cirad

RAPPORT D'EXPERTISE

CONFIDENTIAL

ISOPALM PROJECT

ANNUAL REPORT 2012-2013

CHARACTERIZATION OF MINERAL FLUX N-K FOR OIL PALM

Dr Emmanuelle Lamade

2605

27 th march 2014

Aek Loba, Indonesia

cirad

RAPPORT D'EXPERTISE

ISOPALM Project- Annual report 2012-2013. Characterization of mineral flux N-K for oil palm.

Emmanuelle Lamade, CIRAD, UPR34, Montpellier.

Summary

The main objectives of ISOPALM project is to propose a series of observations on oil palm *in situ* in order to understand the allocation of N and K in all vegetative and reproductive organs and to compare several types of genetic plant materials especially towards K (K+/K-). This experiment is conducted on the trial ALCP10 in Aek Loba. This project aims to answer the research questions as "how the rachis mineral content is pertinent or not compared to leaflets", "why there is some variations within genetic materials (as K+ or K-)" and *in fine* to understand the general trend of N,P,K allocation in all organs. Activities beared on different years (2011,2012,2013/2014). A first annual report for ISOPALM project have been issued in 2012. Interesting results were already pointed out in relation with the research questions. Significant differences were found on N and K contents between heterotrophic tissues compared to autotrophic one with K preferentially located and stocked in trunks and petioles (also rachis). Progenies with different K leaflets contents presented related differences for functionnals traits (LA, SLW, Height, trunk diameter) and leaf metabolism (solubles sugars, starch).The new results for this year are the functional typology of the genetic materials (N+K+,N-K-) belonging to two contrasting adaptive strategies "*the quick return invest*" and the "*slow return invest*" involving minerals and carbon metabolism traits. The palm trees belonging to "quick return", are presenting high minerals contents, small trunk height and high photosynthesis and high metabolism turn-over. They have high minerals requirement and can adapt in difficult ecology.The other palm trees belonging to the "slow return" present low minerals content, high height, low photosynthesis and low metabolism turn-over. They have lower mineral requirement and can only develop in potential environment.Other results are concerning the K allocation in the system rachis-leaflets. Some progenies present a huge difference in K content between rachis and leaflets. This is related to the trend of sugars transportation from the leaflets to the rachis. A relation has been found between this K gradient from rachis to leaflets and the ratio glucose/starch contents in the leaflets. Specifically,in ALCP10, some accumulation of sucrose have been found in leaflets and trunks indicating a possible disfunctionning due to the roots conditions. *Ganoderma* infestation may be at the origin of the poor conditions of the root system.

2605

27 th march 2014

Aek Loba, Indonesia

INTRODUCTION

ISOPALM2 is an ecophysiological project totally devoted to the study of minerals fluxes of N and K which are important for oil palm production. This project started in 2011 with the main aims to answer to agronomical questions about variations in the leaf mineral level coming from the Leaf Diagnosis (LD) and to compare the specific responses of genetic materials at SOCFINDO.

Photo 1. ALCP10 trial at Aek Loba Estate, November 2012, progeny A under K0 (photo E. Lamade)

OBJECTIVES

The main objective of ISOPALM is to propose a series of observations on oil palms trees *in situ*, in the field, as well as under controlled conditions to understand the allocation of N and K in all vegetative and reproductive organs, and compare several types of genetic plant materials especially towards K (K ++/K+/ K-/K--).

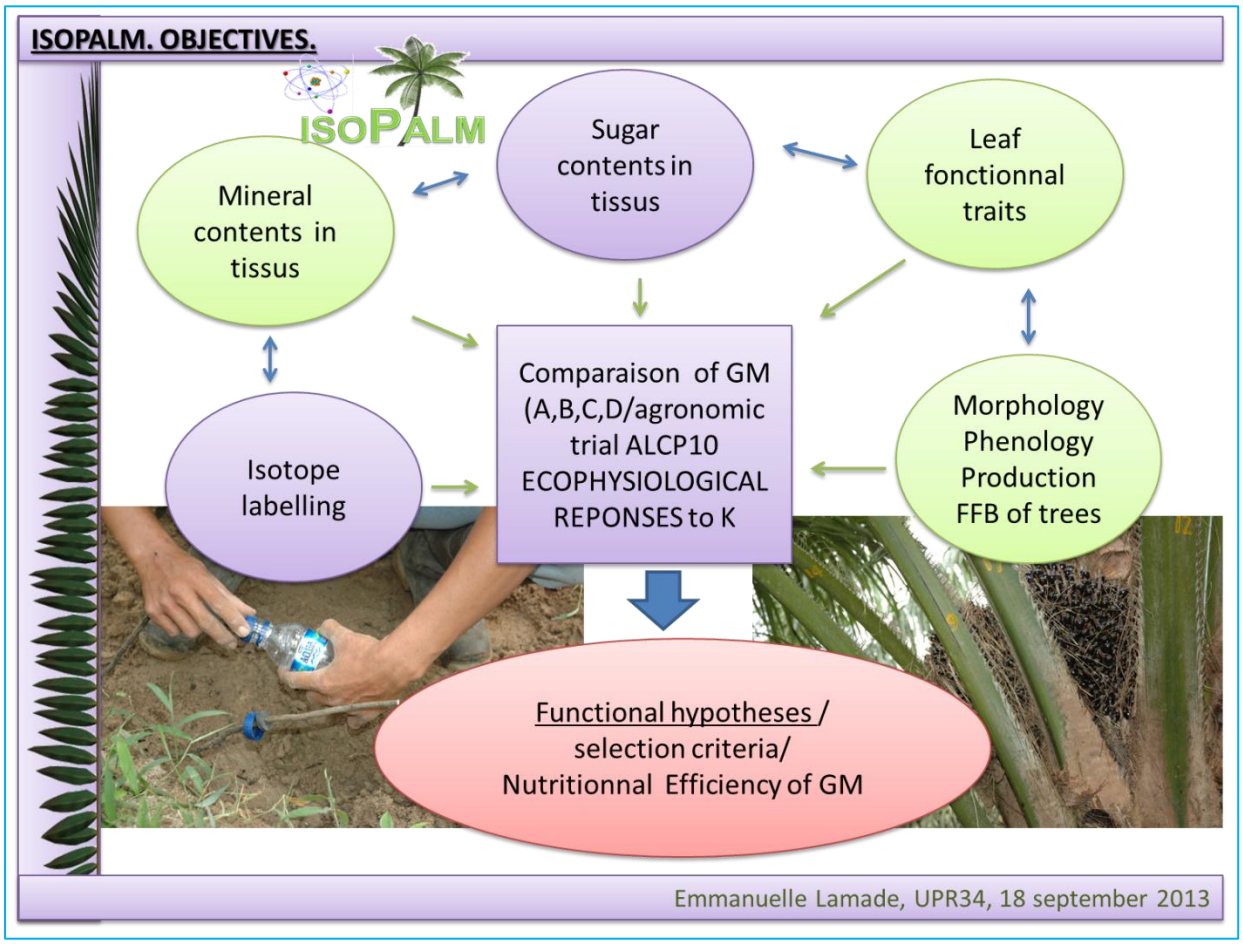


Fig. 1. Overview on ISOPALM research target.

Observations on tissues (leaflets, rachis, petioles, trunk, roots, bunches) are mainly composed by comparison of mineral contents (N,P,K sometimes Mg, Ca), in relation with metabolic contents (starch, soluble sugars as sucrose, glucose and fructose), completed by morphological parameters as leaf area (LA), specific leaf weight (SLW), trunk height and diameter called also "functional traits". Isotope labeling will be used for investigate the potential synergy between N and K entrance in all tissues. The use of stable isotopes (^{15}N, ^{41}K, ^{85}Rb), more and more used as natural tracers in ecophysiology (from the ecosystem scale to the cell) is completing conventional methods of N-K analysis in each organ for each plant material. We also wish to relate the key parameters of the carbon flux (carbon reserves, remobilization of carbon) as soluble sugars and starch levels with N-K flux of the same organs. This last point will include the preferential allocation of K in certain organs in a new light.

Photo 2 and 3. Left : ALCP10 trial in Aek Loba (North Sumatra). Right : fertilizer trial under controlled conditions, Montpellier (France). Photos E. Lamade.

As already described in last report (Lamade, Annual Report - 2011 activities,) an *in situ* fertilizer trial site was selected for this study : the fertilizer trial ALCP10 (SOCFINDO plantation, North Sumatra, Aek Loba), genetic factorial trial K4 Ca2 (with four progenies A, B, C, D, planting year 2004, Photo 2, table 1).

A	BB 6518 D x LM 12989 P
B	BB 8314 D x BB 8847 P
C	BB 8310 D x BB 8844 P
D	BB 6443 D x BB 8844 P

Table 1. Description of the genetic material in ALCP10

For ISOPALM project, the following trees have been selected (it is important to notice that not all the trees of the trial ALCP10 are studied, only a part of them) : it can be seen on Table 2.

trees	prog	trees2	prog2	trees3	prog3	trees4	prog4
100-23	A	81-24	B	62-13	C	63-10	D
100-5	A	100-6	B	62-12	C	64-11	D
63-12	A	101-24	B	67-10	C	67-6	D
63-13	A	102-25	B	68-11	C	67-7	D
69-10	A	61-10	B	67-4	C	69-12	D
69-11	A	61-11	B	67-5	C	69-13	D
69-6	A	67-12	B	81-23	C	83-24	D
69-7	A	67-13	B	82-23	C	84-25	D
81-6	A	68-12	B	81-19	C	83-19	D
81-7	A	68-13	B	82-18	C	83-18	D
83-10	A	69-5	B	82-10	C	83-12	D
83-11	A	70-4	B	82-11	C	83-13	D
83-16	A	82-12	B	83-4	C	83-6	D
83-23	A	81-12	B	83-5	C	84-6	D
84-17	A	81-16	B	99-25	C	101-22	D
84-23	A	81-4	B	99-24	C	101-4	D
99-22	A	81-5	B	101-6	C	101-5	D
99-4	A	82-17	B	101-7	C	102-22	D
		82-25	B				
		99-7	B				

Table 2. ISOPALM trees in ALCP10 for A,B,C,D progenies.

A second phase of the study is conducted under controlled conditions in a greenhouse at Montpellier (Photo 3), on seedlings from materials presenting a "potassium" level contrasted (origine SOCFINDO PSBB).

These two additional experiments were primarily designed to establish a number of explanatory hypotheses about the flow of N and K in the whole plant specific in oil palm, to identify areas of K reserve and mineral remobilization phenomena if they exist. N and K are not *a priori* in the same metabolic compartments, but it is possible to find phenomena of synergy in their transfer mode between the petioles, rachis and leaflets.

RESEARCH QUESTIONS

Our main research questions are :

- how the leaf mineral content are pertinent or not compared to rachis for K
- to undestand why there are some variations within genetic materials (as K+ or K-)
- to understand general trend of N,P,K allocation in all organs

SCIENTIFIC COLLABORATIONS

This project was validated in January 2011, then again in 2012 and 2013 with external collaborations in addition with Palmelit and CIRAD (UPR34) :

- SOCFINDO – Aek Loba – Unit CIRAD (Tim CIRAD) , North Sumatra, Indonesia .
- ESE , laboratory of Ecology (University of Paris XI, Orsay, Prof. J. Ghashghaie)
- IBP-Plateforme Metabolisme-Metabolome (University of Paris XI, Orsay ,Prof. G. Tcherkez)
- James Hutton Institute (Aberdeen, Ecosse, UK) (Dr A. Midwood)

  from CIRAD : Dr E. Gérardeaux.

EXPERIMENTAL PROGRAMM AND SUMMARY OF ACTIVITIES

In year 1 (2011), *the first step of ISOPALM is bearing on fine study of mineral content variations (more specifically N and K) in all organs (leaflets, rachis, petioles, meristem,terminal bud, trunk, roots, bunches with fruits, spikelets and stalk) in relation with environmental ressources and oil palm growth (leaf emission, bunches index, harvesting and prunning, allometric observations).

This study is conducting on a factorial trial, K^4 Ca^2 (ALCP10, SOCFINDO, Aek Loba Estate) on four constrasting materials (A,B,C,D) presenting potentially different mineral foliar concentrations (K+ (A) and K- (B) at adult stage.

Results : *significant differences were found on N and K contents between heterotrophic tissues compared to autotrophic one with K preferentially located in trunk and petioles (and also in rachis) (Fig.1). A and B, showed significant differences for N and K contents as well as for morphological traits (LA, SLW, height/k diameter), metabolism patterns (soluble sugars, starch) phenological recordings.*

In addition with this experimentation *in situ*, another one was conducted in Montpellier, on seedlings, under controlled conditions, on two types of material *a priori* « K+ » et « K-« (equivalent to the ALCP10 material) submitted to nutrient gradient N-K. Similar observations were undertaken on young plants, at nursery stage, as leaf mineral contents, metabolic analyses, phenological recordings and allometric measurements (Lobato Rodriguez et al. 2012, Annexe 4).

**the second step of the study* is concerning the use of stable isotope (^{13}C, ^{15}N , ^{41}K, ^{85}Rb) which will permit us to strengh our knowledge on the internal dynamics of mineral nutrients (N and K) from absorption until allocation, to reserve elaboration and remobilisation. Sugars evolution (starch and soluble sugars) can be characterized as well as sugars fluxes to bunches in relation with mineral fluxes.

In year 2 (2012), original study on A and B, for mineralomass estimation, have been extended, in the field, at two other genetic materials (C,D) presenting intermediate values for K leaf content. Allometric relations were investigated between leaf K content (rank 17) and others tissues in other plant compartments. Isotopic studies are in, 2012, in a second phase with the samples analysis. We will pursue the isotopic analyses to understand the phenomena of internal remobilisation and we shall be

interested in the effects of N and K on the metabolic ways responsible for the filling of the bunches. We shall study then the ecophysiological behavior of the palm tree along a known potassium gradient (K0, K2, K3) with the use of the ^{13}C.

In year 3 (2013), we will complete and pursue all the observations been organized on ALCP10 (Phenology, aerial and belowground biomass of 4 progenies, A, B, C, D on ALCP10). We will move forward on the hypotheses linking the precise location of K in relation with soluble sugars, its dynamic in the tree and the mean to obtain a good nutritional diagnosis of the palm tree. We will also propose a structuring typology of the plant material based on their respective adaptive strategy. Criteria at young stage will be identified and propose to separate the N+K+ from N-K- progenies on a big set of families.

1. ACTIVITIES IN 2012

A. Part 1 : study programm in ALCP10 – SOCFINDO- North Sumatra.

A.1-Mission : was done in 15 October to 3 November 2012 (see all details and programmation en ANNEXE 2)

Experimental conditions : short presentation

The trial ALCP10 in Aek Loba contains 4 levels of potassium (KCl) with KO: nil application; K1: 0,5 kg / palm tree / year, K2: 1,5 kg / palm tree / year; 4,5 kg / palm tree / year and two types of Ca fertilisation (Ca 1: RP-dolomite) and Ca 0 (DAP-kieserite); these "original" applications were able to undergo since the beginning of the agronomic trial, some adjustments consecutive to the results of foliar diagnosis. Four progenies (A, B, C, D) are tested. From a genetic point of view, A was derived from S6305 = (DA5D * DA3D) * selfed LM2T, when B, C, D were derived from : S6325 = (DA5D * DA3D) * LM5T selfed. C and D have the same parents.
We choose at first to focuse on A and B materials (2011) which seem very contrasted when we examine the foliar contents in potassium in relation with the treatment K. At first, A will be qualified of K + and B as K-. They are towards the nitrogen respectively N + and N-.

Only the level K0, K2, K3 are just studied in the application Ca1. Then in 2012, the materials C and D which have intermediate leaf K contents are examined (they are rather N-K-). These two last progenies are under biometrical measurements. On the other hand, for materials A and B, an investigation of the root system and the total mineralomass was undertaken in 2012.

A.2- Realisations

For the realisation of the field study, a complete team of 7 kariawan, full time, was provided by SOCFINDO in Aek Loba.

A-2-1 Phenological study on A and B in 2012

Phenology

At the begining of the project, in February 2011, 72 palm trees chosen on ALCP10 were the object of a precise phenological study according to a classic protocol already used by Dufrêne

(1989). In 2012, we retained only 36 oil palm trees, on the original set, for continuation. These trees are observed carrefully twice a month by the team of Aek Loba (Edyana Suryana) ALSP.

Biometry

The height of every palm tree was again measured (Method IRHO: from the stipe base of the petiole of the leaf of rank 33) to determine the annual growth according to the plant material A,B,C,D and the K level (K0,K2,K3).

The density of the trunk: it is an estimation very important for the estimation of the biomass and the individual mineralomass. In 2011, only a set of 20 samples collected on a single palm tree (at the same time below, in the middle and at the top) allowed to make a first estimation.

In 2012, every studied palm tree (36: A and B) was sampled according to this principle to determine an individual density of every palm tree (A, B according to K0, K2, K3). The sampling is done with an auger of Pressler 45 cms long and 5 mm in diameter.

A.2.2. Estimation of roots biomass for A and B : this estimation which is very time consumming started on the 36 oil palm trees octobre 2012. Voronoï method (simplified one) was applied :

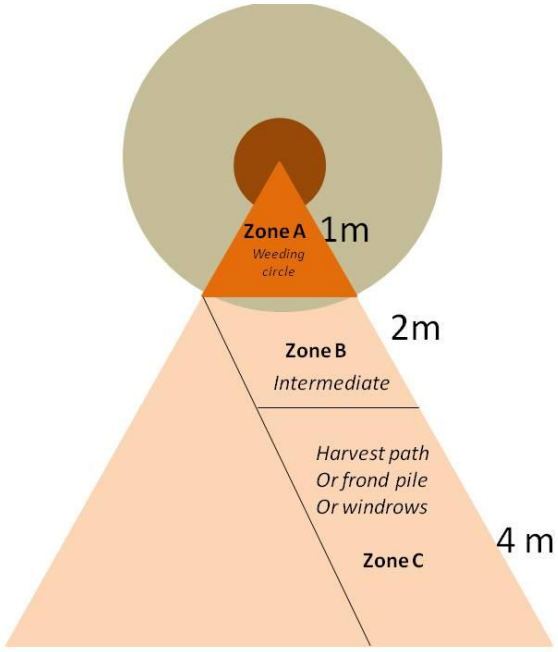


Fig. 2. Experimental scheme used for roots system study for ISOPALM2 in ALCP10.

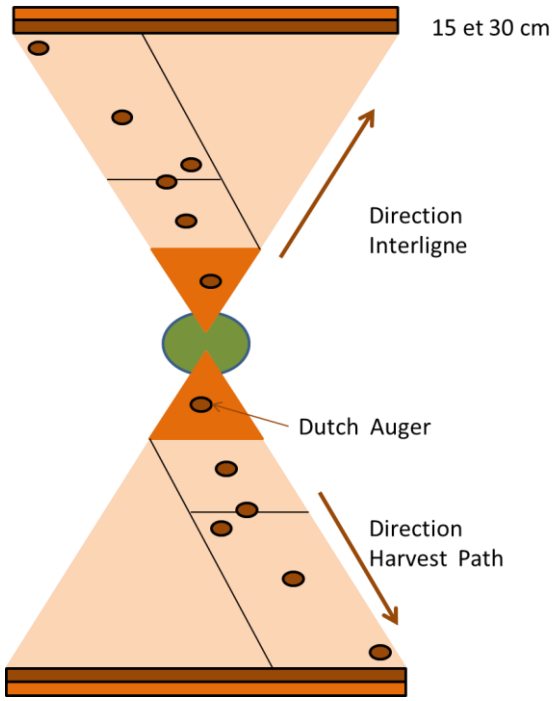


Fig.2bis Localisation of soils + roots samplings with a dutch auger in a « Voronoï » triangle.

For this study : 3 zones (Fig. 1) A,B,C have been delimited from a trunk of palm studied. These zones were bounded in 2 directions for 36 palm trees A and B (Fig. 2 and photo 4/7).

