family n°8 (results until 10/04/95)

tree	yield/year	nbunches	Lpet	Lrach	ab%	SR%
154/5	126200	5	130	589	16	17
154/6	177000	7	118	539	26	32
154/8	175600	8	120	579	30	25
155/5	126400	6	123	585	6	28
155/6	99600	3	115	530	13	22
155/7	146400	5	124	567	24	13
155/8	56000	3	110	570	10	29
156/5	90100	5	112	502	4	22
156/6	111800	7	113	524	12	26
156/7	73400	3	103	557		16
156/8	166400	6	130	587	22	33

mean 5 bunches/year/tree; 122.6 kg/year/tree

172/13	161000	8	134	562	3	49
172/14	121000	4	115	584	12	23
172/15	181800	7	115	593	7	21
172/16	182800	6	125	597	12	26
173/13	231400	9	135	613	12	56
173/14	91800	4	125	590	22	12
173/15	63200	2	120	606	26	17
173/16	110200	5	135	578	7	18
174/13	172400	6	114	543	26	33
174/14	109000	6	126	613	6	21
174/15	144400	4	130	629	12	27
174/16	113000	5	134	590	16	16

mean 5.5 bunches/year/tree; 140.16 kg/year/tree

Quite strong differences can be pointed out within family with yield, with bunches pattern and abortion.

The family from "Lamé" shows clearly better production per tree than "BJ" . The african family is characterized by a production of several small bunches with a quite high sex ratio. The local family "BJ" present bigger bunches but with a very low sex ratio.

## 8. Standing biomass evaluation

To start the model, the total standing biomass of the studied material is required. Evaluation of this biomass have been undertaken for the two families (phenology).

### 8.1 Leaves

Leaves n°17 and 33 of 16 trees per family have been cut. The leaf area was determined with Tailliez' methods. All part of the petiole and rachis and leaflets were dried and weighed.

### 8.2 Trunk

Diameters of 16 per family have been measured to know the volume, in a standard way.

### 9.3 Roots

Roots biomass have been determined by sampling with a specific dutch auger (Ejkelkamp) , 1 m and with a cup of 15 cm long. The four different categories of roots were distinguished (primary, secondary, tertiary, quaternary). Results found on the first 105 cm were quite small (8 to 11 t of DM) compared with the Dufrêne 's results in Aek Kwasan (8 to 19 t of DM until 80 cm deep).

To add more precision on the estimation of the root biomass which represent a very important sink in the model, it was interesting to investigate to roots depth in Indonesia conditions. A depth profile have been built in the border of the circle of a tree belonging to the "Lamé" family. Roots were seen until 3 m depth. Samples of soil were collecting along the profile depth every 15 cm. Data are still in process.

## 10. Meteo : daily PAR recording

Daily recording of PAR has been started in Mai 94 with a quantum sensor Li-Cor and a data logger Li-Cor. In December 94, the data logger show some trouble may be with the internal clock, may be with

logger show some trouble may be with the internal clock, may be with the connection with the batterie pack. It have been send to Li-Cor for reparation. Another data logger (Delta T Devices) was used during the period January- April 95. Other interesting parameters like the relative humidity of the air (with a sensor Vaisala), the air temperature were also recorded at that time.

### **Part 3. Proposals for a following programm (6 months)**

#### **1. Phenology**

To continue the routines observations of all the 48 trees is of prime importance. The cropping practices and especially the pruning of the observed trees must be following the standard in Andarasi. For that the number of leaves of the studied trees after one year will not exceed the local standard. Some data process may be undertaken as following :

#### **2. LAI**

In way to define a good method for all kind of trees (age, density), measurements must go on BJ 28 S (n°1, n°4, n°19, n° 24, n°25), B J30 S (n°1, n°3, n°8), BJ 31 S ( n°2, n°10, n°14) for example always in relation with direct estimation of the LA (with Tailliez'method).

A routine may be instaured on "phenological trees", with the LI-2000 every two weeks. As far as the exact number of fronds present in each crown is well known , it can be interesting to see precisely the accuracy of this equipment and also the effect of the pruning on LAI. Other point is concerning the method to measure with the LI-2000, the foliage density of an isolated tree or a nursery plant (well described in the notice). It can becomes after, for nursery plants, a non destuctive tool for following the vegetative development of young nursery plants submitted to a nutrient or water gradient for example.

### **3. Photosynthesis**

#### **3.1 Leaf rank, leaflet variation**

The effect of the leaf rank have been already started on clonal material. This work may be keep on the same way for all the 3 clonal material (MK10, MK04, MK22) at saturated light with PAR > 1100  $\mu\text{mol.m}^{-2}.\text{s}^{-1}$ .

From last year, it have been highlighted that there is an effect of the leaflet position on the maximal photosynthesis. Quantify this effect require specific experimental design taking into account all representative leaflets along the rachis. This study can be undertaken on the leaf rank n° 9 like the potential.

#### **3.2. Seasonnal fluctuation of potential value of the leaf photosynthesis**

It will be pertinent and helpfull to know the pattern of trees during the months not yet explored from july to october and try to conclude on the effect of environmental parameters like the relative humidity of the air (there is a small decrease from June to August). Soil moisture may be measured at the same time , one time per week for example.