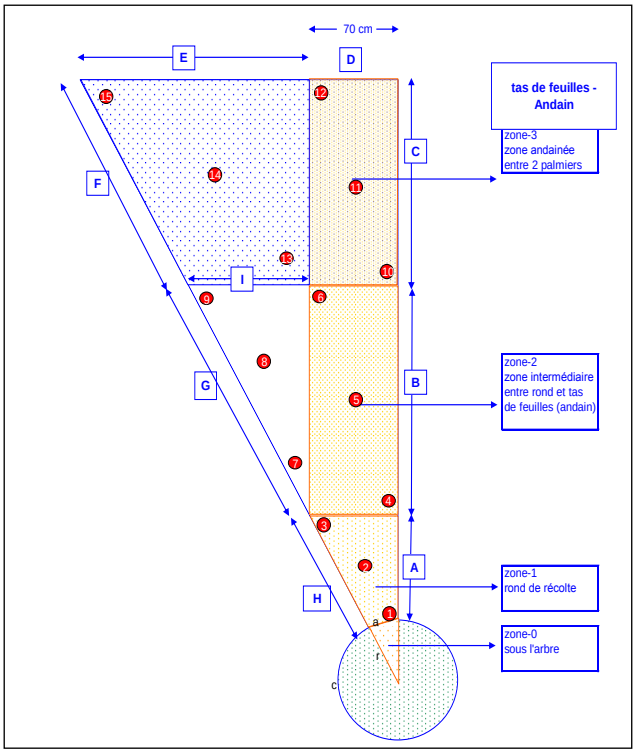


Fig. 3. Specific Voronoï triangle design (From H. Aholoukpé, PhD Thesis)

Samplings were achieved (Fig.2) in the Dutch auger inside these 3 zones on two depths: the first one at 15 cm, the second at 30 cm. The total of samplings by Dutch auger by palm tree is 24. To complete and "calibrate" the study, complete excavations of 3 zones on 15 and 30 cm were made for several palm trees.

The original “voronoi” design is a little bit different as the graph presented in Fig. 3. (from H. Aholoukpé , PhD Thesis) . Then we will adapt calculations in function of our specific design.

All the volume of the soil so excavated is sieved under the water to re-collect roots. These are then dried gently in the oven under 60°C. A sample of soil is also taken by palm tree to estimate the density of the ground. These are also placed in oven under 100°C.

Remark: normally the maximal distribution of the roots system in the conditions of the North of Sumatra is situated between 15 cm and 40 cm. In Aek Loba, the observed maximum is rather situated before 30 cm; this is maybe due to the presence of the water table near the soil surface (fluctuation close to 40 cm) and thus maintain the roots system between 0 and 30 cm.

Photo 4.-5-6-7 . Realization of an excavation of soil for the roots sampling following simplified Voronoï. Samplings with the Dutch auger.

A.2.3. Mineral variation in the canopy for A and B

To determine the gradient of N and K from the young leaves until the oldest, leaflets samplings ware done along the spiral n° 1

- Leaf rank 1 : 5 leaflets at 3 different levels
- Leaf rank 9 : idem
- Leaf rank 17 : idem
- Leaf rank 25 : idem
- Leaf rank 33 and 42 if still present in the canopy

The first 10 palm trees selected for canopy variation study are : 69/10- 83/11-70/4-68/13-82/17-68/23-68/12-69/5-61/11-61/10.

The leaflets collected were dried in the oven under 50-60°C to avoid as much as possible to lose nitrogen. Mineral analyses (N, P, K, Mg, Ca) were done at Sumbio Bah Lias.

A.2 .4. Fine study of the material C and D in the trial ALCP10

A fine characterisation of the progenies C and D was undertaken in October 2012 under a K gradient (3 levels of potassium K0,K2 and K3) : an estimation of the standing biomass is required to estimate the individual mineralomass.

As before for A and B, a total of 36 palm trees was selected. We want to compare A,B,C,D then the next neighbours of A and B were chozen in C and D progenies.

List :

62/13;62/12;63/10;64/11;67/10;63/11;67/4;67/5;67/6;67/7;69/12;69/13; 81/23;82/23; 81/19;82/18; 82/10;82/11;83/24;83/19;83/13; 83/4; 83/5; 83/6; 84/6; 99/25; 99/24; 101/22;101/4; 101/5;101/6; 101/7; 102/22;

Biometrical studies

The 36 palm trees selected for mineral balance were submitted to biometrical investigations as the leaf area (LA) following the method of Ballo & Koffi (1992) already used pour A and B (photo 2). SPAD measurements completed Leaf Area determination. SLW (specific leaf weight) were estimated too.

To complete this first set of data concerning the canopy, the height of each palm trees were measured as well as diameters as 3 different levels. Trunk samplings are completing heights and diameters for individual density estimation.
Simultaneously to the biometrical measurements, as in 2011, samples of biomass were collected at the level of the petioles, the rachis and leaflets.
For the trunk : samplings were done at the base, at the middle at the trunk top.
For 5 palm trees, roots (mixing of I, II, III+IV) are collected at 1.50 m of the trunk (with 5 repetitions around the trunk).

The samplings are dried in a oven, one night, under 60 °C and conditionned for analyses. Wet and dry weights are measured.

Samplings for analyses :

Photo 8-9. Samplings leaflets along rachis, estimation of LA. Samplings stipe, fruits, stalk, spikelets Other samplings are done in the bunches (stalk, fruits and spikelets).

- Mineral analyses will be done (N,P,K, Mg, Ca and sometimes CL) in Bah Lias-Sumbio (PT Lonsum) or the lab CIRAD US49.
- Metabolic analyses : at ESE or IBP (University of Paris XI) .
- Dry weight of collected roots (Voronoï and Dutch Auger)

NB : samples for metabolic analyses and isotopic measurements are put in liquid nitrogen and dried as soon as possible.

A.3 .Control of the meteo station in ALSP

A small meteorological station Watchdog (SPECTRUM , USA, photo 3) was install at ALSP - Aek Loba (SOCFINDO) in february 2011. It can be connected wireless.

General meteo ouput :

- Rainfall (in mm)
- Daily temperature every hours °C
- PAR instantaneous every hours µmol m^{-2} s^{-1}
- Rg (global radiation) in Wm^{-2}
- Soil temperature in °C

- Relative humidity in %

But in 2012 a number of minor problems appeared as the renewal in time of batteries and the lack of answers of certain sensors. These problems were resolved. It remains to use well the internal software to realize output (main weather parameters on a monthly base).

Photo 9 bis. Meteo station Watchdog under test before installation

A small meteorological station Watchdog (SPECTRUM , USA, photo 3) was install at ALSP - Aek Loba (SOCFINDO) in february 2011. It can be connected wireless.

Part B.

Ecophysiological experimentation in controlled conditions : post-doctoral study of Dr Rosario Lobato Rodrigues, Embrapa-Manaus-Brazil)

Objectives

After the starting of ISOPALM2, an additional programming came to be added during Dr Rosario Lobato's arrival to the UPR34 at the end of May, 2011. From two sets of seeds (produced and supplied by the SOCFINDO PSBB, the North Sumatra) originated from crossings "equivalent" to the material A and B of ALCP10 for ISOPALM2 (The oil palm seeds from Deli x La Mé produced in the crossing map 2009A at PSBB whose origins *dura* and *pisifera* show very contrasting leaf contents), a trial was set up in greenhouse in the CIRAD Lavalette, in controlled conditions. The scientific objectives are in all respects comparable to those of ISOPALM2. It was thus agreed that this additionnal programm was an integral part of the global project.

This part of the project ISOPALM2 is essentially going to allow us to use ^{41}K (impossible use on adult palm trees – due to the cost of this isotope) and also to compare the flows of ^{85}Rb and ^{41}K. This finer experiment on germinated plants is essential to determine the metabolic basic functioning of the palm tree concerning the relations between the potassium and the sugars (soluble, starch). It is a complement essential to ISOPALM2.

The experimental design based on a total of 180 plants especially emphasizes the effect of a gradient of potassium (4 levels of potassium K0, K1, K2, K3 and only two levels of nitrogen N1 and N2) on the growth and the allocation of nutriments (mineral elements, carbon tissues) carbon) on the scale of the plant and the comparison of the behavior of two progenies V1 and V2, the first one characterized as K +, the other one as K-.

The different treatments for V1 and V2 are :
With N1 : N1K0, N1K1,N1K2,N1K3
With N2 : N2K0,N2K3

With 3 repetitions blocks and 4/5 recolting dates along plants growth

This experiment has been totally finalized by the end of 2012. Preliminary results were presented to Carthagena 2012.
« Contrasted mineral potassium signature (K++/K--) for two oil palm genotypes (*Elaeis guineensis* Jacq.) in nursery stage : preliminary results".

M. R. Lobato Rodrigues, E. Lamade, J. Ollivier, B. Dubos, J. Ghashghaie.
The poster is added in Annexe 4.

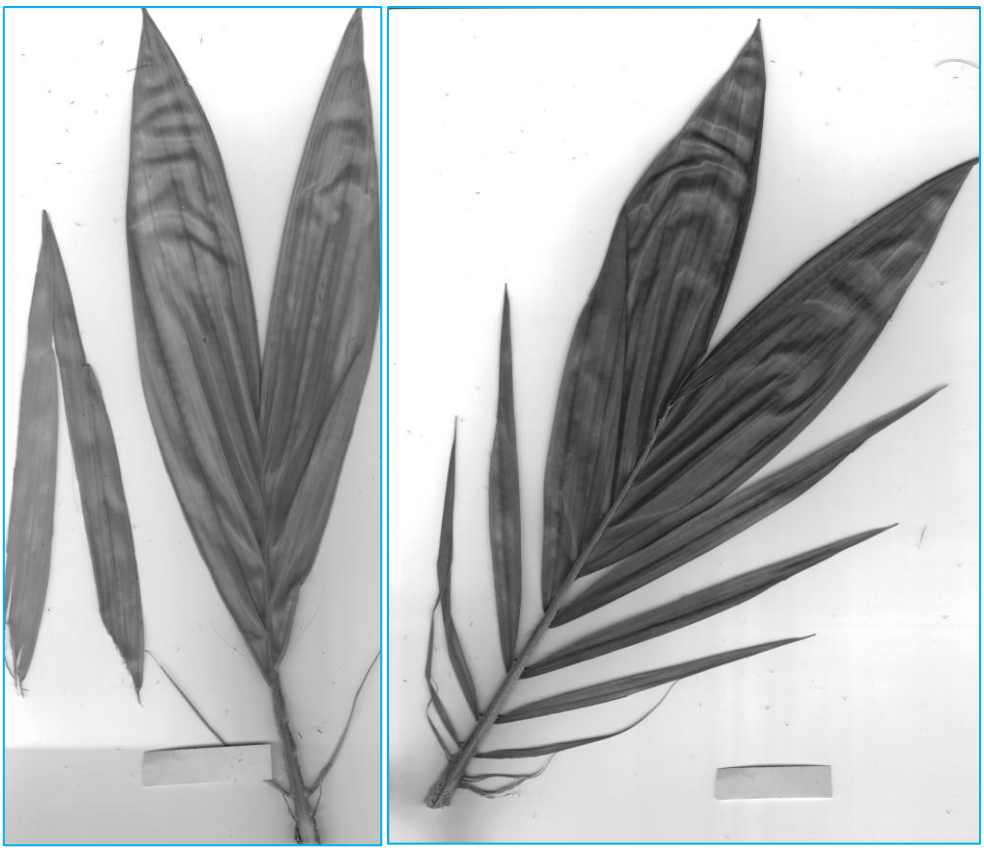


Photo 10-11. Example of dry material collected for leaf area determination

The main research activities were as following :

A. Biometrical evaluation and growth study (4 dates) of 180 plants (V1 and V2), Leaf area evaluation SLW, SPAD (photo 3), cardy K+ et cardy NO3-. (Photo 3)

    1. Biomass Samplings for mineral analysis and metabolic extractions (starch and soluble sugars).

    2. Total sampling of plants at 4 dates for biomass and mineralomass estimation.

Photo 11-12-13-14-15. Experimentation at Montpellier under controlled conditions in green house for two contrasted genotypes (K++, K--). Biometrical measurements and leaf gas exchanges with the PAM GFS-3000 of Walz.

B. Labelling the seedlings with ^{5}N, ^{85} Rb et au ^{41}K (Fig. 4 and photo 13)

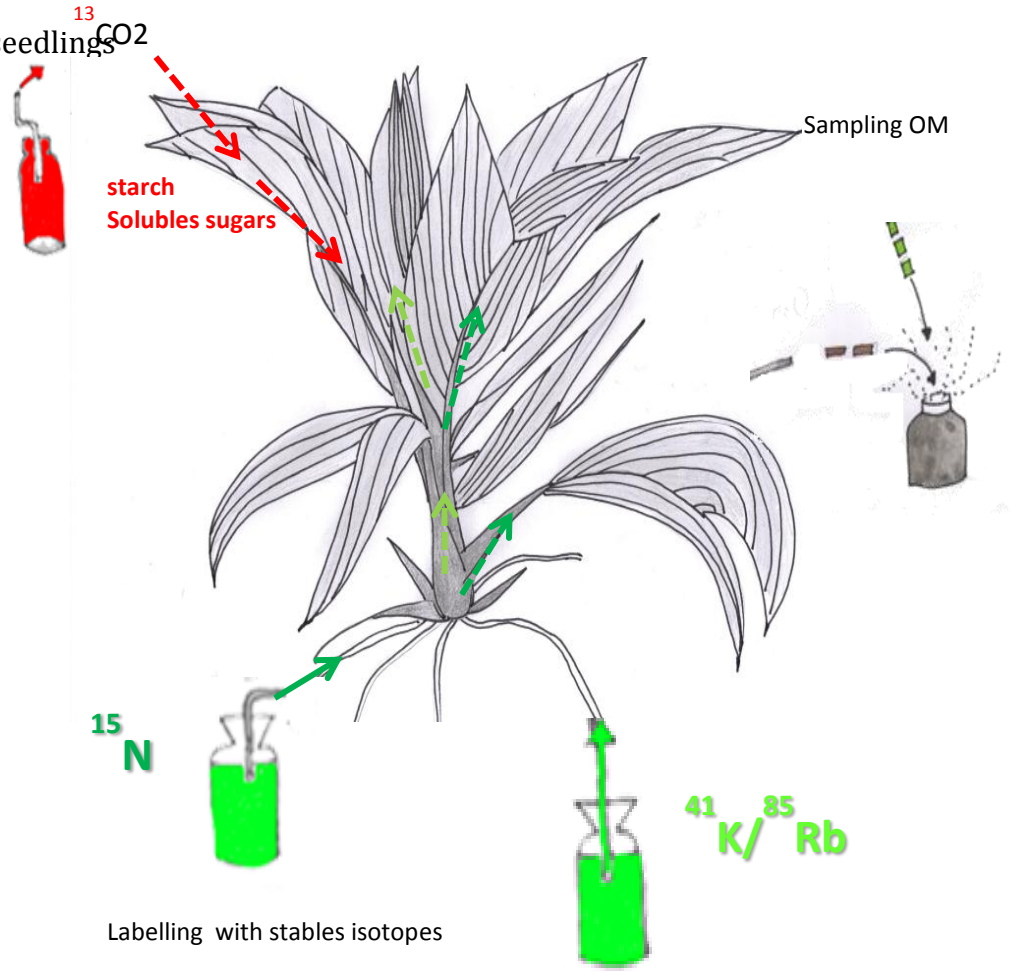


Fig. 4. Labelling experimental design of an oil palm seedling with ^{15}N et ^{85}Rb and ^{41}K .

A specific labeling has been achieved on yound seedlings (K++ K--) with ^{15}N, ^{41}K (it is a first time in this kind of study that 41K is used) and ^{85}Rb.
Quantity of respective isotopes has been estimated from mass studies (considering dilution in the biomasss of young seedlings) and the signal intensity susceptible to be detected by IRMS. Following the draw on fig. 4,(photo13) all isotopes have been applied by passive root absorption.

Then at the end of the experiment, all labelled plants were carefully collected for isotopes analysis.

Photo 16-17-18-19. Labelling of plants with stables isotopes for N,K et Rb : passive absorption by roots.

ACTIVITIES IN 2013

A. METABOLIC ANALYSES ON A,B,C,D AND V1, V2

A.1 On which material :

During 2013, again as in 2012, these analyses were performed in ESE (Ecology Systematic and Evolution) by Diana Sketriene (L1, ESE, University of Paris XI) and Themis Rozier (L2, ESE, University of Paris XI). On A and B progenies, soluble sugars and starch were achieved on following samples :

-Leaflets : 36 oil palm trees (A,B) ALCP10, on leaf rank 17, 10 segments : finishing the analysis (as for 2012)

- Rachis : 36 oil palm trees ALCP10, on leaf rank 17, 10 segments /tree

- Petioles : 36 oil palm trees ALCP10, on leaf rank 17/tree
- Stipa : 36 oil palm trees ALCP10 (3 localisations : trunk up, trunk middle, and trunk base top, and abse) /tree
- Roots : very few …
- Leaflets : V1 and V2 , 45 x 2 samples
- Also C and D progenies in ALCP10.

In 2012 and 2013 same type of analyses were performed on same and others tissues as well for C and D.

- Spikelets : 36 oil palm ALCP10, 3samples
- Rachis (bunches): 36 oil palm trees ALCP10 , 1 sample
- Fruits : 36 palmiers ALCP10, 3 samples
- Stipe : others
- Leaflets : 3 x 45 échantillons V1 et V2 .
- Rachis : that were missing

During 2013 , same rachis, leaflets, and fruits analyses…start for C and D progenies .

A. 2. Methodology (from Lamade et al. 2009)

Starch and soluble sugars were not performed in the place :

-*Starch :* at the laboratory of ESE www.ese.u-psud.fr (Ecology – Systematic-Evolution, University of Paris XI, Orsay) following a method established for the european project ANR "CATS".

-*Soluble sugars* : at the plateform METABOLISME-METABOLOME IFR 87 www.pmm.u-psud.fr of IBP (University of Paris XI, Orsay) with Ing. Caroline Mauve.

For carbohydrate extraction, the same methodology as in Duranceau *et al.* (1999) and Tcherkez et al. 2003) was used on fine ground powder samples. Briefly, for soluble sugars, extraction was done by centrifugation of Eppendorf vials, containing 100mg of sample in distilled water, and by collecting the supernatant. Soluble sugars were analysed by liquid chromatography (HPLC) separation, with no fractionation during the analysis (Duranceau *et al*., 1999). The water soluble fraction was filtered (filter HV 0.45 µm type, Nihon Millipore Kogyo K.K, Japan) before injection to a cation exchange column (Sugar-Pak1 column, Waters, U.S.A) of the HPLC (803C-302, Gilson) and the peaks were detected by a refractometer (Gilson 133). Carbohydrates are manually collected, dried and weighed in tin capsules (From Lamade et al. 2014).

The quantification of starch was carried out by weighing the vials before extraction and after drying the extracted metabolites in the same vials. For starch we did follow the methodology established by Duranceau et al. (1999) and Maunoury-Danger et al. (2009). After washing the pellets containing the insoluble fraction with ethanol (95%, 1mL) successive suspensions were performed with 1mL 6 N HCL and then put during 1h at 5°C to solubilise starch. After centrifugation (20 min at 14000g), each supernatant was mixed with methanol and kept over the night at 5°C. To collect starch for isotopic analysis, the mix was centrifuged (14000 g during 15 min at 5°C) and the supernatant freeze-dried (From Lamade et al. 2014).

B. 4 TH MISSION TO AEK LOBA – ALCP10 –

B.1. Mission schedule

The schedule and the details of this mission can be found in ANNEXE 2. This mission was beared upon the following period : 19 december until 8 january 2014.

Photo 20-21-22-23. Studies on roots system condition in ALCP10 for trees studied.

This mission was totally devoted to **roots sampling** for C and D progenies. Missing data for all the 72 trees was carefully detected and new measurements were done. Some methodological problem as the estimation of the **trunk density**, as well as the measurement of trunk **height** and **diameter** were "re-visited". Phenological observations were continued too. To complete the ecological study of the plot, soil samples were done on K0,K2 and K3 treatment.

B.2 Activities : illustrations

1. ***Roots system study for progenies C and D, ALCP10.***

   The roots system is important for minerals uptake. If the mineral content of the roots in ALCP10 is low (as usual), the estimation of the total roots mineralomass can be consequent and then root turn-over at the origin of mineral soil enrichment as well as for carbon. It is the reason why an attention is beared on the roots in this work even it is not the main target. The same method used for A and B were used for C and D (see previous report).

All the soil collected in A,B,C sector (see activities in 2012) was put into sieve and roots cleaned by water. Then roots were put in oven under 80 °C until dry.

date	mode	tree	B	15	primary	1	dry weight	location
21/12/2013	voronoi	67/10	a	15	primary	1	36,01	rintis
21/12/2013	voronoi	67/10	a	15	primary	1	36,01	rintis
21/12/2013	voronoi	67/10	a	15	primary	1	42,9	rintis
21/12/2013	voronoi	67/10	a	15	primary	1	10,53	rintis
21/12/2013	voronoi	67/10	a	15	primary	1	1,14	rintis
21/12/2013	voronoi	67/10	a	15	secondary	2	65,24	rintis
21/12/2013	voronoi	67/10	a	15	secondary	2	34,01	rintis
21/12/2013	voronoi	67/10	a	15	secondary	2	51,31	rintis

Example file realized during 2013-2014 mission.

There were then weighed (see example file above) in ALSP lab.

2. *Examination of the roots system*

From last year, some irregularity of the root epiderm was found on almost all roots collected especially primary roots in ALCP10.

Photo 24-25-26-27. Roots conditions in ALCP10.