#### **3.2 Photosynthesis and nitrogen**

An experimental design was started on commercial nursery plants with a flexible chamber. A new flexible chamber has to be built up with the new dimension of the nursery trees. Nutrient treatment must be applied (?) before experiment is going on.

### **5. Maintenance of equipment**

\* LCA4 : must be put in a cool box with some silicagel. In the field it's better to use a perchlorate magnesium drier before the air entering the system of the analyzer to avoid the problem of the condensation of the vapour in the circuit.

## 6. Equipment to purchase eventually

\* For the stomatal conductance :

From Li-Cor (USA):

LI-1600 Steady State porometer with  
-1600-01 Narrow Aperture  
-1600-07 Cylindrical chamber  
-SP1600TC Spare leaf thermocouple  
- Spare parts G811 Spare battery  
- 1600SM Service Manual

total price 94 : US\$ 9177 (total CIF Sumatera)

\* Meteo station

Cimel electronique

1. Station ENERCO 407 + 7 sensors

* Central Unit with photodiode.....	8000 US\$
* 1 pyranometer CE 180.....	1000 US\$
* 1 temperature sensor CE 185 A.....	200 US\$
* 1 Humidity sensor CE 191 .....	500 US\$
* 1 pluviometer CE 188.....	500 US\$
* 1 Anemometer CE 155.....	500 US\$

These price are aproximatifs.

CIMEL ELECTRONIQUE : 5, Cité de Phasbourg . 75011 Paris .Tel  
: 43 48 79 33.

\* and surely a computer !



# IOPRI-CIRAD joint programm

## ROOTS BIOMASS

technical note, December 94  
Emmanuelle Lamade

Concerning the roots biomass of the oil palm, many studies have already shown that four kinds of roots may be distinguished (FEWERDA, 1977):

\* PRIMARY ROOTS :

Length : 0.6 to 1 m    diameter : 4 to 10 mm    depth : 3 m ..    color : brown

\* SECONDARY ROOTS :

length : 25 to 35 cm    diameter : 1 to 2 mm    depth : ...    color : brown

\* TERTIARY ROOTS :

length : 10 to 15 cm    diameter : 0.5 to 1 mm    depth : ...    color : brown

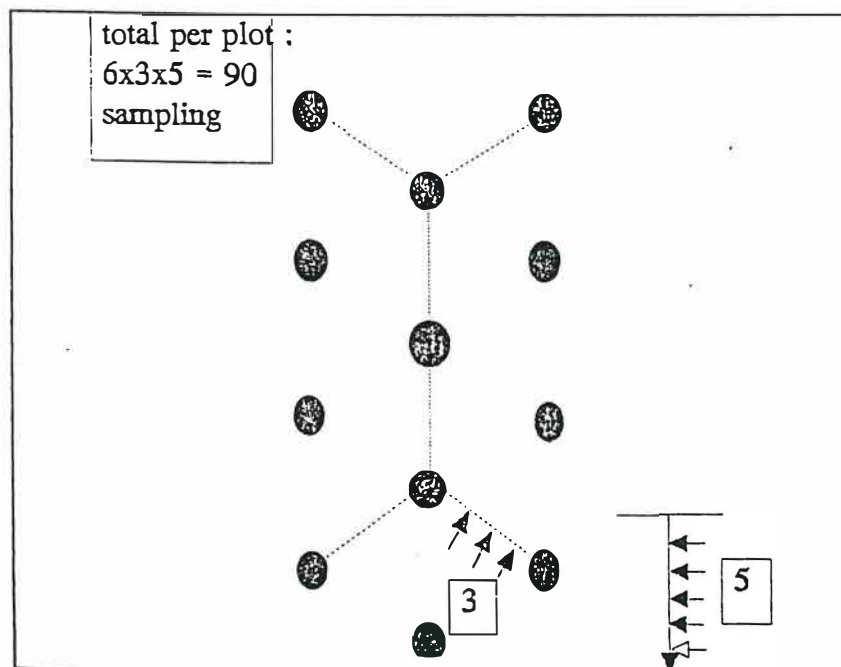
\* QUATERNARY ROOTS :

length : 1 to 4 mm    diameter : 0.2 to 0.5 mm    depth : ...    color : white

In any case it will be difficult to get with the sampling all the roots, especially the finest one (IV) , the following methodology is only one example with the equipment available. This sampling must be completed by a study of the roots profile (one per family at least). But most probably roots are mainly situated near the surface (may be 40 cm depth not more..).

1. Collecting soil samples with the dutch auger (Ejkelkamp) 1m long with a cup of 15 cm long. Per location 5 samples along the depth profile : every 15 cm until 1m depth.

For oil palm we will consider locations around one tree and it's 3 others neighborowh as followi  
ng:



2. Total of sampling per tree will be (see fig.)  $3 \times 3 \times 5 = 45$ .
3. After collecting samples of soil will be put in a plastic bag and in a cool room until preparation.
4. Each sample of soil will be "wash" softly upper one sieve of 1mm and roots mainly floating at the water surface will be carefully collected.
5. Distinction will be made between dead and alive roots and also within categories (I, II, III+IV) . For that all the roots previously collected will be put in a basin full of water.
6. The roots collected in each sample will be dried at 85 °C during one night and after weighed.
6. Distinction will be made between

## IOPRI-CIRAD joint programm

Physiology

### PHOTOSYNTHESIS and NUTRITION

for nursery plants

technical note : proposal design

january 95

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The main purpose of this present study is to look at the relation between the photosynthesis and nutrient level, as far as nitrogen is concerned in first, of oil palm at the nursery stage and to answer at the following question

***Does the nitrogen level applied to plants has an effect on the potential response of the photosynthesis to the light ?.***

We know already that variation in nitrogen content in the plant can affect

- directly the chlorophyll content and the activity of the RUBPC in leaves (Evans, 1983)
- the stomatal conductance and the internal resistance of CO<sub>2</sub> fixation by chlorophyll (Goudriaan and van Keulen 1979)
- the allocation of the carbon at the plant scale (Saugier, pers. comm.)
- the leaf area

This study will be divided in two parts : a first one conducted on nursery plants and a second one by survey of in situ conditions on fertilizer trials for example.

We expose, for the moment the planned operations for the first study on nursery plants.

#### . Material

We want to investigate the genetic effect, for that, we choose 4 contrasting families for origin and production and 8 individual per families. We will apply 4 level of fertilizer.

**Total of plants :  $4 \times 8 \times 4 = 128$  plants**

Best thing is to choose plants of 4 months which had already receive the standard "Marihat" for fertilizer.

## 2. Treatment

Application of four different levels of nitrogen fertilizer

level 1	N0 : standard "Marihat" already apply without nitrogen P K Mg
level 2	N0.5 : standard "Marihat" with only 0.5 rate of nitrogen : 1/2 N, P, K, Mg
level 3	N1 : standard "Marihat" : N, P, K, Mg
level 4	N1,5 : standard "Marihat" plus 1,5 rate of nitrogen : 1,5 N, P, K, Mg

## 3. Methods

The photosynthesis will be measured at the plant scale. For that an assimilation chamber will be built with aluminium corners and flexible polypropylen film (can be found in flowers shops). The volume of the chamber will follow plant size of course. Because it is easy to built, it will be possible to built new one during the plant growth. The photosynthesis of the canopy will be measured with closed system (see El Kohen and Mousseau, 1991).

The chamber will include

- a fan (Micronel, 12 volt) to mix air in the chamber
- a thermistance 10 k to follow the temperature inside the chamber during measuring
- a bottle with ice which will concentrate the vapour coming from the transpiration of the plant
- a light gallium sensor (Pontailer, 1990)

The chamber will be put on PVC table especially inside a throat (excavated from the PVC surface) full of water to avoid air lost.

The nursey plant, during the measuring, will be put in a hole coved by a plastic film to avoid the contamination of the chamber by the roots respiration.

A plastic tube of 3 mm diameter , connected to a magnesium perchlorate drier , will bring the air from the chamber to the IRGA CO2 analyzer.

The formula used to get photosynthesis is one commonly used for closed system (Long and Hallgren, 1985; Barigah, 1991; El Kohen, 1993).

#### 4. Observations

Regularly during the growth of the plants the photosynthesis of all the plants will be measured (from 10h to 12h, every two weeks) and also the LAI with the LAI 2000.

At the same time , portions of limbe will be analyzed to know the nitrogen content in leaf.

The growth of plant will be also follow : number of leaves, height of the plant.

At the end of the experiment, plants will be bring out of soil : following parts will be weighed (in DM)

- roots
- rachis
- petioles
- leaflets

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#### References

- El Kohen A Mousseau M.** 1991 Effet d'un doublement de la teneur en CO<sub>2</sub> atmosphérique sur le bilan carboné des jeunes châtaigniers. Bull. Soc. Ecophysiol. 15 (2) : 135-147.
- Evans J R** 1983 . Nitrogen and photosynthesis in the flag leaf of wheat. Plant. Physiol, 72, 297-302.
- Goudriaan J and van Keulen H .** 1979. The direct and indirect effects of nitrogen shortage on photosynthesis and transpiration in maize and sunflower. Neth. J. Agric. 27, 227-234.
- Long SP and Hallgren J E** 1985 . Measurements of CO<sub>2</sub> assimilation by plants in the field and the laboratory. In " techniques in bioproductivity and photosynthesis". Pergamon Press, London.
- Pontuiller JY** 1990 . A cheap quantum sensor using a gallium arsenide photodiode. Funct. Ecol. 4 : 591-596.
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# Adjustment for Specific Leaf Weight Improves Chlorophyll Meter's Estimate of Rice Leaf Nitrogen Concentration