In addition, the total part between the epiderm and the central cylinder is deseappearing and white fibreous parts (photo 24-25-26-27). *Ganoderma* is highly suspected. Already many trees in the plot are infected (photo 28).

Photo 28. Tree under *ganoderma* attact around ALCP10.

3. ***Improvement method for estimate trunk density***

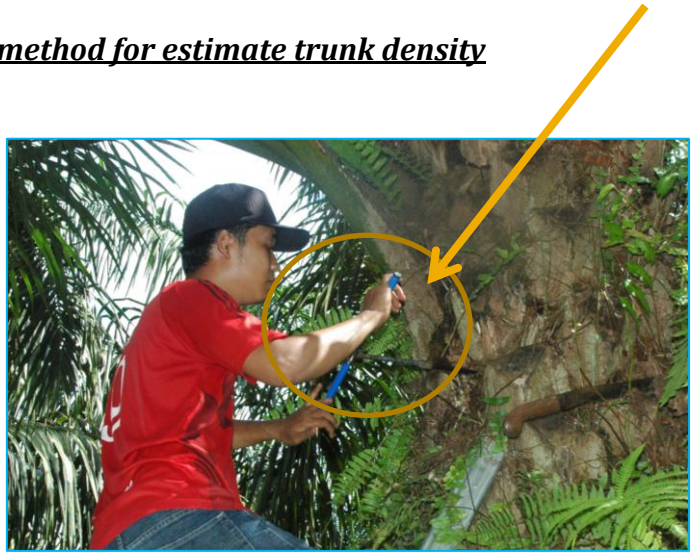


Photo 29. Dutch auger for trunk density estimation.

The Pressler auger is a good tool to sample the trunk but sometime their length do not allow us to overcome the problem of the remaining petiole bases. Then there were added by an extra spart part in iron. (Photo 29).

NO	BARIS	POKOK	ATAS	TENGAH	BAWAH
			Panjang	Panjang	Panjang
1	61	10	36,5	33,5	37
2	63	13	35,5	35,5	35,5
3	67	13	34,5	32,5	44,5

4	67	12	35,5	34	39,5
5	68	12	32	36	37,5
6	69	10	33	35,5	38,5
7	70	4	33	34,5	35,5
8	81	4	30,5	34,5	40,5
9	81	24	34,5	35,5	34,5
10	81	16	34,5	34,5	37,5
11	82	17	28,5	28	38

File extract for "trunk density" study.

Then all the 72 trees studied belonging to A,B,C,D progenies were sampled. All trunk samples were carefully dried in ALSP oven then weighed at the same place.

Photo 30. A trunk sample carefully extracted , ALCP10.

c/d

NO	Baris	Pokok	UKURAN	DIAMETER					
				ATAS		TENGAH		BAWAH	
				A	B	A	B	A	B
1	62	13	300	53	0	52	49	90	90
2	62	12	316	50	48,5	52,5	50	90	87,5
3	63	10	379	44,5	46	47	48,5	89	92
4	64	11	354	51	59	52,5	55	89	91

5	67	10	357	49,5	50	54,5	51,5	83	84,5
6	67	7	337	52	54,5	55	57,5	85	88,5
7	67	6	397	60	59,5	60	57,5	94	91,5
8	67	5	358	62	59,5	61	59,5	95,5	92
9	67	4	303	61,5	60	62,5	60,5	86,5	90
10	68	11	318	51,5	52	56,5	54	84,5	86

tree	date	lenght	weight			v	density
83/23	26/12/2013			*		0	
82/23	26/12/2013	30	1,0716	atas		5,8875	0,18201274
100/23	27/12/2013	31	0,838	atas		6,08375	0,13774399
100/5	27/12/2013	32	1,0278	atas	*	6,28	0,16366242
100/6	27/12/2013	33	1,4536	atas	*	6,47625	0,22445088
101/22	27/12/2013	34,5	1,0293	atas	*	6,770625	0,15202437
101/24	27/12/2013	34	1,3999	atas		6,6725	0,20980142
101/4	27/12/2013	35,5	1,1825	atas	*	6,966875	0,16973177
101/5	27/12/2013	34,5	1,2831	atas	*	6,770625	0,18950983

File extract for “trunk density” and trunk diameter study.

4. Improvement method for trunk diameter measurement

Trunk diameter is a key variable for calculating the amount of minerals in trunks and biomass too.

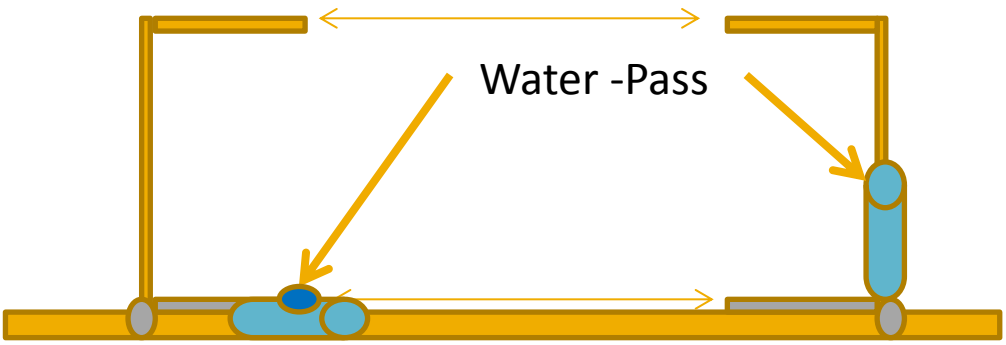


Fig. 5. Specific caliper for trunk diameter measurement.

In order to avoid mistake when the caliper is put on the trunk, two water-pass (Fig. 5) are installed : they participate to the good position of the caliper. New measurements were done with this method on all 72 trees (see extract file below and photo 15).

Photo 31. Diameter : revisited with water–pass on caliper (ALCP 10, January 2014).

5. Improvement for height trunk measurements and petiole lenght.

Each year, the 72 studied are controlled and the height is measured following IRHO 's method. This year, we controlled also the accurancy of the method by adding water-pass at two crucial points (see Fig. 6).

(File extract for petiole length)

NO	Baris	Pokok	UKURAN PETIOLA
1	62	13	153
2	62	12	156
3	63	10	147
4	67	10	148
5	67	5	158
6	67	6	130
7	68	11	156
8	69	13	149
9	81	23	132
10	81	19	156

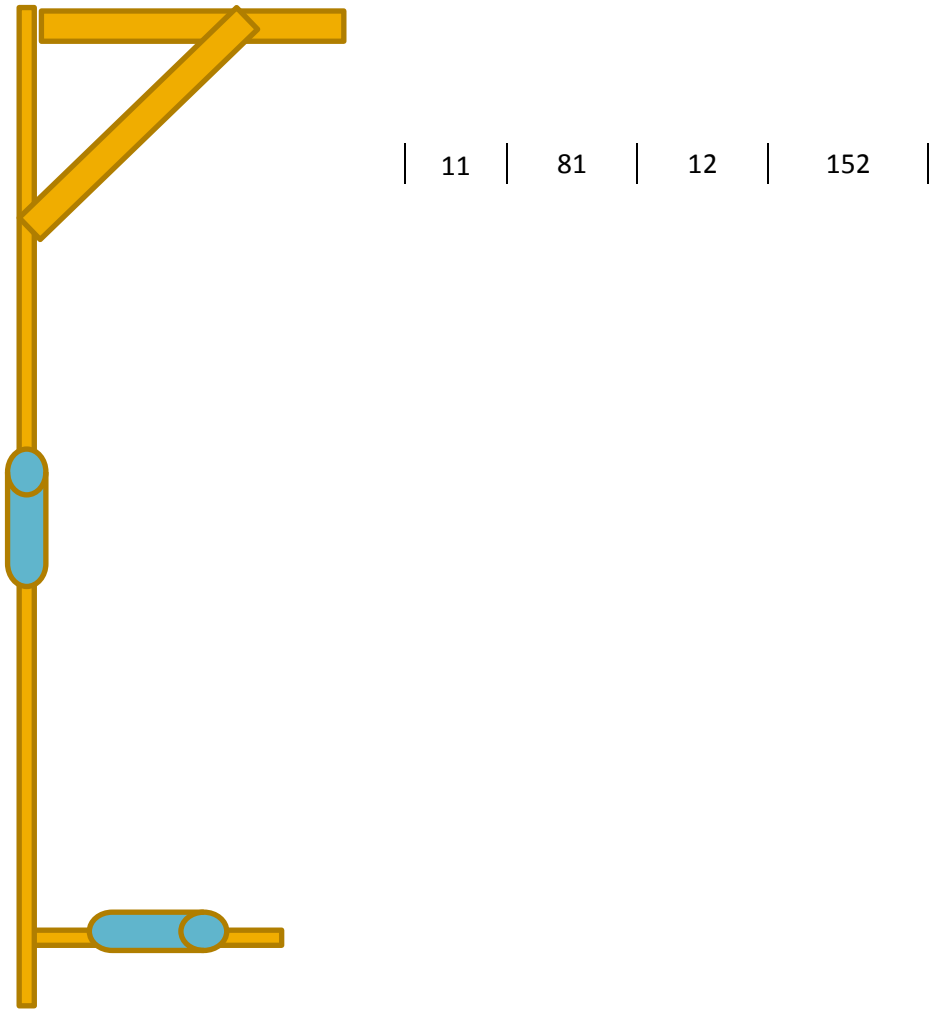


Fig. 6. Height gauge with two water –pass (in blue).

For the petiole also new measurements were done on the 72 trees because with the leaf area 's method described previously in the 2012 annual report, do not permit to get the total petiole length. Then the petiole from C point to the base of its insertion on trunk was examined and re –determined with precision (see file extract above) and Fig.7.

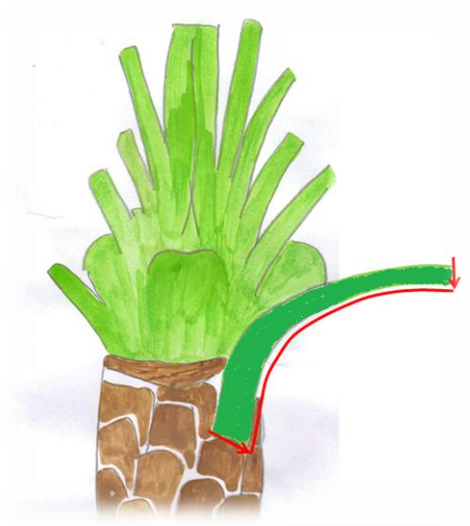


Fig. 7. Method for petiole length measurements (Isopalm method). Petiole are measured with flexible meter from the base (until inside other petiole bases) to the C point.

RESULTS 2012-2013

1. Funtionnal traits of A,B,C,D in ALCP10

Normally leaf functional traits are predictor of performance. Here, we aim to identify relations between some leaf functional traits as Leaf area, length of rachis, petiole diameter and leaf mineral contents.

1.1. **Leaf Area** (leaf rank 17) in m^2 (from Ballo Koffi and Tailliez, 1992)

Proc mixed procedure was used for statistical analyses for all functional traits measured on A,B,C,D in ALCP10 (Aek Loba Estate).

The leaf area of A is different from B,C and D. Progeny C is presenting the highest LA with 10.72 m^2 for leaf rank 17 (Tab.1, Annexe 1, Tab.3.). There is no effect of the K treatment on LA.

progenies	LA (m^2)	SLW (g/m^2)	rachis lenght (cm)
A (LM2T)	7.033±0.52 a	305.70±14.93 a	533.77±20.08 a
B (LM5T)	9.85±0.88 bc	312.385±18.07 a	597.75±31.48 d
C(LM5T)	10.72±1.14 d	285.93±2.74 b	594.36±27.36 cd
D(LM5T)	10.31±1.21 cd	302.72±29.16 b	570.52±41.18 b

Tab.3 Leaf functional traits (Leaf area, Specific leaf weight, rachis length)

The implication of this difference for leaf mineral content study can be huge. LA is the most important functional trait (plant performance predictor) and the total adaptive strategy of any plant is centralized in the leaf. For oil palm, the LA is at the origin of an other parameter, the Leaf Area Index "LAI " which is the bare bone of any production model (see Dufrêne et al., 1992). For ALCP 10 , the further calculation for LAI estimations are :

	LAI	FFB (2013)
A	2,81	20,02
B	3,94	19,05
C	4,29	21,27
D	4,12	29,06

Table 4. LAI of the 4 progenies in ALCP10 in 2013 for a planting density of 143 tree ha^{-1} (FFB for Isopalm trees)

The LAI of all progenies in ALCP10 is very low at adult stage. The minimum for best FFB production is around 4.5 (generally admitted).Then it is recommended to leave a bigger amount of leaves on the trees. For the moment, the average of leaf standing in the canopy is around 28 which far below

recommendation in Indonesia (42). The implication of a low LAI for carbon balance is important. LAI is the main light captor to transfert photon energy towards biomass.

1.2. **SLW** (specific leaf weight) in g DM /m^2

The specific leaf weight seems also to be related to progenies differences. There is no effect of the K treatment. It is B progeny which shows the thicker leaves compared to C which shows the thinner leaves (Tab. 3).

The SLW is an important parameter for leaf biomass estimation. B which is identified as a K- , because of a very high SLW, the total amount of minerals (N,P,K) will be higher than K+ progenies.

Then it is very important to understand what is the physiological meaning of high/low leaf minerals content and what can be the main direction to take for plant selection.

It is the main objective of the present work.

1.3. **Rachis length** in cm

There is no effect of the K treatment on rachis length (Tab.3). Rachis length as Leaf Area is totally under the dependence of the genotype. A progeny shows the smallest rachis length compared to B which presents the longest. C and D progenies show intermediate features.

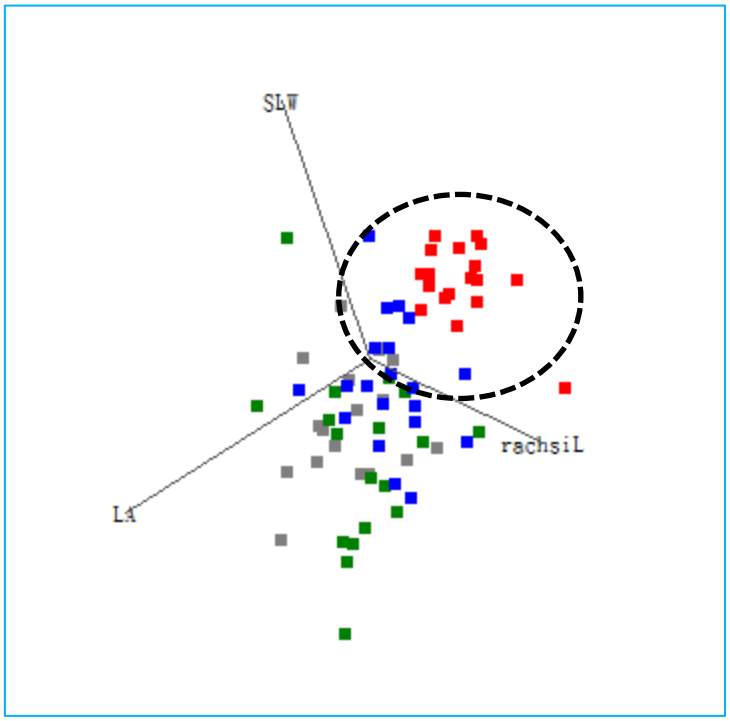


Fig. 4bis. Discrimination of A (LM2T) in red , B(LM5T) in blue, C(LM5T) green, D(LM5T) in grey with the 3 main leaf funtionnal traits , LA, SLW and rachis length.

1.4. **Trunk diameter**

Trunk diameter is an important parameter for estimating trunk biomass. Then the diameter of each tree studied was examined with caution: a double check for each measurements has been done with a special caliper (see Annexe 3).

progenies	trunk base	trunk middle	trunk top
A (LM2T)	82.50±6.12 a	59.55±3.71	53.10±4.45 b
B (LM5T)	75.10±5.14 b	56.00±2.40	48.87±4.18 a
C(LM5T)	81.74±8.44 a	59.28±7.30	57.54±5.31 b
D(LM5T)	87.77±7.60 a	57.35±3.83	55.35±4.70 b

Tab. 5. Diameter trunk at 3 locations (base, middle, top) for A,B,C,D progenies , ALCP10.

Most constrated features are seen between progeny B (the thinner at the trunk base) and the D (the bigger) (Table 5). This morphological difference may indicated a physiological difference with an accumulation of soluble sugar at the base of the trunk for D progeny.

No difference may be observed at the middle part of trunks for all progenies. B seems to be the thinner…

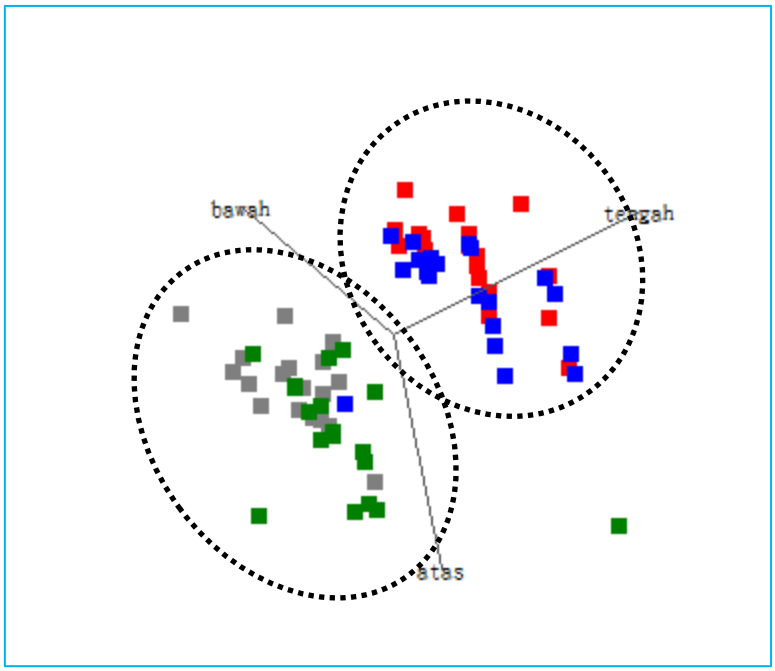


Fig. 4 ter. Individualization of two progeny groups : A and B in one side (red and blue) and C, D (green, grey) for trunk diameter (atas : top, bawah : base and tengah : middle).

When we observed the 3 measurements of the trunk diameters (Fig. 4ter) for the four progenies A,B,C,D, there is obviously a differenciation between A and B in one side and C and D in the other side.

The B progeny shows the thinner diameter at the top of the trunk. We can suspect two different causes : one is morphological - B has taller and thinner trunks – and physiological causes : the amount of starch stocked at the top is lower due to its mobilization for bunch filling.

Trunk Height in cm (all measured in 2012)

Effect	Num DEF	DenDF	F value	Pr<F
Repet	2	4	0.41	0.68 ns
NivK	2	4	0.05	0.95 n.s.
Progeny	3	13	5.93	0.0089 ns
Nivk*Prog	6	13	2.43	0.0850 ns

progeny	K0	K2	K3	average
A (LM2T)	267.27±25.71	271.95±13.87	273.53±18.57	273.12±18.52 a
B (LM5T)	314.48±22.63	324.85±32.89	281.00±34.60	304.72±36.08 b
C(LM5T)	296.14±30.28	278.00±25.93	293.00±26.43	290.21±27.31 ab
D(LM5T)	303.60±10.99	288.33±17.51	319.16±27.88	303.70±23.39 b

Tab. 6. Height comparison for A,B,C,D in ALCP10 in Aek Loba. *Proc mixed* , SAS.