Shaobing Peng,\* Felipe V. García, Rebecca C. Laza, and Kenneth G. Cassman

## ABSTRACT

The chlorophyll meter provides a simple, quick, and nondestructive method to estimate leaf N status of rice (*Oryza sativa* L.), but the linear relationship between leaf N concentration on a dry-weight basis ( $N_{dw}$ ) and the meter reading differs depending on developmental stage and genotype. The objective was to determine whether prediction of  $N_{dw}$  with the chlorophyll meter can be improved by a simple correction for specific leaf weight (SLW). Leaf N status was estimated by a chlorophyll meter (SPAD-502) and measured directly by micro-Kjeldahl procedure. Specific leaf weight was calculated as the ratio of dry weight to leaf area. In one field study with 'IR72', measurements were taken at midtillering, panicle initiation, and flowering stages on the uppermost fully expanded leaves of both N-deficient and N-sufficient plants. There was a linear relationship between  $N_{dw}$  and SPAD values at each stage, but regression lines differed significantly between growth stages. Based on pooled data from all stages, the degree of linear fit was poor ( $r^2 = 0.49$ ). Adjusting SPAD values for SLW (SPAD/SLW) improved the prediction of  $N_{dw}$  ( $r^2 = 0.93$ ). For another set of measurements made on the flag leaves of five genotypes grown in the field and greenhouse, prediction of  $N_{dw}$  was also improved, from  $r^2 = 0.51$  based on SPAD values alone to  $r^2 = 0.87$  based on the SPAD/SLW ratio. These results demonstrate that SLW influences the prediction of  $N_{dw}$  by the chlorophyll meter, and that the adjustment of SPAD values for SLW greatly increases the accuracy of the prediction. However, when SPAD values are adjusted for SLW, the chlorophyll meter's estimate of  $N_{dw}$  is no longer as quick, simple, or nondestructive as the nonadjusted SPAD values.

THE MEASUREMENT of leaf N by the Kjeldahl procedure is laborious, time consuming, and costly. It is also a destructive method, which limits its use as a diagnostic tool in germplasm screening for higher N use efficiency. The chlorophyll meter provides a simple, quick, and nondestructive method for estimating leaf chlorophyll content (Watanabe et al., 1980). The ability to predict chlorophyll content on a leaf-area basis from chlorophyll meter readings was demonstrated for rice (*Oryza sativa* L.), cotton (*Gossypium hirsutum* L.), soybean [*Glycine max* (L.) Merr.], sorghum [*Sorghum bicolor* (L.) Moench], maize (*Zea mays* L.), grape (*Vitis vinifera* L.), tomato (*Lycopersicon esculentum* Mill.), and apple (*Malus domestica* Borhk.) (Jiang and Vergara, 1986; Yadava, 1986; Marquard and Tipton, 1987; Takebe and Yoneyama, 1989; Tenga et al., 1989; Campbell et al., 1990; Dwyer et al., 1991; Fanizza et al., 1991).

The chlorophyll meter has also been used to estimate N concentration on a dry-weight basis ( $N_{dw}$ ) of rice leaves with the goal of predicting the need for fertilizer-N topdressing (Chubachi et al., 1986; Miyashita et al., 1986; Takebe and Yoneyama, 1989; Takebe et al., 1990; Turner and Jund, 1991). Turner and Jund (1991) demonstrated that the chlorophyll meter

can determine, with reasonable accuracy, the need for N topdressing of semidwarf rice cultivars when meter readings were taken at specific growth stages (either pre-panicle initiation or panicle differentiation). For rice, the degree of correlation between  $N_{dw}$  and chlorophyll meter readings ranged from  $r = 0.82$  to  $0.98$  (Chubachi et al., 1986; Miyashita et al., 1986; Takebe and Yoneyama, 1989; Takebe et al., 1990). However, the regression equations for leaf chlorophyll content or  $N_{dw}$  on the chlorophyll meter reading differed markedly depending on growth stage, genotype, and environment (Takebe and Yoneyama, 1989; Campbell et al., 1990). Therefore, the accurate prediction of plant N status using the chlorophyll meter requires the separate calibration of the relationship between  $N_{dw}$  and the chlorophyll meter readings for different cultivars grown under specific growth conditions and at a specified growth stage.

The lack of a more consistent relationship between leaf  $N_{dw}$  and chlorophyll meter readings at different sites, growth stages, and for different cultivars limits the potential use of this technology for in-season modification of N management. Because the chlorophyll meter readings are based on the leaf chlorophyll's light absorption of specific spectral bands, Campbell et al. (1990) suggested that differences in leaf thickness may contribute to the variability in the linear relationship between  $N_{dw}$  and chlorophyll meter readings. To test this hypothesis for rice, we compared predictions of leaf  $N_{dw}$  at different growth stages and for different genotypes based on chlorophyll meter readings alone, or based on readings normalized by specific leaf weight (SLW), which is related to leaf thickness (Chiariello et al., 1989). The objectives of study were to determine if SLW is responsible for the growth stage and genotype influence on the chlorophyll meter reading, and if so, to determine whether the prediction of  $N_{dw}$  by the chlorophyll meter could be improved by considering SLW.

## MATERIALS AND METHODS

Two studies were conducted in the 1992 dry season at the International Rice Research Institute, Los Baños, Philippines. The first study used a split-plot layout, with main-plot treatments in a randomized complete block design and three replicates. Main plots were six N fertilizer regimes with three rates (0, 60, and 120 kg N ha<sup>-1</sup>) broadcast-incorporated before transplanting in factorial combination with two rates (0 and 60 kg N ha<sup>-1</sup>) applied at midtillering (MT). All plots received 60 kg N ha<sup>-1</sup> at panicle initiation (PI) and 45 kg N ha<sup>-1</sup> at flowering (FL). The MT stage was defined as the midpoint between transplanting and PI. Subplots were four hill spacings (0.20 × 0.20, 0.14 × 0.14, 0.115 × 0.115, and 0.10 × 0.10 m). Fourteen-day-old seedlings of IR72 were transplanted on 17 January with five plants per hill.

Measurements were taken 1 d before N topdressing at MT, PI, and FL. A chlorophyll meter [SPAD-502, Soil-Plant

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**Abbreviations:** FL, flowering; MT, midtillering;  $N_a$ , leaf N content per unit area;  $N_{dw}$ , leaf N content per unit dry weight; PI, panicle initiation; SLW, specific leaf weight; SPAD, [Soil-Plant Analysis Development] chlorophyll meter reading.

Analysis Development (SPAD) Section, Minolta Camera Co., Osaka, Japan] was used to obtain SPAD values of intact leaves. At each stage, the five uppermost fully expanded leaves were selected from each plot. Three chlorophyll meter readings were taken around the midpoint of each leaf blade, 30 mm apart, on one side of the midrib. Fifteen SPAD readings were averaged to represent the mean SPAD value of each plot. After SPAD readings were recorded, the five leaves from each plot were pooled for measuring area, dry weight, and N concentration. Leaf area of the five leaves was measured by a leaf area meter (LI-3100, Li-Cor, Lincoln, NE). Dry weight was determined after oven-drying at 70 °C to constant weight. Specific leaf weight was calculated as the ratio of dry weight to leaf area. Leaf N concentration was determined by micro-Kjeldahl digestion and distillation (Bremner and Mulvaney, 1982) and is reported on an oven-dry basis.

In the second study, SPAD measurements were made on the flag leaves of five genotypes that differed in SLW. The genotypes were grown in different environments: lines IR64478-AC2-7-3 and IR66072-11-3-1-5-2 were planted in a breeding nursery; a new tropical hybrid (IR64616H) and IR72 were grown in an agronomic field experiment; and IR50 was planted in a greenhouse pot experiment. In each environment, measurements were taken within 2 wk of flowering on 10 flag leaves from each line, 8 from both hybrid and IR72, and 20 from IR50. Methods for determining SPAD values, SLW, and  $N_{dw}$  were the same as in the first study.

Data were subjected to simple and multiple regression analyses (SAS Inst., 1982), with  $N_{dw}$  as the dependent variable and SPAD value and SLW as independent variables. Intercepts and slopes of regression lines for different growth stages were compared using an *F*-test (Johnson and Neyman, 1936). For the first study, each observation in the regression analyses represents the data from a single plot, and plot values are means of the five individual leaves sampled from each plot. In the second study, each observation represents separate measurements of individual leaves sampled from the five genotypes grown in different environments.

## RESULTS

Correlations between  $N_{dw}$  and SPAD values were greatest at MT and PI, and weaker at FL of IR72 in the first study (Table 1, Fig. 1a). Slopes of the regression lines of  $N_{dw}$  against SPAD decreased as plants aged. Statistical comparisons among the regression equations indicated that the slope at FL was significantly different from those at MT and PI ( $P < 0.05$ ), and their intercepts were similar ( $P > 0.05$ ). However, it is obvious in viewing Fig. 1a that the intercept differences had a larger effect on the prediction of leaf N content compared with the slope differences within the range of SPAD values observed. When data of the three stages were pooled, the coefficient of determination decreased considerably ( $r^2 = 0.49$ ) due to the different regression lines at the different growth stages. Mean SPAD value at FL was higher than at PI, although  $N_{dw}$  was similar at PI and FL (Table 1). Leaves might be thicker at FL, as indicated by a mean SLW of 58.8 g m<sup>-2</sup> compared with 50.5 g m<sup>-2</sup> at PI. Effects of N fertilizer and plant spacing on SLW were small and inconsistent compared with the effect of growth stage (data not shown).

Multiple regression (stepwise) analysis indicated that both SPAD value and SLW were significant independent variables ( $P < 0.01$ ) for explaining variability in leaf  $N_{dw}$  at all growth stages. The contribution of SLW to variation in  $N_{dw}$  was greater at FL than at MT or PI (Table 1). For the pooled data from the three growth

stages, 93% of total variation in  $N_{dw}$  was accounted for by a regression equation that included SPAD value and SLW as independent variables. Adjusting SPAD values for SLW using the SPAD/SLW ratio resulted in a similar improvement of the linear regression for the pooled data set (Fig. 1b). When each growth stage was considered separately, the degree of linear correlation between  $N_{dw}$  and the SPAD/SLW ratio did not increase compared with that of unadjusted SPAD values except at FL (Fig. 1b vs. 1a).

In the second study, the linear relationship between  $N_{dw}$  and SPAD values for flag leaves of five genotypes was poor (Fig. 2a). Flag leaf SLW of these genotypes at the time when SPAD measurements were taken ranged from 36.2 to 82.0 g m<sup>-2</sup> (data not shown). Significant improvement of the linear regression was observed when SPAD values were adjusted for SLW (Fig. 2b). The slope and intercept of the regression line between  $N_{dw}$  and SPAD/SLW were significantly different from those in the first study (Fig. 2b vs. 1b), but the magnitude of this difference was small. When the data from Study 1 and 2 were combined, there was still a good linear relationship between  $N_{dw}$  and SPAD/SLW [ $N_{dw} = 5.30 + 34.22(\text{SPAD/SLW})$ ,  $r^2 = 0.86$ ].