The annual growth rate in ALCP10 for A and B only can be calculated as below :

GR = (H2012-H2011)/ (n° month)*12

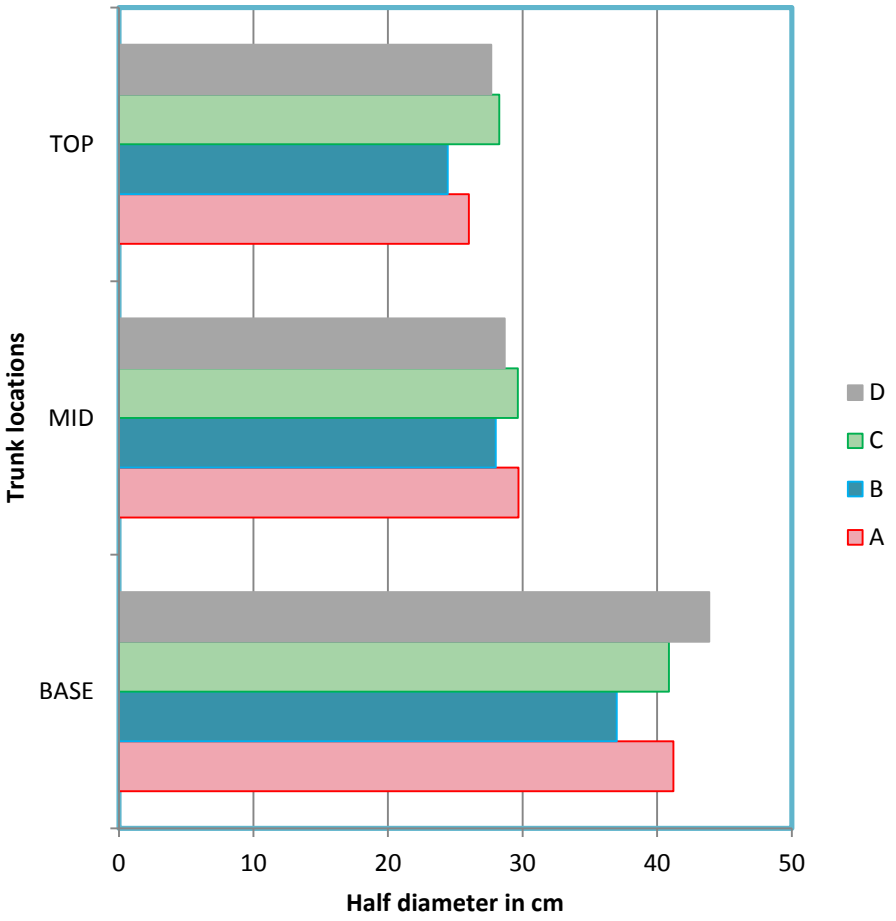


Fig. 5. Trunk diameters for A ,B,C and D progenies. Evolution from the base to the top.

For the height, some differences are observed among the four progenies studied. A progeny (LM2T) show the smaller height when B (LM5T) shows the higher one. C and D shows intermediate values but are very near B value.

For the annual growth rate calculated on A and B between 2011 and 2012, there is no difference with a growth rate for A equal to 50.97 cm ±10.84 and B , 50.74 ±15.36 cm.

Trunk density : only A and B were investigated at the beginning. New final results will be given for A,B,C and D at the end of 2014 in the ISOPALM final report.

Trunk density is increasing with age (Corley et al. 1971). The old formula they proposed was :

Trunk Density = 7.62. year + 83 in g of DM per liter.

We found same order than Corley (0.18 g cm^{-3} for Corley at 9 -10 years old). Strong individual variations were observed. But B (density : 0.138 g cm^{-3} is presenting the highest density compared to A progeny : 0.123 g cm^{-3}). It must be the most important parameter to estimate mineralomass because trunk stocks also a lot of minerals.

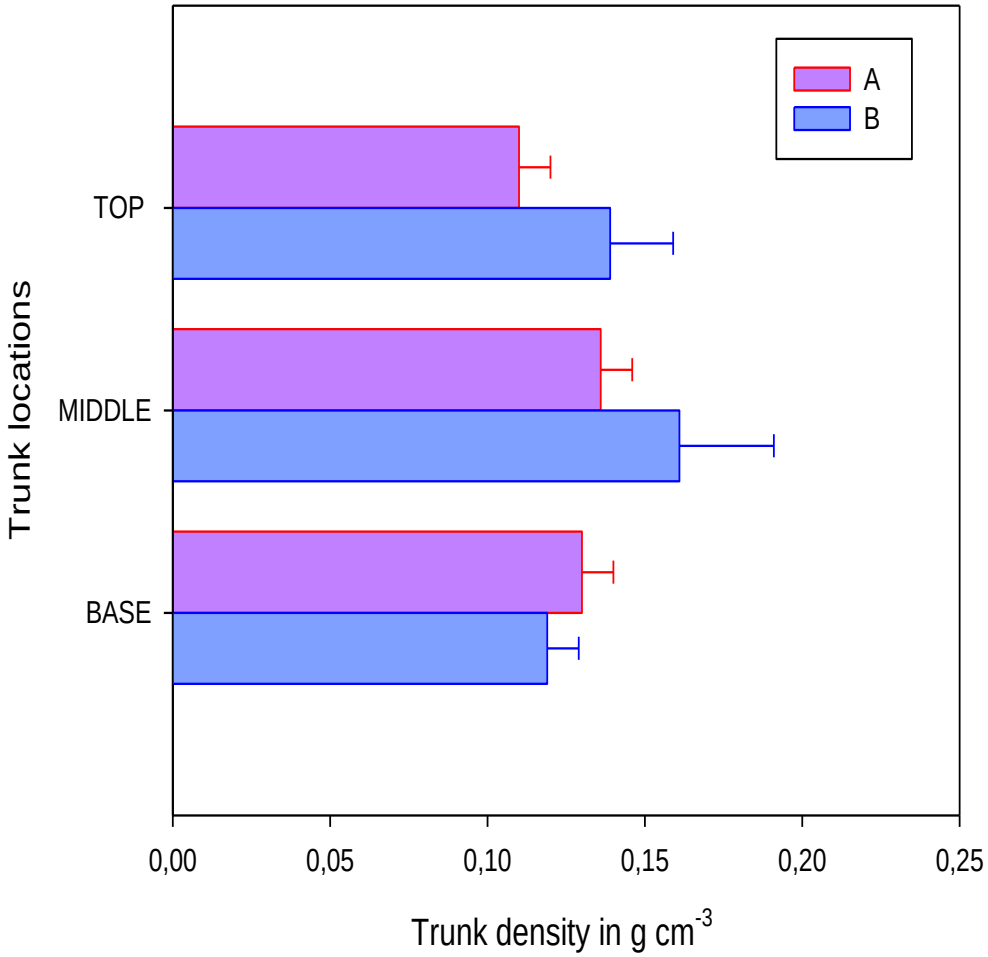


Fig. 6. Variation of trunk density along height for A and B in ALCP10.

Only at trunk base, the B (LM5T) progeny is presenting a smaller density that A. There is no significant effect of K treatment on trunk density. A seems more homogeneus than B along the trunk height. Trunk sampling for density estimation have been done on C and D in 2014. (see annexe 2).

2. Estimation of individual total above ground biomass

A better estimation than last year is given for individual biomass because diameter and trunk density have been better estimated and measured. Last year individual mineralomass was overestimated due to high trunk density measurements. At least all these measurements must be done by individuals.

- **Trunk biomass in kg DM $tree^{-1}$**

ANOVA (*proc mixed* : no convergence)

progenies	trunk biom	leaflets	rachis	petioles
A (LM2T)	146.40±19.8	73.51±8.3 a	39.56± 4.56 b	25.61± 2.91 bc
B (LM5T)	148.812±29.4	99.11±14.0 b	50 ±7.26 a	28.54 ±3.52 a
C(LM5T)	132.90±21.3	99.72±20.4 b	48.89±9.51a	27.03±3.55 bc
D(LM5T)	146.01±24.1	91.09±12.2 b	41.33±7.39 b	24.48±2.32 c

Tab. 7. Above ground biomass for A,B,C,D in ALCP10.

For the trunk biomass, progeny C shows the lowest one (Tab.7) but no significant difference is found among all four progenies for this parameter. K treatments seem to have no effect on trunk biomass.

IMPLICATION for SOIL FERTILITY : carbon input from biomass

Estimation of carbon amount returning to soil when re-planting from trunk release :

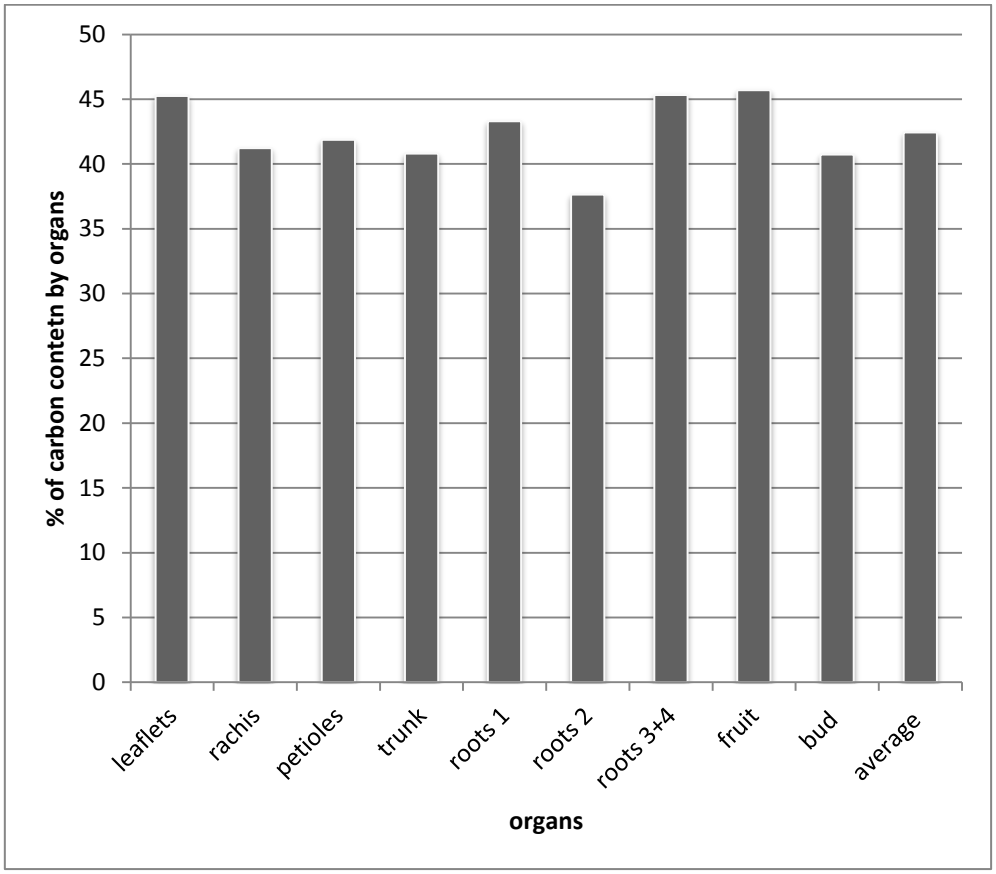


Fig. 6 bis. % of carbon content for all organs measured by IRMS (Lamade et al. 2009).

We can estimate the total carbon amount returning to soil from trunk biomass when re-planting in the conditions of ALCP10. The % of carbon content average used for trunk is 40.79 % of the total biomass.

-For A : 764 g of C by m^2 of soil

-For B : 777 g of C by m^2 of soil
-For C : 693 g of C by m^2 of soil
-For D : 762 g of C by m^2 of soil

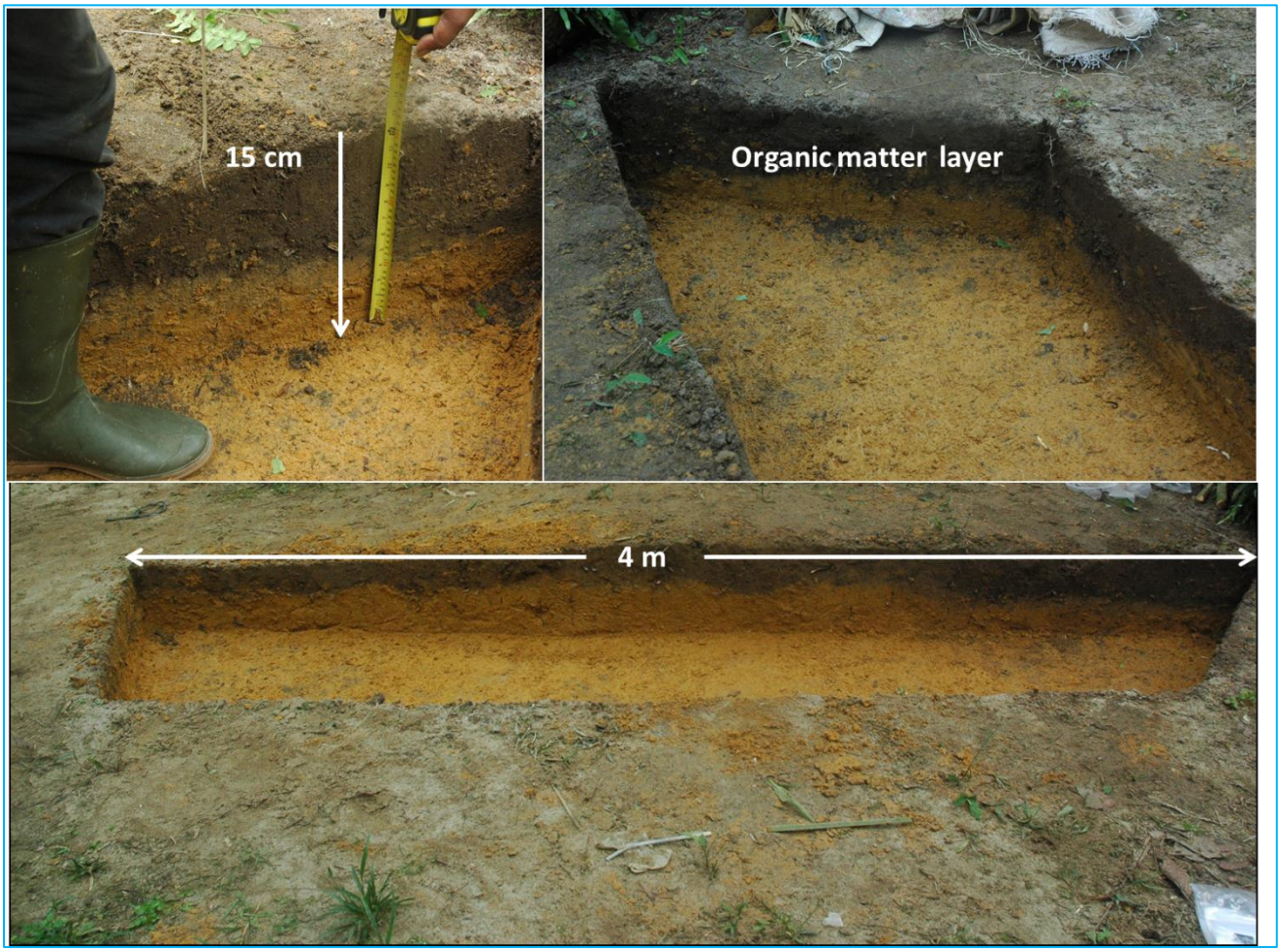


Photo 32. Illustration of organic matter layer in ALCP10 top soil from trunk circle to harvest path.

- **Leaflets biomass in kg DM $tree^{-1}$**

For leaf biomass, there is a strong effect of the progenies. A progeny has the lowest leaf biomass (73 kg DM) compared to the 3 others. The genetic origin (LM2T) is probably at the main discriminative factor for this parameter.

SOIL FERTILITY : carbon imput from leaflets biomass

Estimation of carbon amount returning to soil from leaflets release in the frond piles

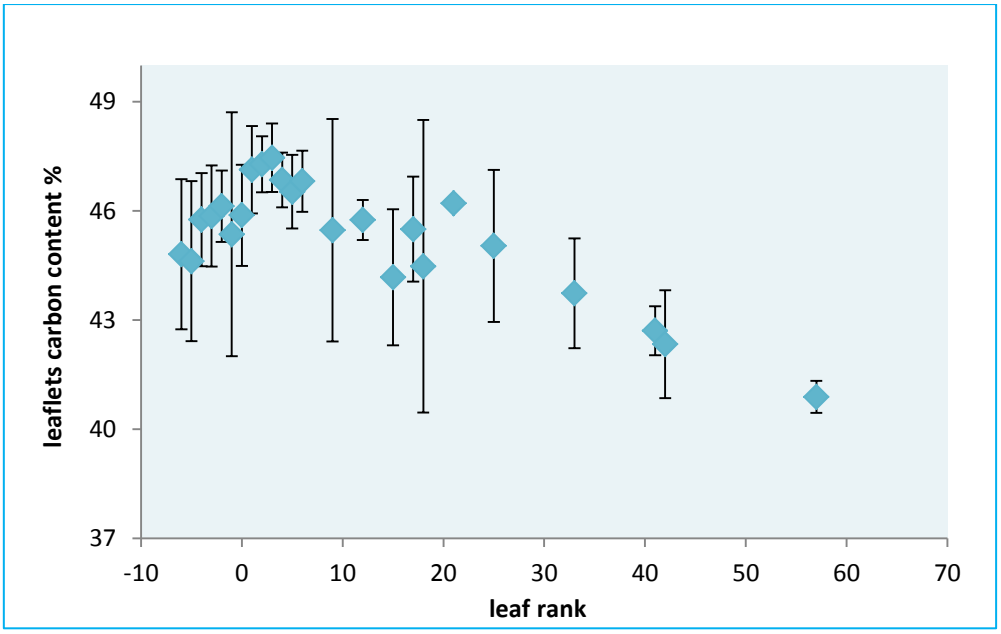


Fig. 6 bis .Variation of carbon content in leaflets biomass depending on rank. (From Lamade et al. 2010, ICOPE, see annexe 5)

A variation of carbon content in leaflets is observed depending on rank (Fig. 6 bis). But for carbon release , the average of 45 % is used.

For A : carbon release in the frond piles from leaflets decomposition : 425 g C m^2 per year ; for B : 573 g C m^2; for C : 577 g of C m^2 and for D : 527 g of C m^2 .

- **Rachis biomass in kg DM tree^{-1}**

  Rachis biomass has been determined by direct method for A and B progenies by weighing the all 10 segments (see Leaf Area method) in fresh weight, then by apply per tree the individual ration Fresh Weight/Dry Weight coming from mineral analysis. This ratio is not susceptible to vary along the rachis. A strong relation was found (Fig.7) between rachis fresh weight and the length.

Rachis Weight = 13.84 * Length – 4424.9 (allometric relation)

Then, because A,B,C and D progenies do not exibit very constrasting morphology, this relation was applied for estimate C and D rachis biomass from rachis length. New measurements were done at the end of 2013 (see annexe 4).

A, as D, exibit smaller rachis than the other progenies (B,C). There is maybe a link between rachis mineral contents (high for A) and rachis biomass. The question of the mass dilution may be pointed out.

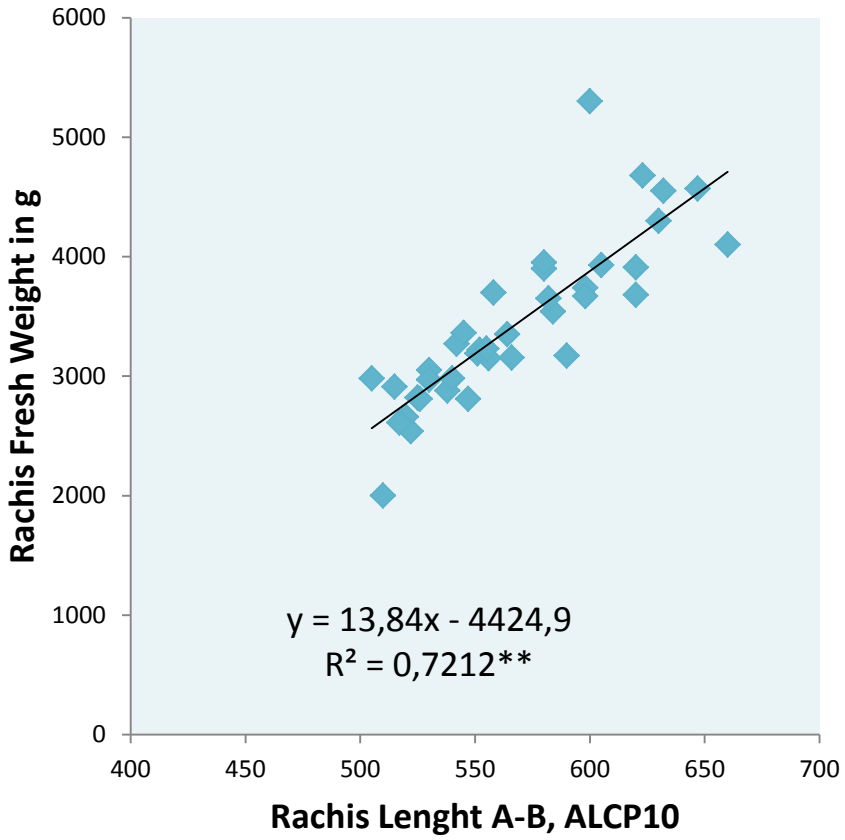


Fig. 7. Relation between rachis length in cm and rachis fresh weight in g.

Rachis Weight = 13.84 * Length – 4424.9 (allometric relation)

Then, because A,B,C and D progenies do not exibit very constrasting morphology, this relation was applied for estimate C and D rachis biomass from rachis length. New measurements were done at the end of 2013 (see annexe 4).

A, as D, exibit smaller rachis than the other progenies (B,C). There is maybe a link between rachis mineral contents (high for A) and rachis biomass. The question of the mass dilution may be pointed out.

- **Petiole biomass in kg DM tree^{-1}**

The biomass of the petiole is difficult to evaluate with precision due to the limit of the organ which is not easy to determine directly on the tree. Then results have to be considered with caution. We see on the table 11, that the petioles of the B represent a bigger biomass that the other progenies but these differences cannot be really interpreted.