## DISCUSSION

Consistent with previous studies, the relationship between  $N_{dw}$  and SPAD values differed markedly, depending on developmental stage and genotype. Much of the difference was eliminated when SPAD values were adjusted for SLW, or when SLW was introduced as a second independent variable in the multiple regression; therefore, the prediction of  $N_{dw}$  by SPAD was influenced by SLW. In the first study, measurements of  $N_{dw}$  and SPAD were taken 1 d before N topdressing at MT, PI, and FL in a field experiment with six N-rate and four plant-density treatments. The N-rate treatments ranged from 105 to 285 kg N ha<sup>-1</sup> and density ranged from 125 to 500 plants m<sup>-2</sup>, to provide both N-deficient and N-sufficient plants. The close relationship between  $N_{dw}$  and SPAD/SLW across leaves with different N status suggests that the influence of SLW on the chlorophyll meter's estimation of  $N_{dw}$  was the same in N-deficient and N-sufficient plants.

The differences in slope and intercept of the regression line between  $N_{dw}$  and SPAD/SLW in Study 1 and 2 (Fig. 1b vs. 2b) were fairly small, even though they were statistically significant. This is evidenced by the fact that there was still a good relationship between  $N_{dw}$  and SPAD/SLW when the data from Study 1 and 2 were combined ( $r^2 = 0.86$ ). The small differences in slope and intercept between the two studies could be due to the older leaves (flag leaves) used in the second study. Measurements were taken on the flag leaves in the second study to achieve a wide range of SLW among genotypes.

The chlorophyll meter calculates the SPAD value based on the intensities of light transmitted in the red band (around 650 nm) where absorption by chlorophyll is high and in the infrared band (around 940 nm) where absorption is low (Minolta, 1989). The improved correlation from adjusting SPAD values for SLW suggests that leaf weight per unit area affects absorption of red light more than infrared light in leaves with similar chlorophyll con-

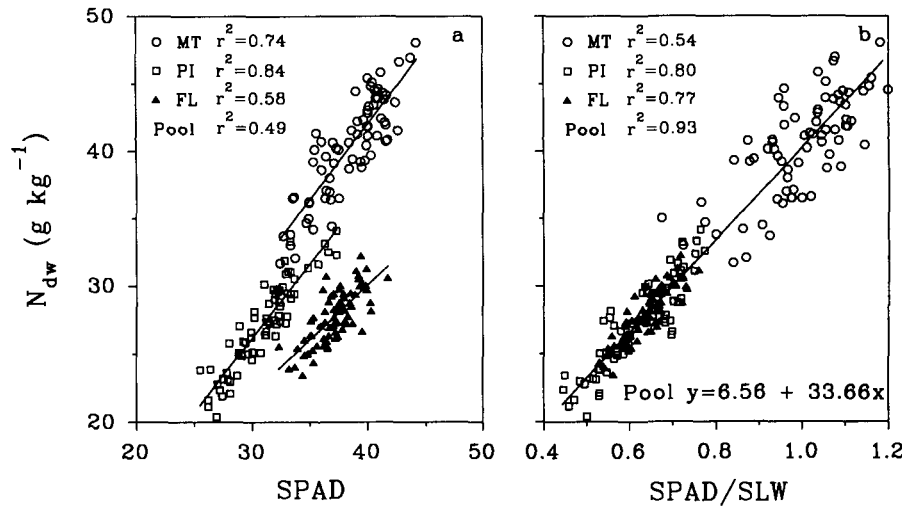


Fig. 1. Linear regression of leaf N per unit dry weight ( $N_{dw}$ ) on (a) chlorophyll meter readings (SPAD values) of IR72 rice at midtillering (MT), panicle initiation (PI), and flowering (FL), with regression equations as given in Table 1, or (b) on SPAD values adjusted for specific leaf weight (SPAD/SLW) for pooled data from the three developmental stages.

concentration on a dry-weight basis. Therefore, using the SPAD/SLW ratio as an independent variable is physically more meaningful than introducing SLW as a second independent variable, even though the degree of improvement in the prediction of leaf  $N_{dw}$  was similar for the two different models (Table 1 and Fig. 1b).

There is no instrument available for the direct measurement of SLW. Currently, SLW is calculated as the ratio of leaf dry weight to leaf area. Therefore, when SPAD values are adjusted for SLW the chlorophyll meter's estimate of leaf N concentration is no longer as quick, simple, or nondestructive as the nonadjusted SPAD values. Since SLW is largely a function of leaf thickness (Chiariello et al., 1989), leaf thickness may influence the estimation of leaf N using SPAD. Adjusting SPAD values for leaf thickness could also improve the prediction of  $N_{dw}$  by SPAD. Although there is not an instrument to directly and accurately measure leaf thickness, the measurement of leaf thickness could be nondestructive and relatively easier than the measurement of SLW. As technology advances, a device for measuring leaf thickness could be developed and incorporated into the chlorophyll meter to provide SPAD values adjusted for leaf thickness. Leaf N determination using near-infrared

reflectance spectroscopy (NIRS) is also a rapid method (Schaalje and Mundel, 1991), but the high cost of an NIRS spectroscope limits its use by researchers in developing countries.