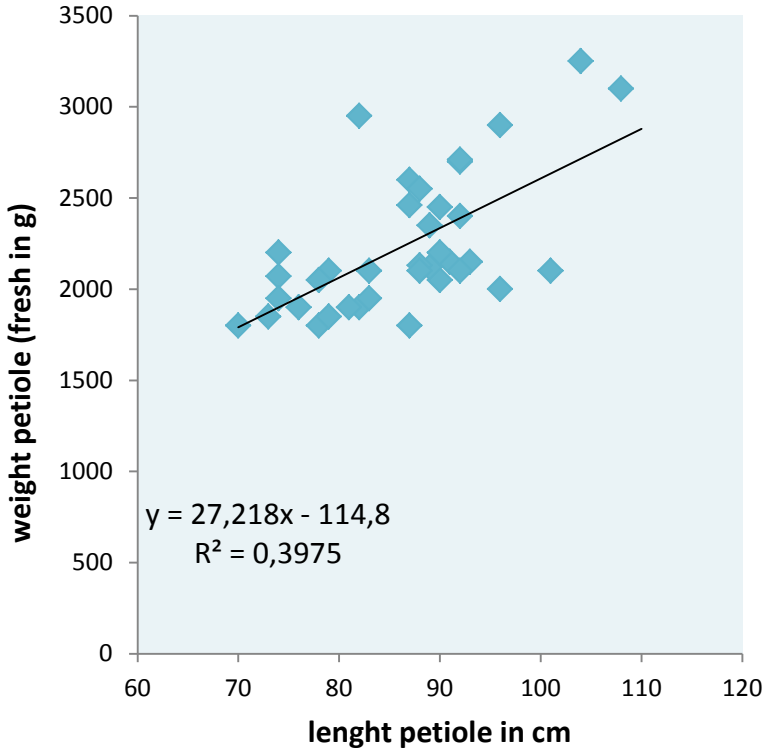


Fig. 8. Relation between petiole length and petiole fresh weight.

- **Total above ground biomass in kg DM tree^{-1}**

Effect	**Num DEF**	**DenDF**	**F value**	***Pr*<F**
Repet	2	4	0.96	0.455 ns
NivK	2	4	0.78	0.51 n.s.
Progeny	3	17	2.54	0.09 +
Nivk*Prog	6	17	1.18	0.3 ns
progeny	K0	K2	K3	Average
A (LM2T)	276.36±23.62	279.68±11.68	296.44±27.71	285.09± 23.57 a
B (LM5T)	330.78±26.06	322.91±52.41	302.05±47.13	319.01 ±43.77 b
C(LM5T)	301.49±48.16	306.59±20.55	317.59±34.32	308.56±34.71 ab
D(LM5T)	279.59±26.61	296.24±28.55	332.95±30.54	302.93±35.33 ab

Table 5. Total above ground biomass depending on progenies (A,B,C,D) and K0, K2, K3. *Proc mixed, SAS.*

A significant difference is found between the two origins LM2T and LM5T, more specially between A progeny and B progeny. C and D are presenting intermediate values. More or less the addition of K may increase vegetative biomass but with no significance on tree studied. Better results may be obtained by increasing the number of tree studied.

Figure 9 illustrate the fact that on the base of the estimation of the above ground biomass, it is difficult to discriminate the different progenies A,B,C,D towards their response to K gradient. It is still better to look at the foliar content.

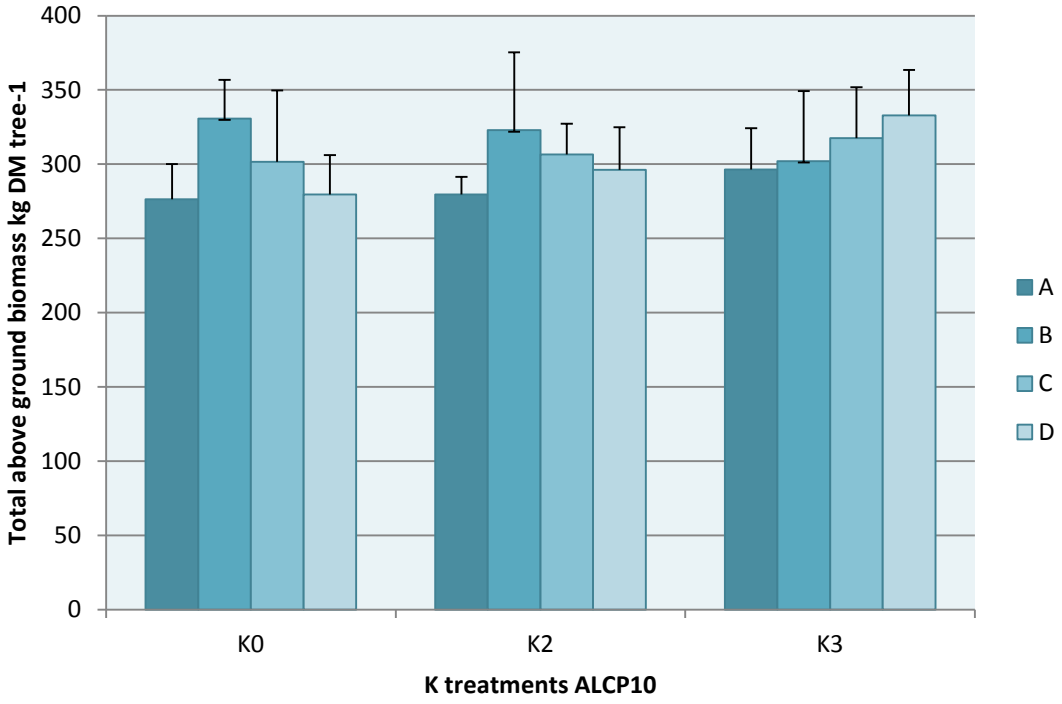


Fig.9. Estimation of total above ground biomass for A,B,C,D progenies along K treatment , ALCP10.

3. Relation between the leaf content (N ,P and K) and leaf functional traits

For A and B progenies

What the theory says ? In the plant world, foliar levels are related to adaptive strategies of species or varieties according to their relative investment between carbon production and allocation of mineral elements in the leaves.

Thus species (or varieties) with high foliar mineral levels will have specific morphological characteristics enabling them to adapt to demanding ecologies when others (low mineral content leaf) present growth and largest morphology adapted to favorable ecological conditions (Wright et al. Nature 2004). Then species as far as their mineral foliar content are concerned can be ordered along a LEAF ECONOMIC SPECTRUM. At the two extremities, of this spectrum, there are very different species as the artic species on one side and tropical trees at the other.

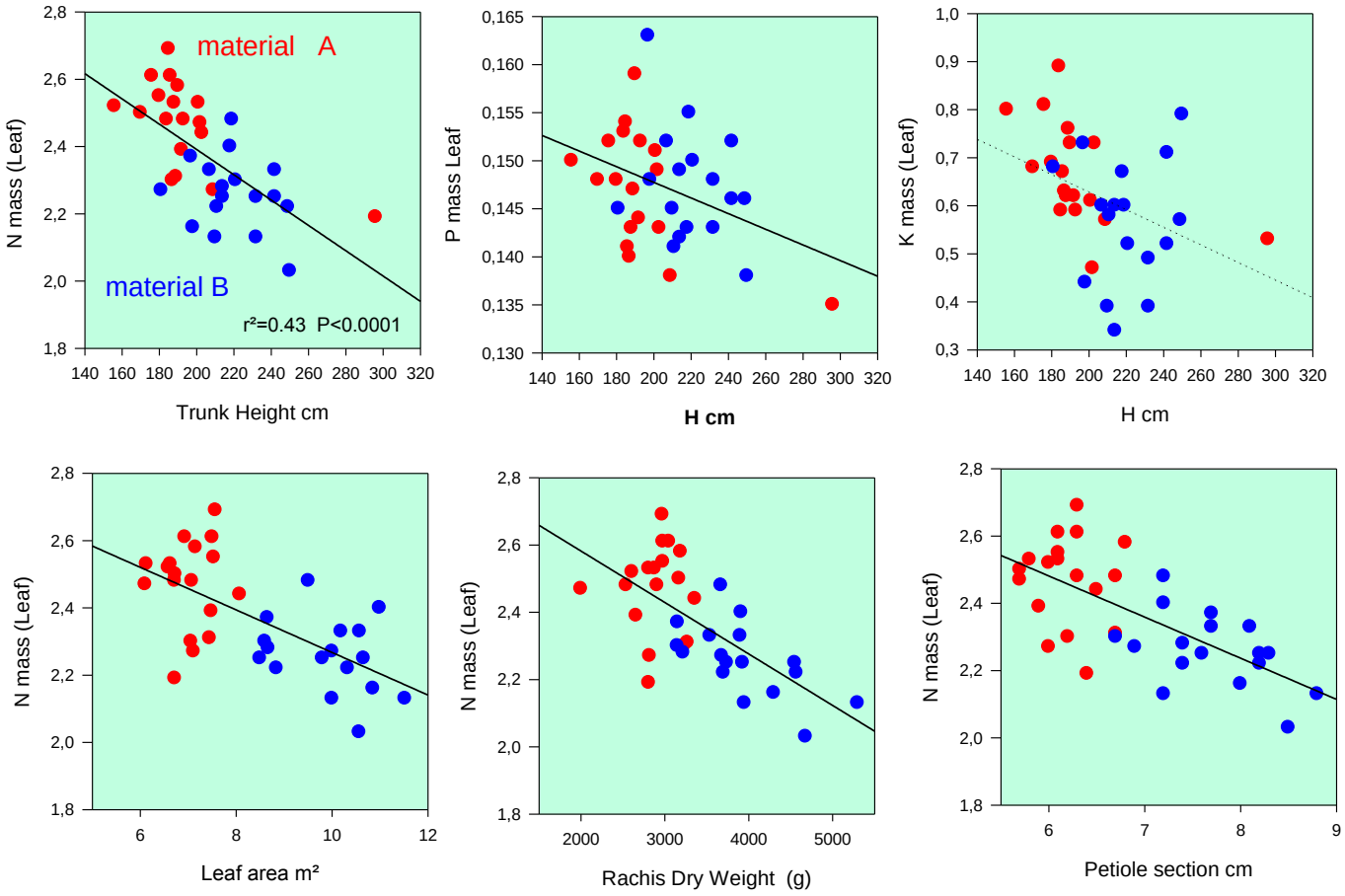


Fig. 10. Relation between leaf mineral content (N,P,K) and some functional traits as LA, H, petiole section, rachis length and so one for A and B materials. (A) N mass means N content in %. (B) P mass means P content , K mass means K content in %. H for trunk height.

We can thus establish a ranking between species along a leaf economic spectrum. Their mineral requirements are not the same: the species or varieties have high foliar concentrations of greater than species with low foliar levels of basic needs.

Progenies A and B seems to follow this theory. In Figure 10, we see net relationship between the levels of foliar nitrogen, foliar surfaces, heights, dry weights of rachis and petiole sections. The most interesting relation is concerning nitrogen leaf content and height. A which is a smaller plant material than B is presenting a higher mineral content. The length of rachis is even more correlated than other traits to N leaf content.

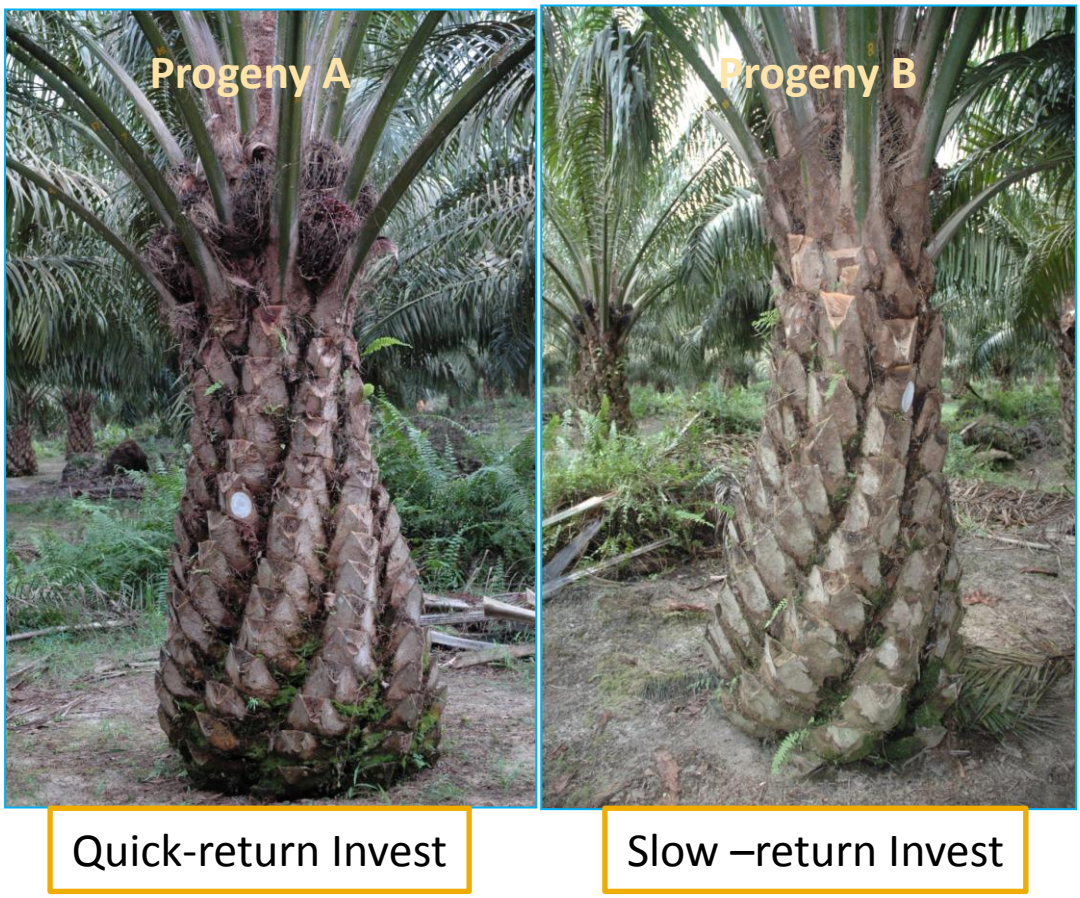
The result of these investigations is a point in favor of the central place of the LEAF MINERAL STATUS as the main pilot of the plant adaptive strategy regarding nutrition.

In the leaf (for oil palm the leaflets) are gathered the photosynthetic apparatus and the minerals which can “help” the production of leaf sugars and theirs translocations via the rachis. Then the

investment effort for high minerals may indicate an increasing sugars production rate and turn over. A leaf mineral spectrum could be defined with two extreme limits. Low foliar mineral content in plant material defines the "slow return invest " opposed to the "quick return-invest" one.

QUICK-RETURN INVEST PLANT	SLOW- RETURN INVEST PLANT
-short life duration - high photosynthetic rate - small H, small LA **- high N,P,K …** -small biomass ….	- Long life duration - Low photosynthetic rate - High H, high LA - **Low N,P,K** - High biomass ….

Tableau 13. Functionnals traits related to the two plant groups ; the QUICK-return invest (C/minerals) and the SLOW return invest. (Photo 14-15 : illustration in ALCP10).



We can propose, as hypothesis, that A (LM2T) could belong to Quick-return invest group when B (LM5T) to Slow return invest one. (Photo 14 et 15, A and B in ALCP10)

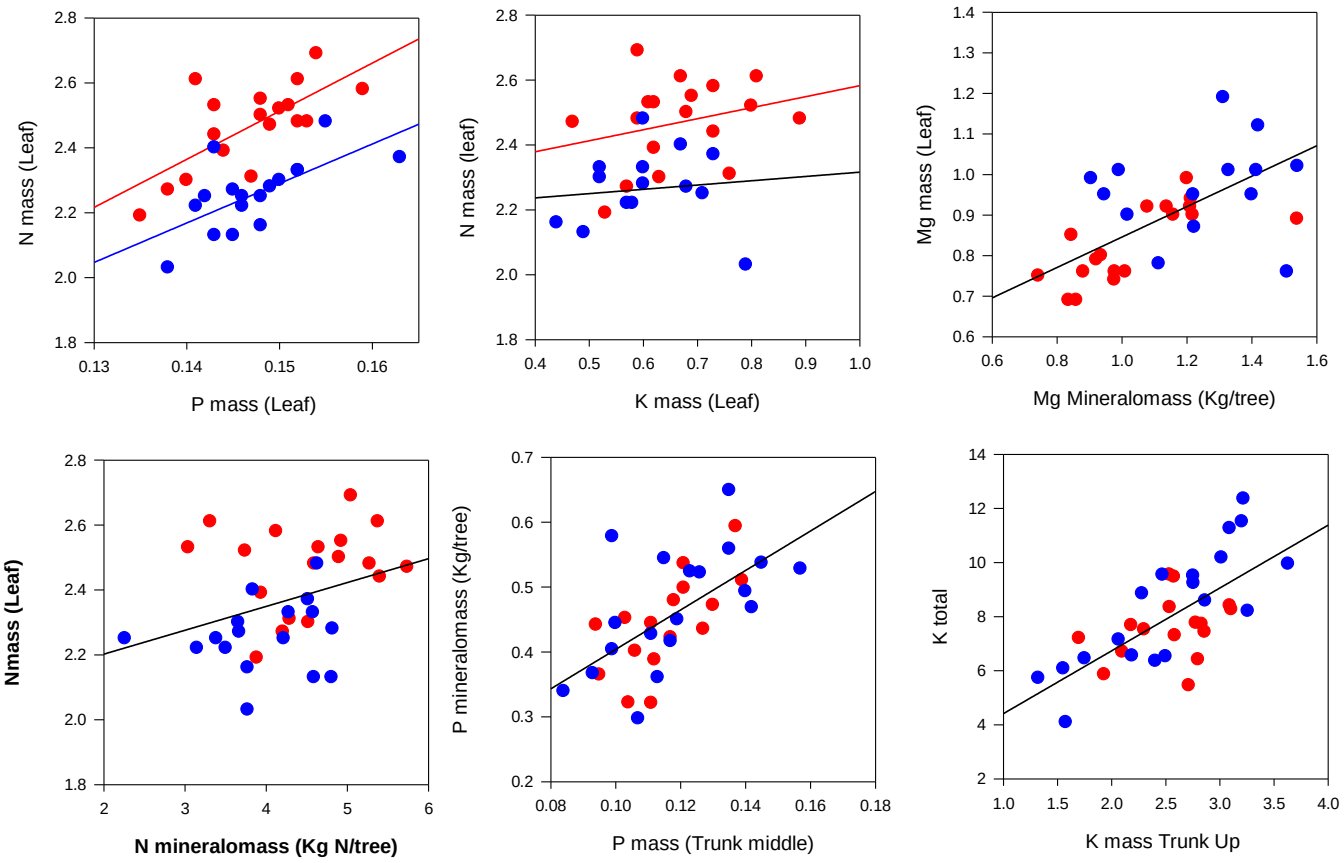


Fig. 11. Exploration of stoechiometric relation between, N,K , and P foliar as well as mineralomass for A (red) and B(blue) progenies. Proxy determination for N,P,K mineralomass. (on 2011 analyses).

On figure 11, stoechiometric investigations were beared on N/P/K equilibrium. Pour N/P, A (red spot) progeny hows higher level than B (blue spot) indicating higher minerals needs for A compared to B. Mg % content in leaf is the best "proxy" for Mg total mineralomass. The same observation may be done for N. For P , it is the P content at the middle of the trunk which is a good proxy for Pmineralomass. For K mineralomass, the best proxy is the K content at the top of the trunk.

For A,B,C and D progenies …

When looking to the relation betwen N % leaf content and the leaf area of the four progenies in ALCP10 (A,B,C,D), we can make the same remark than for A, and B (Fig. 11 bis).

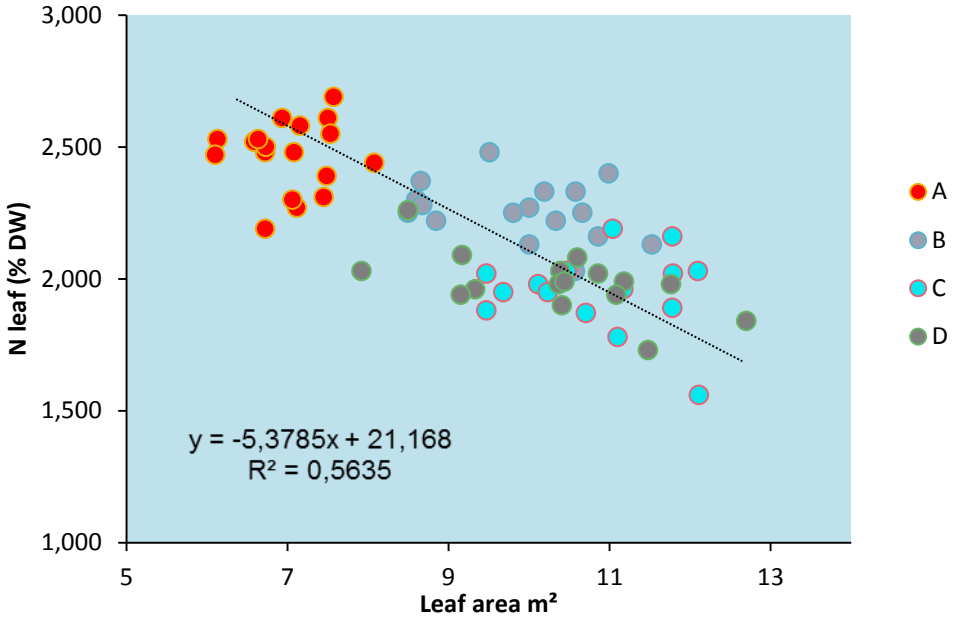


Fig. 11 bis. Relation between N% and LA for A,B,C, and D in ALCP10.