Adjustment of SPAD values for SLW is required to accurately predict leaf N status of different genotypes at different growth stages. Because leaf thickness and SLW varies with light intensity (Osmond et al., 1989), adjusting SPAD values for SLW might also help improve predictions of  $N_{dw}$  in different seasons or years. Another advantage to the SLW-adjusted SPAD values may be that most genotypes will have a common critical SLW-adjusted SPAD value above which no N topdressing is needed. The use of SPAD to diagnose the N status of rice plants may provide a useful tool for managing research experiments and varietal trials where adequate N supply must be maintained in diverse environments and on different soils. The use of SPAD for determining the N status of different breeding lines as it relates to N-absorbing ability or rate of leaf senescence could also be a powerful and rapid research tool.

Based on the measurement principle of the SPAD chlorophyll meter, SPAD values should relate to chlorophyll or N content on a leaf-area basis ( $N_a$ , g m<sup>-2</sup>)

Table 1. Mean and standard deviation of leaf N content per unit dry weight ( $N_{dw}$ ), chlorophyll meter reading (SPAD value), and specific leaf weight (SLW) of IR72 rice at midtillering (MT), panicle initiation (PI), flowering (FL), and the relationship between  $N_{dw}$  and SPAD, or SPAD and SLW at each growth stage and for the pooled data using all growth stages.

Growth Stage	Mean values			Simple and multiple regressions	n	$r^2$	$R^2$
	$N_{dw}$ g kg <sup>-1</sup>	SPAD	SLW g m <sup>-2</sup>				
MT	40.3 ± 3.8	38.5 ± 2.9	38.9 ± 3.4	$N_{dw} = -3.01 + 1.13(\text{SPAD})$ $N_{dw} = 5.40 + 1.12(\text{SPAD}) - 0.21(\text{SLW})$	72	0.74***	0.78***
PI	27.3 ± 3.2	31.0 ± 2.7	50.5 ± 4.1	$N_{dw} = -6.83 + 1.10(\text{SPAD})$ $N_{dw} = 5.81 + 0.99(\text{SPAD}) - 0.18(\text{SLW})$	72	0.84***	0.88***
FL	27.9 ± 2.0	37.2 ± 1.9	58.8 ± 3.3	$N_{dw} = -2.35 + 0.81(\text{SPAD})$ $N_{dw} = 19.28 + 0.70(\text{SPAD}) - 0.29(\text{SLW})$	72	0.58***	0.80***
Pooled				$N_{dw} = -9.41 + 1.16(\text{SPAD})$ $N_{dw} = 25.43 + 0.89(\text{SPAD}) - 0.51(\text{SLW})$	216	0.49***	0.93***

\*\*\* Significant at  $P < 0.001$ .



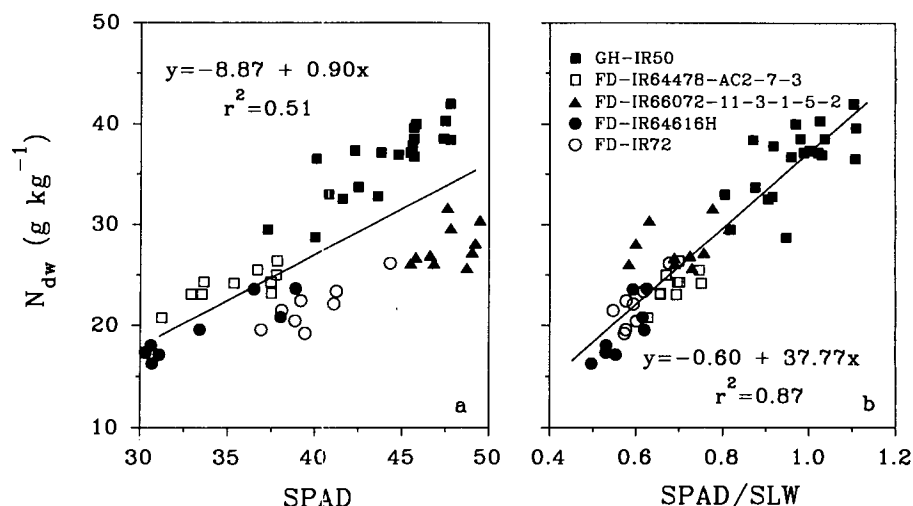


Fig. 2. Linear regression of leaf N per unit dry weight ( $N_{dw}$ ) on (a) chlorophyll meter readings (SPAD values) of five rice genotypes grown in the greenhouse (GH) and field (FD) at the first week after flowering, or (b) on SPAD values adjusted for specific leaf weight (SPAD/SLW) for the same genotypes.

better than on a dry-weight basis. Marquard and Tipton (1987) reported that the relationship between chlorophyll content and SPAD values was stronger when chlorophyll was expressed on a leaf-area rather than on a fresh-weight basis. The improved relationship between  $N_{dw}$  and SPAD values adjusted for SLW also suggests that the chlorophyll meter predicts  $N_a$  better than  $N_{dw}$ . In follow-up studies now in progress, we are testing the hypothesis that the chlorophyll meter estimates  $N_a$  more precisely than  $N_{dw}$ , and determining whether SLW affects the relationship between  $N_a$  and SPAD values. Because the rate of photosynthesis for a single leaf or a canopy depends on leaf area as well as leaf N content, a nondestructive method to estimate leaf N on an area basis would be useful to predict net assimilation or as input for growth simulation models.