B,C,D which have the same origin (male parent LM5T) exhibit a larger LA compared to A. There is clearly a difference between A in one side and B,C,D in the other side. The relation observed with N % leaf content and LA was expected. Inside each progeny this kind of relation is more weak. Then this kind of relation must be investigated upon a bigger trees samples.

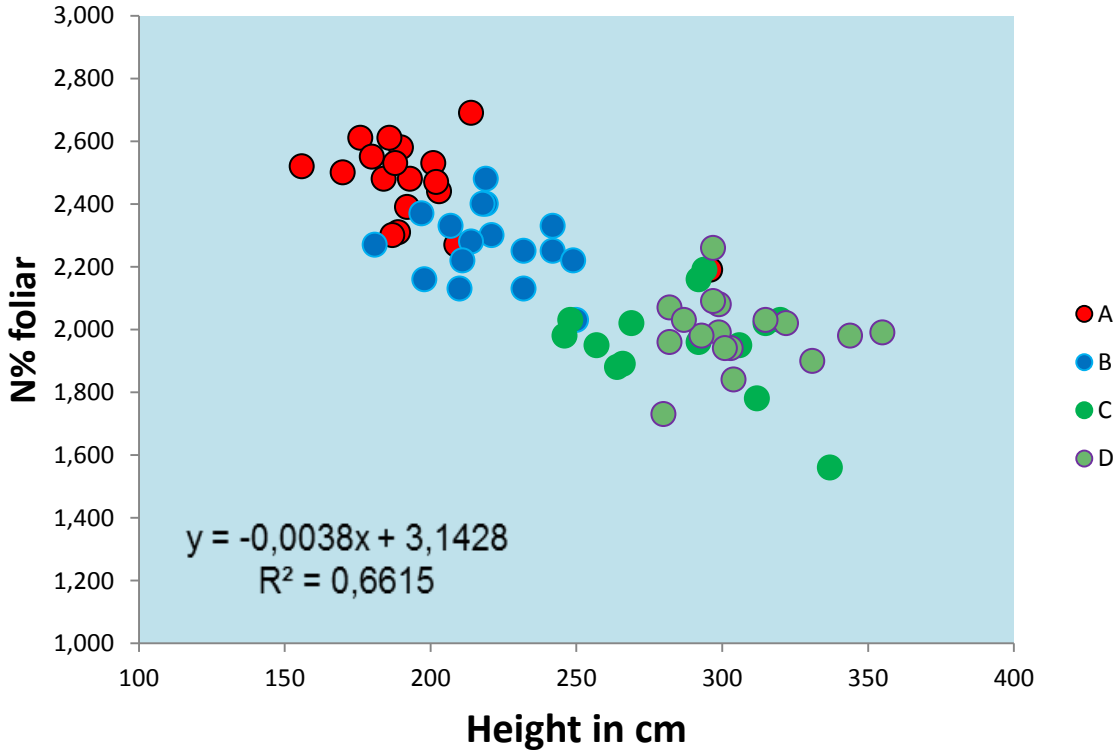


Fig. 11 ter. Relation between LA and palm height for four progenies (A,B,C,D) in ALCP10.

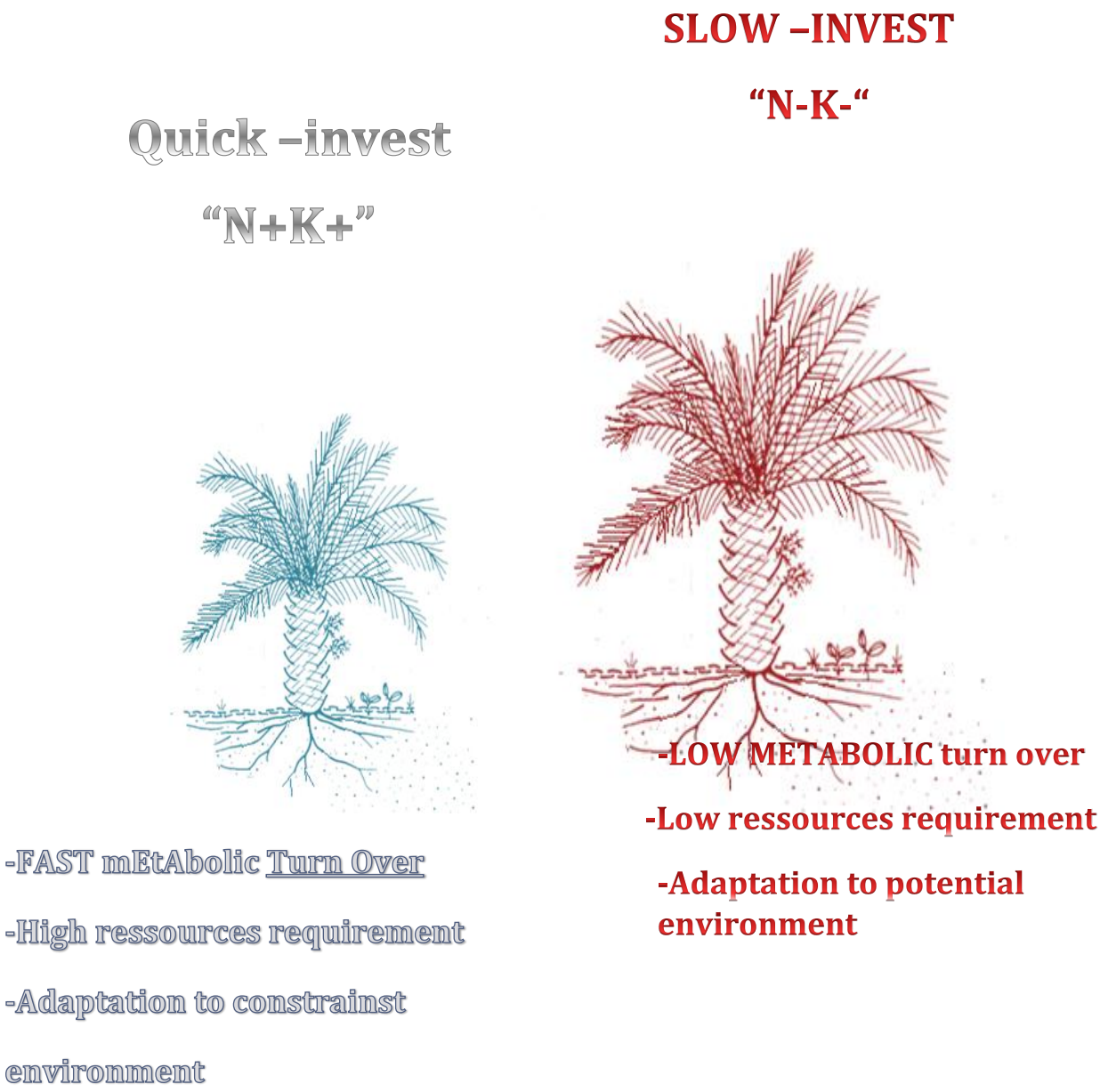
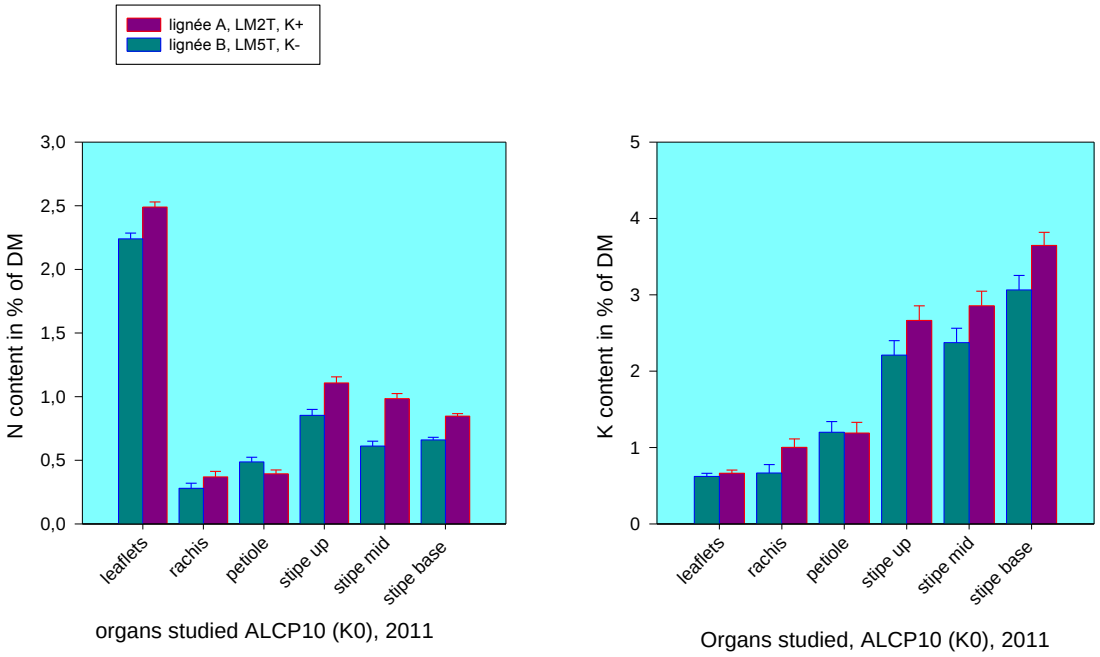


Fig. 11/b. General Concept Model for Nutrient Adaptive Strategy for Oil Palm.

Regarding funtionnal traits, strong relationship is always found between LA and trunk height (Fig. 11 ter). It is the case with A,B,C, and D. Similar to last relation between LA and N, only weak realtion is found within progenies. Then this relation must be investigated again on bigger trees sample.

4. Final estimation of individual mineralomass (N,P,K,Mg Ca)

N,P K,Ca, Mg are in different concentrations along the plant tissues and this general trend can be observed for A and B. N is present in quantity in the leaflets and K is accumulated more in heterotrophic tissues with a maximum at the base of the trunk (Fig.12).



TRUNK MINERALOMASS : N,P,K, Ca, Mg

Fig. 12. Allocation mode for N and K in plant tissues. Means are plotted with SD at 5 %.

TRUNK MINERALOMASS

N.B. These estimations are different from that of the first report because the trunk density was not well measured. The very high trunk density found before did lead to overestimation of the total amount of mineral element N,P,K . It is an occasion to see that trunk density is a very important parameter when we want to estimate mineralomass.

We do separate autotrophic (leaflets) tissues from heterotrophic one (rachis, petiole, trunk, roots …) for mineral content corrections.
For autotrophic tissues we used the following relation to correct Sumbio analyses.

N : $y = 0.7992 * N(BahLias) + 0.2116$ $r^2=0.66$ (limit)

P : $y = 0.9041*P(BahLias)+0.0168$ $r^2=0.49$ (over limit)

K : $y=0.527*K(BahLias)+0.499$ $r^2=0.32$ (over limit)

Mg : $y=0.993*Mg(BahLias)+0.028$ $r^2=0.87$ (acceptable)

Ca : $y=0.9309*Ca(BahLias)+0.0497$ $r^2=0.87$ (acceptable)

For N

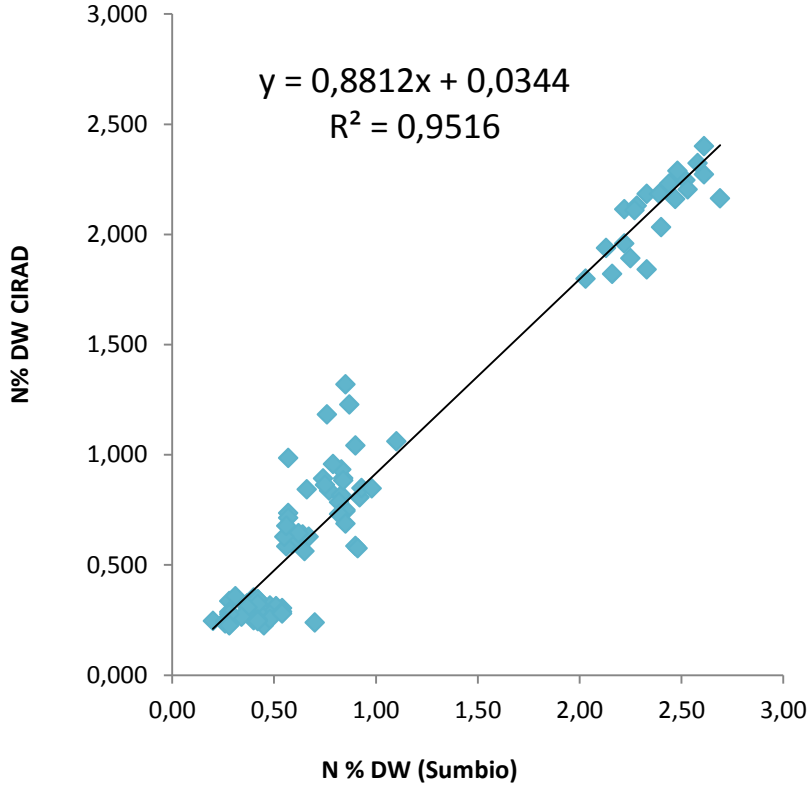


Fig. 13 . Example of corrections made on Sumbio analyses for N total mineralomass estimation,(heterotrophic tissues only).

- For trunk nitrogen in kg tree^{-1}

  (only CIRAD analyses were used for this estimation and correction were made when Sumbio analyses are taking into account, see Fig. 13).

progenies	trunk N kg/tree	Trunk P kg/tree	Trunk K kg/tree
A (LM2T)	1.27 a	0.177 b	4.10 ns
B (LM5T)	0.99 b	0.157 c	3.67 ns
C(LM5T)	0.39 c*	0.237 a	3.67 ns
D(LM5T)	0.33 c *	0.205 a	4.00 ns

Table 14. Total N in trunk . For C and D , a problem was pointed out for Sumbio analyses , then results are not very accurate for N trunk. (**)

(**) new checking will be done this year by sending new analyses to PSBB lab.
For total N in trunk, there is no effect of the K treatment. But there is a strong effect of the progenies. A shows higher quantity (1.27 kg tree^{-1}) compared to B (and also C and D).

For K

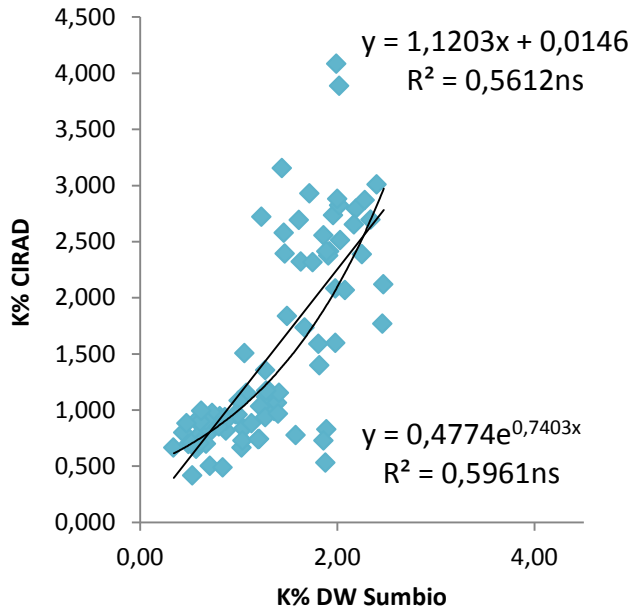


Fig. 14. Example of corrections made on Sumbio analyses for K total mineralomass estimation,(heterotrophic tissues only).

- For trunk potassium in kg tree^{-1}

For K in trunk, we did observed no K treatment effect and no progenies effect. The only remark which can be done is that A pointed out a higher K stock (4.10 kg tree^{-1}) that B,C and D.

For P

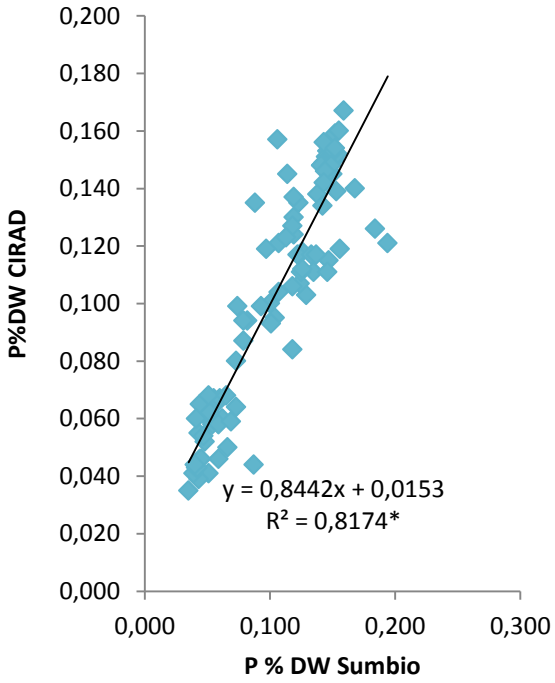


Fig. 15. Example of corrections made on Sumbio analyses for P total mineralomass estimation (heterotrophic tissues only).

- For trunk phosphorus in kg tree $^{-1}$

For P total in trunk, there is an effect of the progenies. C and D progenies have the higher P total in trunk (Table 14) compared to A and B. (corrections were made following relation showed on Fig. 15).

For Mg

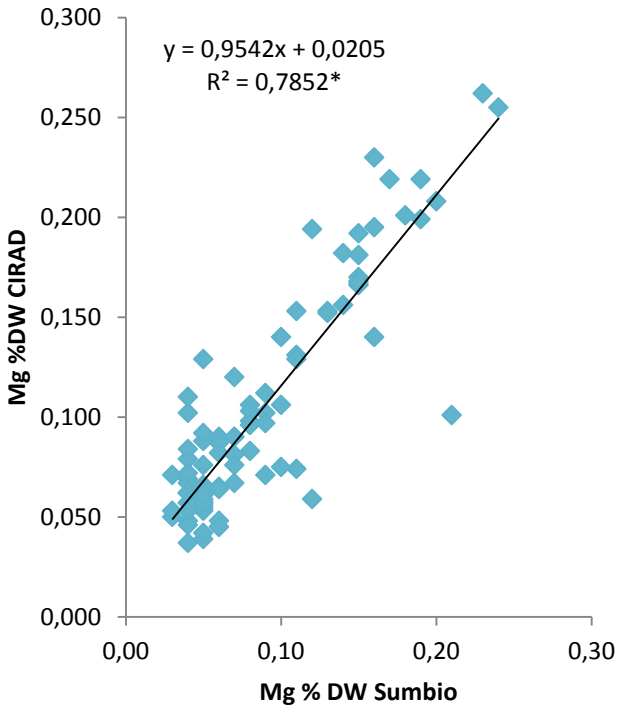


Fig.16. Example of corrections made on Sumbio analyses for Mg total mineralomass estimation (heterotrophic tissues only).

- For trunk Calcium in kg tree^{-1}

progenies	trunk Ca kg /tree	trunk Mg kg/tree
A (LM2T)	0.404ns	0.109ns
B (LM5T)	0.339ns	0.112ns
C(LM5T)	0.328ns	0.112ns
D(LM5T)	0.375ns	0.102 ns

Table 15. Total trunk mineralomass for Ca and Mg for A,B,C and D.