## REFERENCES

- Bremner, J.M., and C.S. Mulvaney. 1982. Nitrogen—Total. p. 595–624. In A.L. Page et al. (ed.) *Methods of soil analysis*. Part 2. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.
- Campbell, R.J., K.N. Mobley, R.P. Marini, and D.G. Pfeiffer. 1990. Growing conditions alter the relationship between SPAD-501 values and apple leaf chlorophyll. *HortScience* 25(3):330–331.
- Chiariello, N.R., H.A. Mooney, and K. Williams. 1989. Growth, carbon allocation and cost of plant tissues. p. 327–366. In R.W. Pearcy et al. (ed.) *Plant physiological ecology: Field methods and instrumentation*. Chapman & Hall, New York.
- Chubachi, T., I. Asano, and T. Oikawa. 1986. The diagnosis of nitrogen nutrition of rice plants (Sasanishiki) using chlorophyll-meter. *Jpn. J. Soil Sci. Plant Nutr.* 57(2):190–193.
- Dwyer, L.M., M. Tollenaar, and L. Houwing. 1991. A nondestructive method to monitor leaf greenness in corn. *Can. J. Plant Sci.* 71:505–509.
- Fanizza, G., C. Della Gatta, and C. Bagnulo. 1991. A nondestructive determination of leaf chlorophyll in *Vitis vinifera*. *Ann. Appl. Biol.* 119:203–205.
- Jiang, X.X., and B.S. Vergara. 1986. Chlorophyll meter (SPAD-501) to quantify relative cold tolerance in rice. *Int. Rice Res. Newsl.* 11(3):10–11.
- Johnson, P.O., and J. Neyman. 1936. Tests of certain linear hypotheses and their application to some educational problems. *Stat. Res. Mem.* 1:57–93.
- Marquard, R.D., and J.L. Tipton. 1987. Relationship between extractable chlorophyll and an *in situ* method to estimate leaf greenness. *HortScience* 22(6):1327.
- Minolta Camera Co. 1989. *Manual for Chlorophyll Meter SPAD-502*. Minolta Camera Co., Osaka, Japan.
- Miyashita, K., H. Shinke, M. Endo, and M. Takahashi. 1986. Vegetative diagnosis and growth forecast of rice: I. Adaptability of SPAD-chlorophyll-meter. *Tohoku Agric. Res.* 39:53–54.
- Osmond, C.B., W.W. Adams III, and S.D. Smith. 1989. Crassulacean acid metabolism. p. 255–280. In R.W. Pearcy et al. (ed.) *Plant physiological ecology: Field methods and instrumentation*. Chapman & Hall, New York.
- SAS Institute. 1982. *SAS user's guide: Statistics*. 4th ed. SAS Inst., Cary, NC.
- Schaalje, G.B., and H.H. Mundel. 1991. Use of residual maximum likelihood to evaluate accuracy of two NIRS calibration procedures, relative to Kjeldahl, for determining nitrogen concentration of soybeans. *Can. J. Plant Sci.* 71:385–392.
- Takebe, M., and T. Yoneyama. 1989. Measurement of leaf color scores and its implication to nitrogen nutrition of rice plants. *JARQ* 23:86–93.
- Takebe, M., T. Yoneyama, K. Inada, and T. Murakami. 1990. Spectral reflectance ratio of rice canopy for estimating crop nitrogen status. *Plant Soil* 122:295–297.
- Tenga, A.Z., B.A. Marie, and D.P. Ormrod. 1989. Leaf greenness meter to assess ozone injury to tomato leaves. *HortScience* 24(3):514.
- Turner, F.T., and M.F. Jund. 1991. Chlorophyll meter to predict nitrogen topdress requirement for semidwarf rice. *Agron. J.* 83:926–928.
- Watanabe, S., Y. Hatanaka, and K. Inada. 1980. Development of a digital chlorophyllometer: I. Structure and performance. *Jpn. J. Crop Sci.* 49(special issue):89–90.
- Yadava, U.L. 1986. A rapid and nondestructive method to determine chlorophyll in intact leaves. *HortScience* 21:1449–1450.

IOPRI-CIRAD joint programm

April 95, 15 th.

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## PHENOLOGY

Concerning the pruning palm trees must be normaly maintained

1. One pruning round per year : during April . At least not more than 5 fronds per spirale;  
 . The total remaining fronds per tree will be between 30 and 40.

Other routine

LAI of both families "LAME", "RISPA" will be followed every two weeks with the LAI-2000.

## ROOTS

In order to observe the maximun depth of the root system, two trenches (one per family) have to dig out just outside the plot very close to the trunk in the weeded circle. AT least 5 m depth, 2 m width and 5 m lenght.

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