No effect is observed on Ca (correction were made Ca trunk tissues values following 12 quater) on total in trunk on progenies and K treatment factors (Tab 15). Only A show the higher quantity…

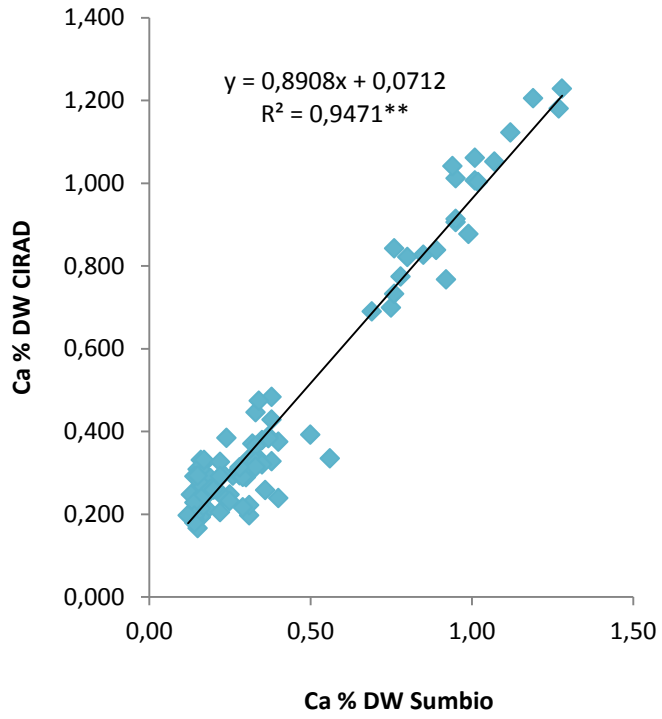


Fig. 17 . Example of corrections made on Sumbio analyses for Ca total mineralomass estimation (heterotrophic tissues only).

No effect is observed on Ca total in trunk on progenies and K treatment factors (tab 15). Only A show the higher quantity…

- For trunk Magnesium in kg tree^{-1}

For Mg, as for Ca, there is no effect of the progenies and the K treatment (Table 15).

Mineralomass is important to quantify the amount of mineral element returning to the soil when re-planting. When dead trunk remain on re-planting the following quantities are susceptible to be added to the substrat in the windrow part only.

From dead trunk :

NITROGEN ……..144 kg /ha
PHOSPHORUS……24
POTASSIUM……496
MAGNESIUM……14
CALCIUM ……..46

From dead trunk in windrows, in ALCP10 conditions, the following minerals quantity can return to soil and be available under certain conditions to young trees after re-planting : 144 kg ha^{-1} for N, 24 kg ha^{-1} for P, 496 kg ha^{-1} for K, 14 kg ha^{-1} for Mg and 46 kg ha^{-1} for Ca.
The first remark is the importance of the potassium : around 500 kg/ha returning from dead trunk to the soil. Then it is difficult to install real K0 treatment in such condition.

LEAF MINERALOMASS

THE LEAFLETS

- For N total in leaflets in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.67	0.56 ns
NivK	2	4	0.22	0.80 ns
Progeny	3	17	11.17	0.0003 ***
Nivk*Prog	6	17	0.78	0.78 ns
progeny	K0	K2	K3	Average
A (LM2T)	1.78±0.14	1.74±0.15	1.90±0.15	1.81 b
B (LM5T)	2.27±0.14	2.22±0.14	2.39±0.15	2.28 a
C(LM5T)	1.81±0.15	1.97±0.14	1.61±0.16	1.81 b
D(LM5T)	1.54±0.14	1.60±0.14	1.78±0.14	1.64 b

Table 16. Total N in leaflets for A,B,C and D in ALCP10. *Proc mixed*, SAS.

This result is very important. We see that it is B (which is N- and K-) that show the highest N mineralomass with 2.28 kg of N in the leaflets compared to A (1.81 kg of N).
This is due to the fact of the big leaf area of B (more than 10 m^2) compared to the others progenies and specifically B.
Then mineralomass which related to the biomass cannot be discriminant for mineral status of trees.

- For P total in leaflets in kg tree $^{-1}$

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.76	0.52 ns
NivK	2	4	0.95	0.95 ns
Progeny	3	17	10.63	0.0004 ***
Nivk*Prog	6	17	1.24	0.33 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.105±0.009	0.106±0.01	0.111±0.008	0.108 b
B (LM5T)	0.148±0.009	0.144±0.009	0.165±0.01	0.149 a
C(LM5T)	0.137±0.01	0.152±0.009	0.129±0.01	0.140 a
D(LM5T)	0.117±0.09	0.128±0.009	0.149±0.009	0.132 a

Table 17. P total in leaflets for A,B,C,D under K treatment. *Proc mixed*, SAS.

For P again, B is showing the highest mineralomass (Table 17) as far as leaflets is concerned. The only significant difference is for the progeny A (P mineralomass).

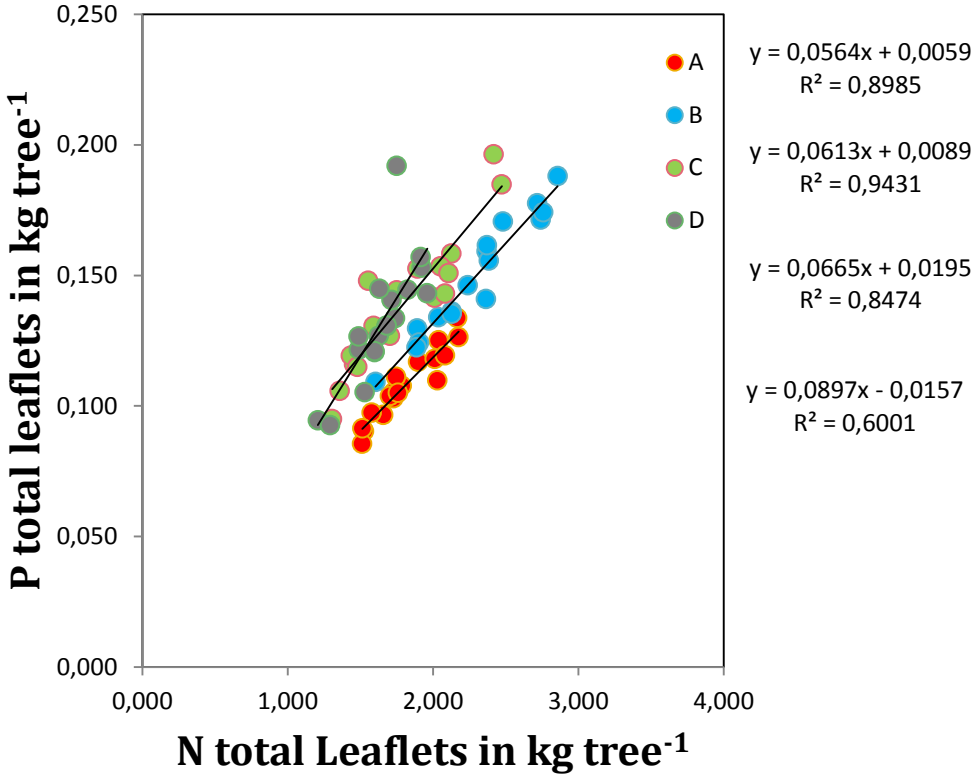


Fig. 18. Stoechiometric investigation on N/P leaflets mineralomass for A,B,C,D in ALCP10.

- For K total in leaflets in kg tree^{-1}

Another interesting result is concerning the K total mineralomass of the leaflets (Table 21). There is a strong progeny effect on this variable. If A is considered as K+, its mineralomass is low (0.491 kg tree^{-1}) compared to B,D and especially C (0.818 kg tree^{-1}).

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.77	0.52 ns
NivK	2	4	0.30	0.75 ns
Progeny	3	17	10.55	0.0004 ***
Nivk*Prog	6	17	0.58	0.74 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.479±0.077	0.458±0.08	0.539±0.07	0.491 b
B (LM5T)	0.613±0.077	0.507±0.07	0.579±0.08	0.562 b
C(LM5T)	0.789±0.08	0.866±0.07	0.769±0.09	0.818 a
D(LM5T)	0.682±0.07	0.747±0.07	0.837±0.07	0.764 a

Table 18. K total in leaflets for A,B,C,D progenies under K treatment. *Proc mixed, SAS.*

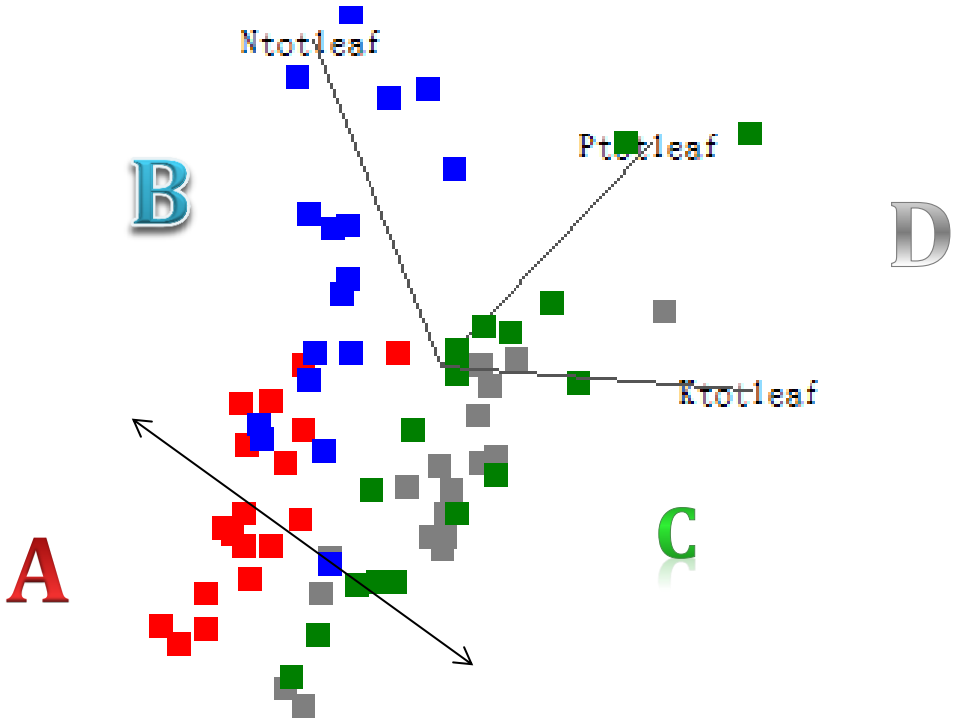


Fig. 19. Stoechiometric investigation on 3D for N,P,K leaflets mineralomass for A,B,C and D in ALCP10. A progeny : red ; B progeny : blue; C progeny : green; D progeny : grey. SAS graph, proc insight.

Another interesting result is concerning the K total mineralomass of the leaflets (Table 18). There is a strong progeny effect on this variable. If A is considered as K+, its mineralomass is low (0.491 kg tree^{-1}) compared to B,D and especially C (0.818 kg tree-1).

- For Ca total in leaflets in kg tree^{-1}

Effect	**Num DEF**	**DenDF**	**F value**	***Pr*<F**
Repet	2	4	0.47	0.65 ns
NivK	2	4	1.25	0.37 ns
Progeny	3	17	21	0.0001 ***
Nivk*Prog	6	17	1.96	0.128 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.570±0.06	0.569±0.07	0.676±0.06	0.61 c
B (LM5T)	0.956±0.06	1.035±0.069	1.11±0.07	1.027 a
C(LM5T)	0.738±0.07	1.97±0.07	0.598±0.07	0.738 bc
D(LM5T)	0.630±0.07	1.60±0.07	0.79±0.069	0.71 bc

Table 19. Ca total in leaflets for A,B,C,D progenies under K treatment. *Proc mixed, SAS.*

For Ca same situation that for K is observed. B progeny, because of its LA very high, exhibit a high total ca content (1.027 kg by individual canopy). A shows a very low total amount of Ca for all its leaflets (Table 19).

For Mg total in leaflets in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.78	0.52 ns
NivK	2	4	0.95	0.45 ns
Progeny	3	17	16.49	0.0001 ***
Nivk*Prog	6	17	2.30	0.083 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.089±0.01	0.092±0.01	0.093±0.01	0.0920 c
B (LM5T)	0.214±0.01	0.160±0.015	0.1709±0.01	0.181 a
C(LM5T)	0.178±0.01	0.166±0.01	0.120±0.01	0.155 b
D(LM5T)	0.129±0.01	0.143±0.016	0.167±0.01	0.147 bc

Table 20. Mg total in leaflets for A,B,C and D progenies under K treatments. *Proc mixed SAS.*

For Mg , the same situation as for other minerals was found : B exhibit the higher amount due to its large LA.

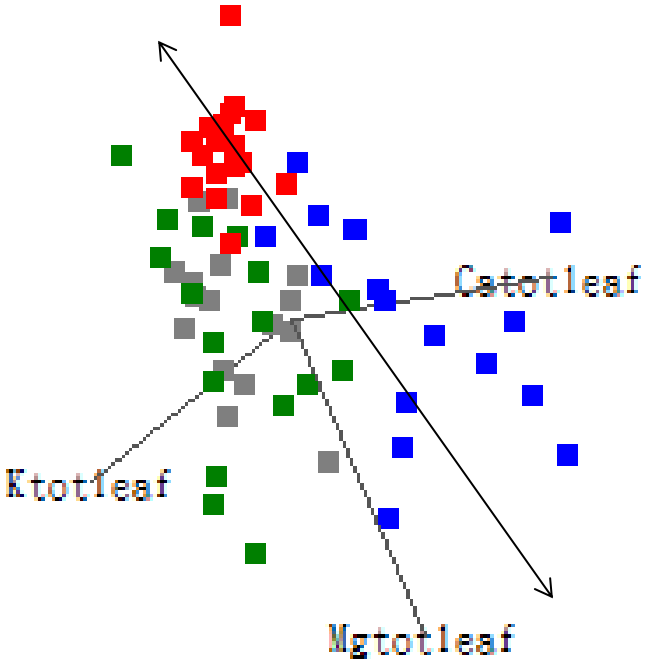


Fig. 20. Cations relations in total leaflets mineralomass. For A,B,C and D progenies, ALCP10.Rotating plot 3D with *proc insight procedure*, SAS.

When considering the behaviour of all the four progenies, with the cations (here K+, Ca++, Mg+), the maximum discrimination is with Mg total content in leaf with very few amount for A progeny (Fig. 20).

RACHIS MINERALOMASS

The rachis mineralomass must be interesting to investigate compared to rachis mineral analysis.

- N total in rachis in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.77	0.519 ns
NivK	2	4	0.33	0.738 ns
Progeny	3	17	37.18	<0.0001 ***
Nivk*Prog	6	17	0.75	0.61 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.103±0.01	0119±0.01	0.095±0.01	0.105 b
B (LM5T)	0.147±0.01	0.120±0.01	0.124±0.01	0.129 a
C(LM5T)	0.044±0.01	0.04±0.01	0.038±0.01	Pb
D(LM5T)	0.03±0.01	0.04±0.01	0.043±0.01	Pb

Table 21. N total in rachis, in kg/tree, for A,B,C,D progenies,ALCP10. *Proc mixed*, SAS.

There was a problem for N rachis for C and D due to error in Sumbio analysis. It is the reason that we can only focuses on A and B; In table 21, we see that B present a higher N mineralomass than A.

- P total in Rachis in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	2.31	0.215 ns
NivK	2	4	0.68	0.55 ns
Progeny	3	17	11.54	0.0002 ***
Nivk*Prog	6	17	1.25	0.329 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.023±0.004	0.0234±0.004	0.023±0.004	0.0236 c
B (LM5T)	0.0347±0.004	0.0293±0.004	0.0381±0.004	0.034 ab
C(LM5T)	0.0433±0.004	0.044±0.004	0.0398±0.004	0.0427 a
D(LM5T)	0.0318±0.004	0.0044±0.044	0.0477±0.004	0.04 ab

Table 22. P total in rachis for A,B,C,D progenies, *Proc mixed, SAS.*

A strong effect of the progenies is observed for P mineralomass in rachis (Table 25). A is presenting the lowest total P quantity in the rachis (all the canopy) compared to B,C and D. It is the C progeny which shows the highest P total amount (0.0427 kg tree^{-1}).

- **K in Rachis in kg tree^{-1}**

K rachis which is can be involved in LD as complementary data for fertilization pilot shows interesting result with a double effect of the K level treatment (Fisher : 12.8, table 26) and the progeny (Fisher : 7.76, table 26). First of all, a low K rachis mineralomass is observed for B (0.35 kg of K for the total canopy of an individual tree) with a higher for C progeny (0.62 kg).

Effect	**Num DEF**	**DenDF**	**F value**	***Pr*<F**
Repet	2	4	1.25	0.37 ns
NivK	2	4	12.88	0.01*
Progeny	3	17	7.76	0.0018**
Nivk*Prog	6	17	1.43	0.261 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.426±0.07	0.412±0.07	0.701±0.06	0.538 a
B (LM5T)	0.367±0.07	0.280±0.067	0.431±0.07	0.356 b
C(LM5T)	0.493±0.06	0.654±0.068	0.728±0.069	0.625 a
D(LM5T)	0.376±0.07	0.543±0.068	0.770±0.067	0.563 a
Significance at 5%	b	b	a	

Table 23. Effect of K levels for rachis K mineralomass for A,B,C,D progenies.

For the treatment effect (K0,K2,K3 levels), a significant effect is found between K0 and K3 only for rachis K mineralomass (table 23, Fig. 24). An increase of K total quantity is observed with the level of K treatment.

Then K accumulation to heterotrophic tissues is observed when nothing comparable is observed in leaflets (Fig. 14bis). The lack of K entrance in the leaflets is maybe a sign that the sugars coming from photosynthesis activity are not circulating properly from source organs to sink organs and then K+ is not circulating with H+ and sucrose.

We will see further that an abnormal accumulation of sucrose is observed in leaflets, whatever progenies and also in the trunk.

When we consider N,P,K stoichiometric relation with rachis total mineralomass, bigger discrimination among progenies A,B,C and D is obtained with the N tot rachis axis and P tot rachis (Fig. 22).

There is an evident relation between the K rachis content in % of DW (Fig. 21) and the K total rachis mineralomass (in kg tree^{-1}).

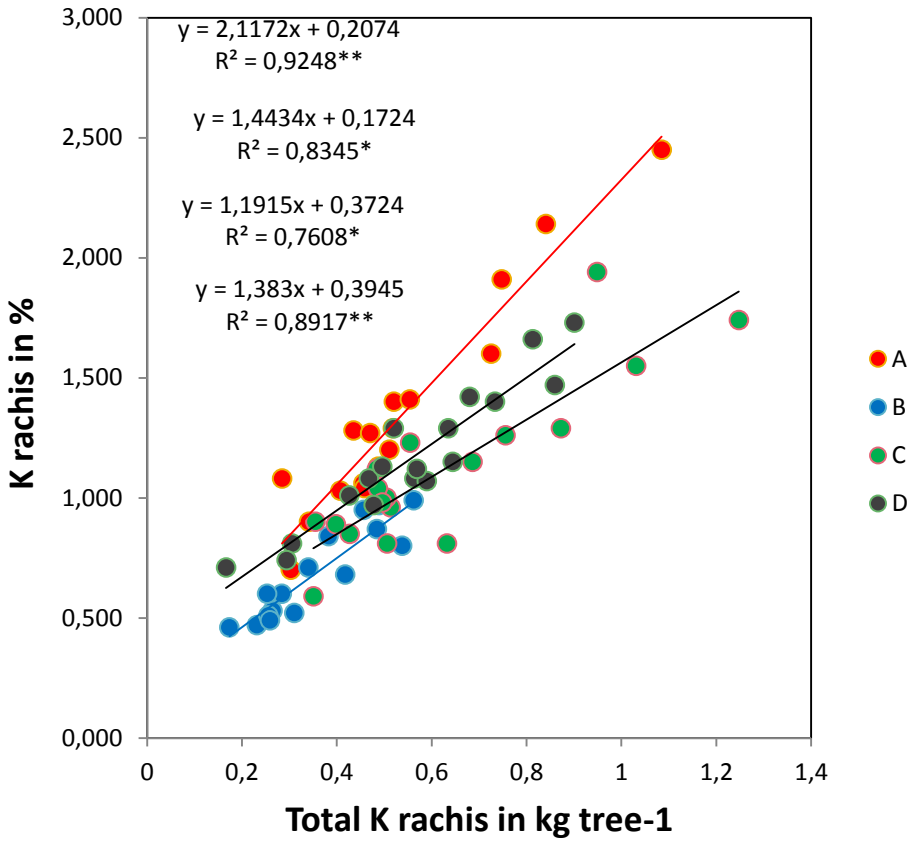


Fig. 21. Relation between K content in rachis (Krach) in % of DW and the total K rachis mineralomass (K tot rach in kg tree^{-1}) (r^2=0.73**).

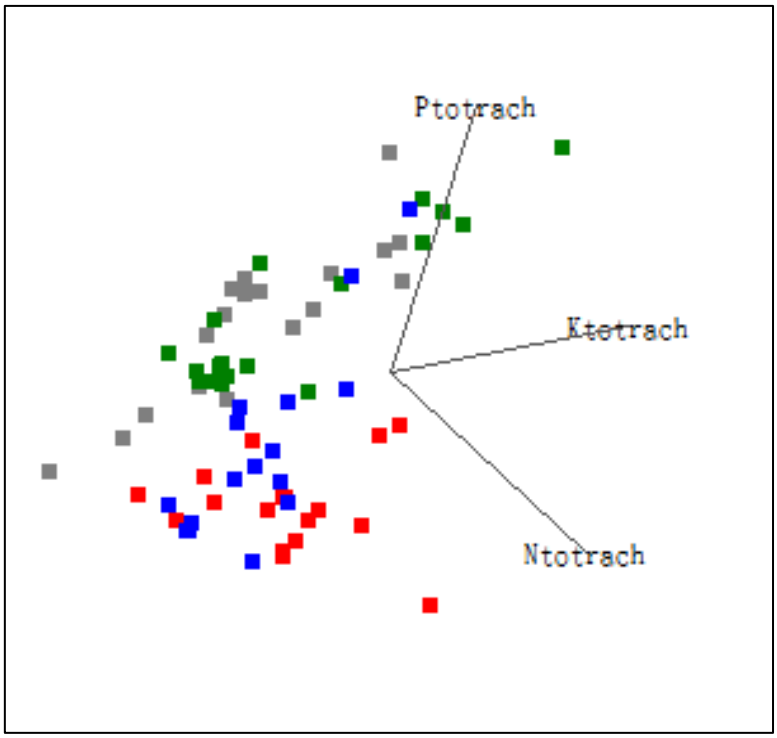


Fig. 22. Stoechiometric investigation for N,P,K rachis mineralomass for A,B,C and D in ALCP10. SAS graph, *proc insight*.

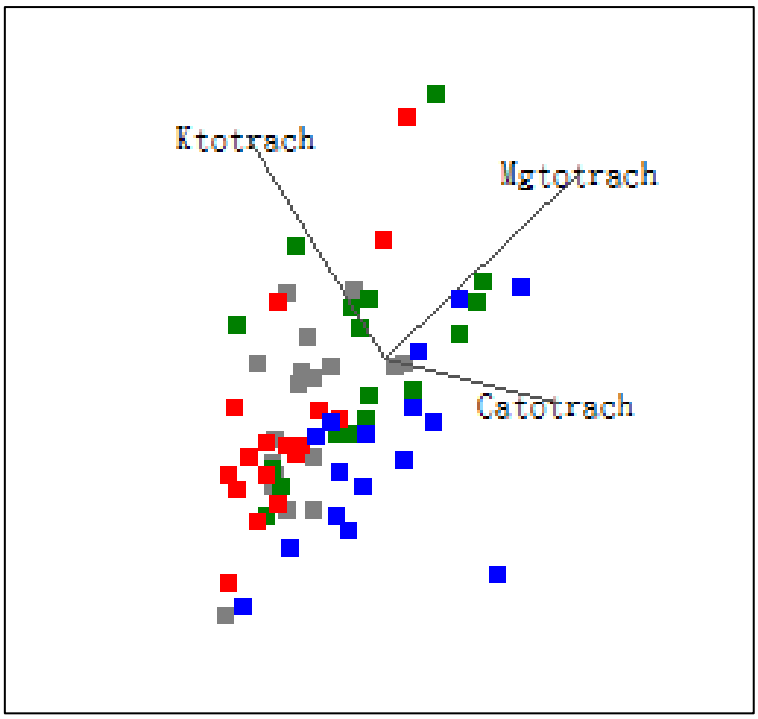


Fig 23. Cations (K+, CA++, Mg+) total rachis investigations among four progenies in ALCP10. SAS graph, *proc insight*.

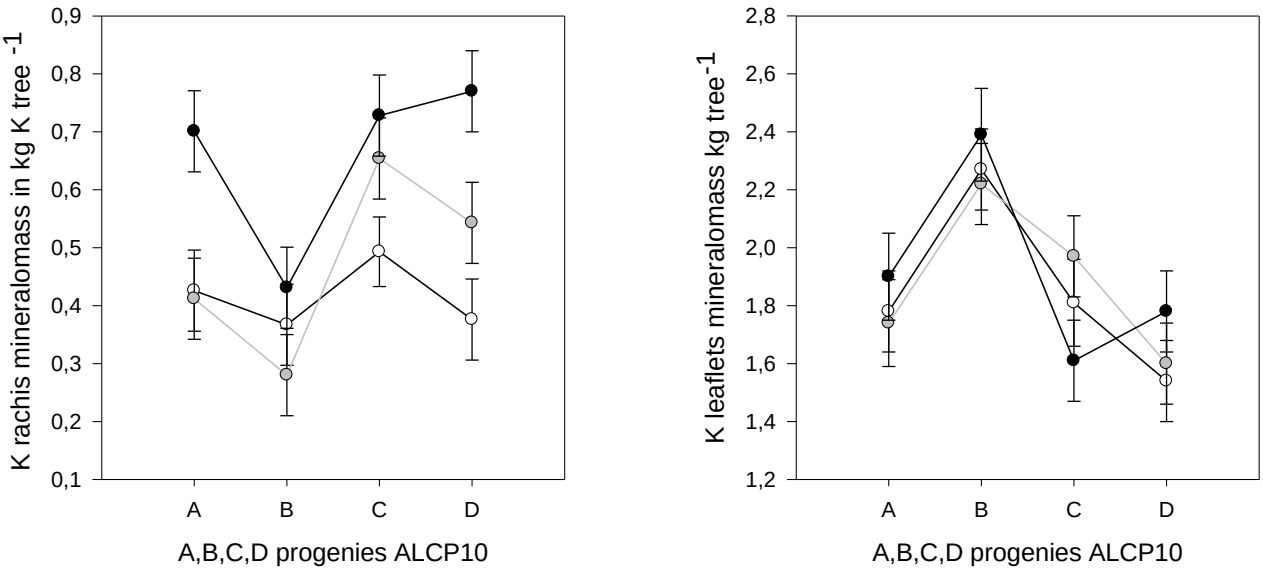


Fig. 24. Evolution of K total rachis in kg K/tree (left side) and leaflets (right side) for the progenies A,B,C and D under K0 (white circle), K2 (grey circle), K3 (black circle).

- Mg total in rachis in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	2.31	0.215 ns
NivK	2	4	0.68	0.55 ns
Progeny	3	17	11.54	0.0002 ***
Nivk*Prog	6	17	1.25	0.329 ns

progeny	K0	K2	K3	Average
A (LM2T)	0.023±0.004	0.0234±0.004	0.023±0.004	0.0236 b
B (LM5T)	0.0347±0.004	0.0293±0.004	0.0381±0.004	0.034 a
C(LM5T)	0.0433±0.004	0.044±0.004	0.0398±0.004	0.042 a
D(LM5T)	0.0318±0.004	0.0044±0.044	0.0477±0.004	0.04 a

Table 24. Effect of K level treatment on Mg rachis mineralomass, ALCP10 for A,B,C and D progenies. *Prox mixed , SAS.*

For Mg, a strong effect of the progenies is observed (table 24) with a big difference observed between A in one part (Low Mg) and B,C and D in other part. Mg quantity in rachis is low, maybe situated in the green part of the organ contrary to the potassium totally situated in the white parenchym.

- Ca total in rachis in kg tree^{-1}

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.59	0.597 ns
NivK	2	4	1.24	0.38 ns
Progeny	3	17	6.40	0.0042**
Nivk*Prog	6	17	0.81	0.573 ns

progeny	K0	K2	K3	Average
A (LM2T)	0.117±0.022	0.099±0.02	0.137±0.019	0.12 b
B (LM5T)	0.144±0.022	0.194±0.02	0.173±0.022	0.172 a
C(LM5T)	0.182±0.02	0.211±0.02	0.177±0.02	0.190 a
D(LM5T)	0.128±0.02	0.149±0.02	0.167±0.02	0.148 ab

Table 25. Effect of K level treatment for Ca rachis mineralomass for A,B,C and D progenies in ALCP10. *Proc mixed , SAS.*

For the total amount of Ca in the rachis, again a strong effect of the progenies is observed with C showing the bigger quantity (Table 25, Ca = 0.190 kg tree^{-1}). The lower amount is observed for the A progeny (Ca= 0.120 kg tree^{-1}).

PETIOLE MINERALOMASS

For the petiole mineralomass, these estimations below are provisory calculations because in 2012, petiole were quite roughly measured. The new method developed during last mission in 2013-2014 will change the petiole length and then the biomass and mineralomass.

progeny	PetioleN Kg	Petiole P kg	Petiole K kg	Petiole Ca kg	Petiole Mg kg
A (LM2T)	0.105 b	0.0117 b	0.393	0.089 b	0.0233
B (LM5T)	0.129 a	0.0174 a	0.375	0.121 ab	0.0329
C(LM5T)	0.044 c pb	0.0110 b	0.459	0.149 a	0.0287
D(LM5T)	0.038 c pb	0.0119 a b	0.442	0.127 ab	0.0255

Table 26. Effect of K level treatment for N,P,K,Ca,Mg petioles mineralomass for A,B,C and D progenies in ALCP10.

- **N total in petiole in kg tree^{-1}**

There is a strong effect of the progeny factor on N petiole mineralomass (table , table 26), but due the problem of the wrong analysis in Sumbio for nitrogen, we can only compare progenies A and B (CIRAD analysis). Because B is presenting bigger petiole than A, we can observed than the total N petiole is higher for B (0.129 kg N /tree) that for A (0.105 kg N/tree).

- **P total in petiole in kg tree^{-1}**

A strong effect of the progenies (Table in annexe, table 26) could be seen for P mineralomass in petiole. B progeny exhibit the larger amount of P in petiole (0.0174 kg P/tree compared to A and C. No significant difference was found between B and D (0.0119 kg P/tree).

- **K total in petiole in kg tree^{-1}**

The petiole biomass is very difficult to estimate properly. It is the reason why the petiole mineralomass cannot be really seriously considered for discriminating progenies or see any effect of fertilizer treatment. There is no significant effect of the two factors, K treatment and progeny (table annexe , table 26). We can only notice that C and D show higher K petiole mineralomass compared to A and B. Then it is obvious that any "mineralomass" must be considered with caution.

- **Mg total in petiole in kg tree^{-1}**

There is no effect of the K treatment and the progenies origin on Mg petiole mineralomass (table , annexe). Only higher Mg petiole quantity is observed for the B progeny (Table 26). Mg is not related to heterotrophic organs.

- **Ca total in petiole in kg tree^{-1}**

For Ca total in petiole, there is obviously an effect of the progeny factor : it is the progeny C which has the higher amount of Ca in petiole (Table 33).

The crown

What about the total mineralomass of the crown ? The crown of each oil palm tree is composed by the leaflets, the rachis and the petiole. For the mineralomass of the crown, the sum of all the 3 mineralomasses is done . This new balance is interesting to understand the "standing" mineral quantity in individual tree depending of the progeny and the K level treatment.

- **N total in crown in kg tree^{-1}**

For N total in the crown, there is a strong difference between A and B progenies. If A is considered as N+ and B as N-, when the total crown mineralomass is considered, A will be N- and B, N+. Then it is important to investigate the relation between the total mineralomass and its meaning as physiological property and its relation with FFB production.

- **P total in crown in kg tree^{-1}**

For P total in the crown, there is a big difference again between A in one side with a low P crown mineralomass compared to B,C and D (Table 35, annexe 1, table 30 bis).

- **K total in crown in kg tree^{-1}**

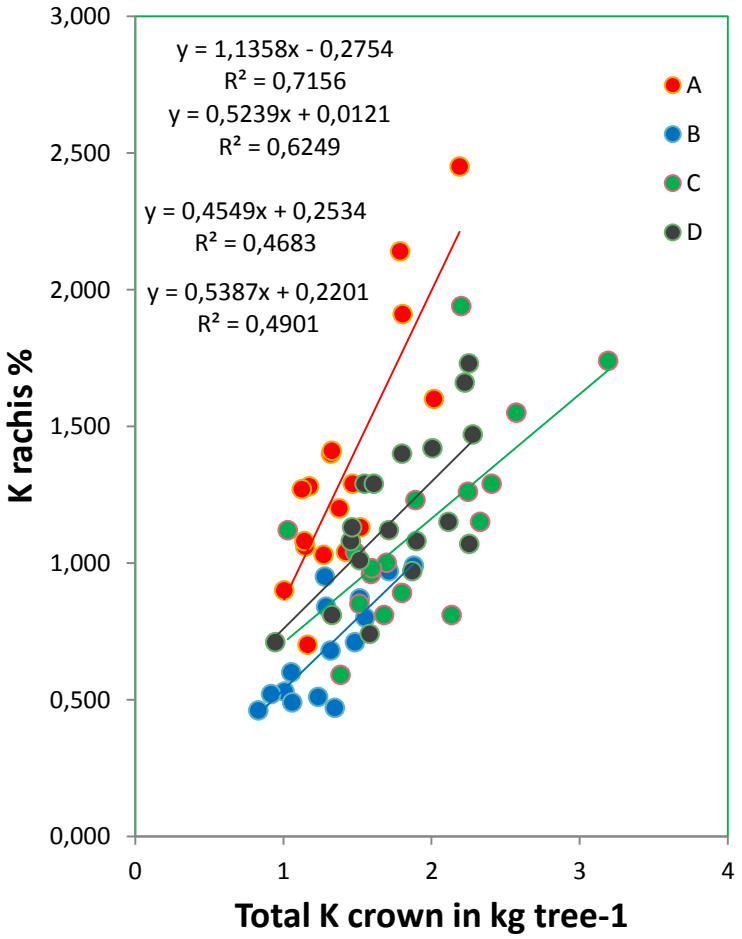


Fig. 25. Relation between K rachis in % of DW and the total amount of K in the crown (in kg tree^{-1}), r^2=0.37**.

The total crown K is a discriminant factor among the four progenies studied (Table ,annexe).

Again we can notice that K rachis is a good "proxy" for the total amount of K in the crown (Fig. 15). C shows the highest quantity of K in individual crown with 1.9 kg of K per tree when A shows the lowest with only 1.3 kg tree^{-1}. Then the question of the use of the mineralomass to qualify progenies can be pointed out.

- **Mg total in crown in kg tree^{-1}**

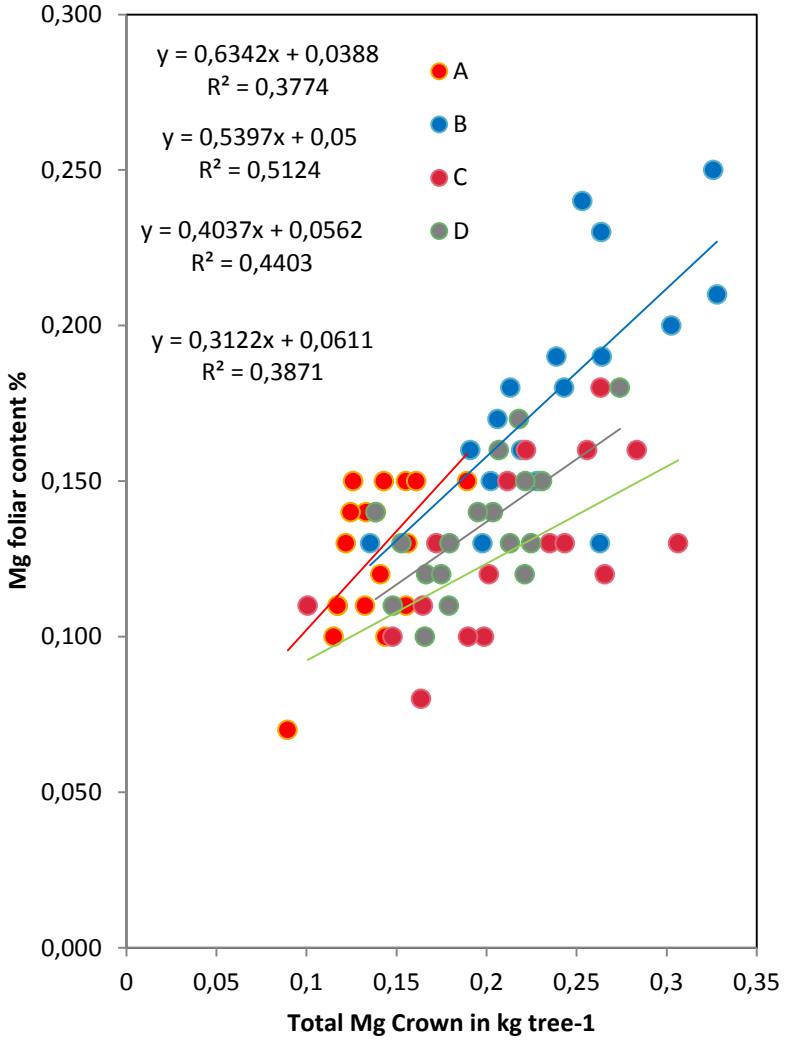


Fig. 27. Relation between Mg in leaflets and the total Mg in crown." Best proxy" .

As for K, there is an effect of the progenies, for Mg crown mineralomass (table 37, annexe 1). B considered as K- for K leaf content is Mg + for the crown mineralomass. Mg leaf content (in % of DW) is the best proxy (Fig. 16) for Mg crown mineralomass (kg tree^{-1}).

- **<u>Ca total in crown in kg tree^{-1}</u>**

There is a big effect of the progenies (table 38, annexe 1), in Ca crown mineralomass. A shows the lowest Ca amount in the crown (0.814 kg tree^{-1}) when B shows the highest amount (1.172 kg tree^{-1}).

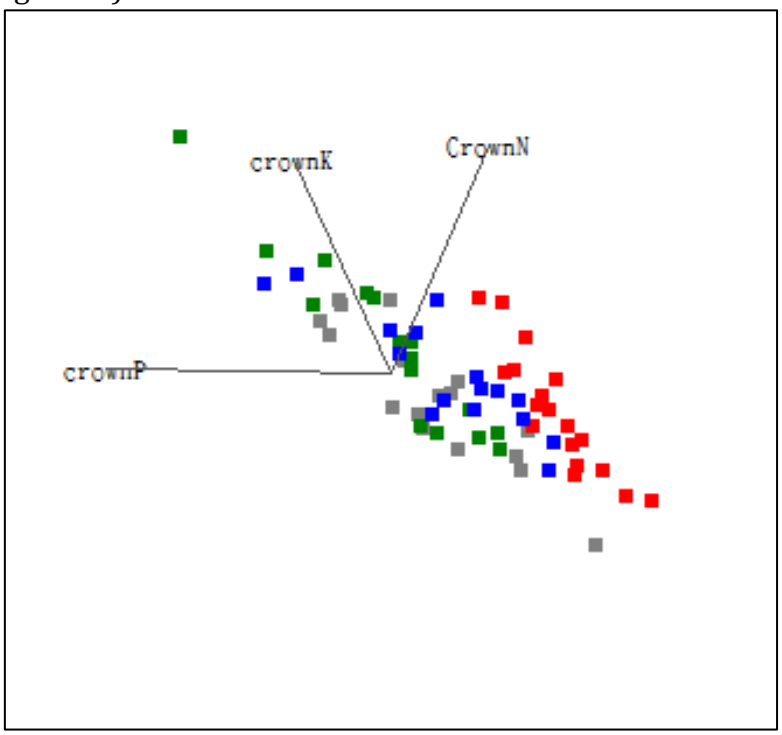


Fig. 28. Main direction for A,B,C,D discrimination of N,P,K crown content ; SAS graph, *proc insight.* A in red, B in blue, C in green, D in grey.

When we look at the 3D plot N,P,K crown for A,B,C and D. K crown is main discriminant factor (Fig. 28) compared to P and N.

FINAL TOTAL ABOVE GROUND MINERALOMASS in kg tree^{-1}

What about the total mineralomass of the crown ? The crown of each oil palm tree is composed by the leaflets, the rachis and the petiole. For the mineralomass of the crown, the sum of all the 3 mineralomass is done. This new balance is interesting to understand the "standing" mineral quantity in individual tree depending of the progeny and the K level treatment.

For above ground mineralomass, we can look at the synthesis for the four progenies : A,B,C and D (Table 27).

In kg tree^{-1}	A	B	C	D
N total above	3.331 (-)	3.545 (+)	2.142pb	2.120pb
P total above	0.319 (-)	0.356 (+)	0.346 (+)	0.380 (+)
K total above	5.49 (+)	4.97 (-)	4.55 (-)	5.77 (+)
Mg total above	0.541 (-)	0.579 (+)	0.448 (-)	0.571 (+)

Ca total above	0.923 (-)	1.422 (+)	1.159 (-)	1.061 (-)

Table 27. Total amount of minerals (N,P,K Mg, Ca) for A,B,C,D for above ground biomass

For mineralomass, contrary to mineral foliar content, we can establish the following list :

- A will be N-,P-, K+, Mg-, Ca-
- B will be N+,P+,K-,Mg+,Ca+
- C will be(N-), P+,K-,Mg-,Ca- (N with pb)
- D will be (N-),P+,K+,Mg+,Ca- (N with pb)

Then it is different from what was observed with direct leaflets minerals content : A was N+P+K+ and B N-P-K- ….. then mineralomass must be well estimated or measured and taken into account with caution when compare progenies.

What about K allocation and accumulation in all organs and progenies ?

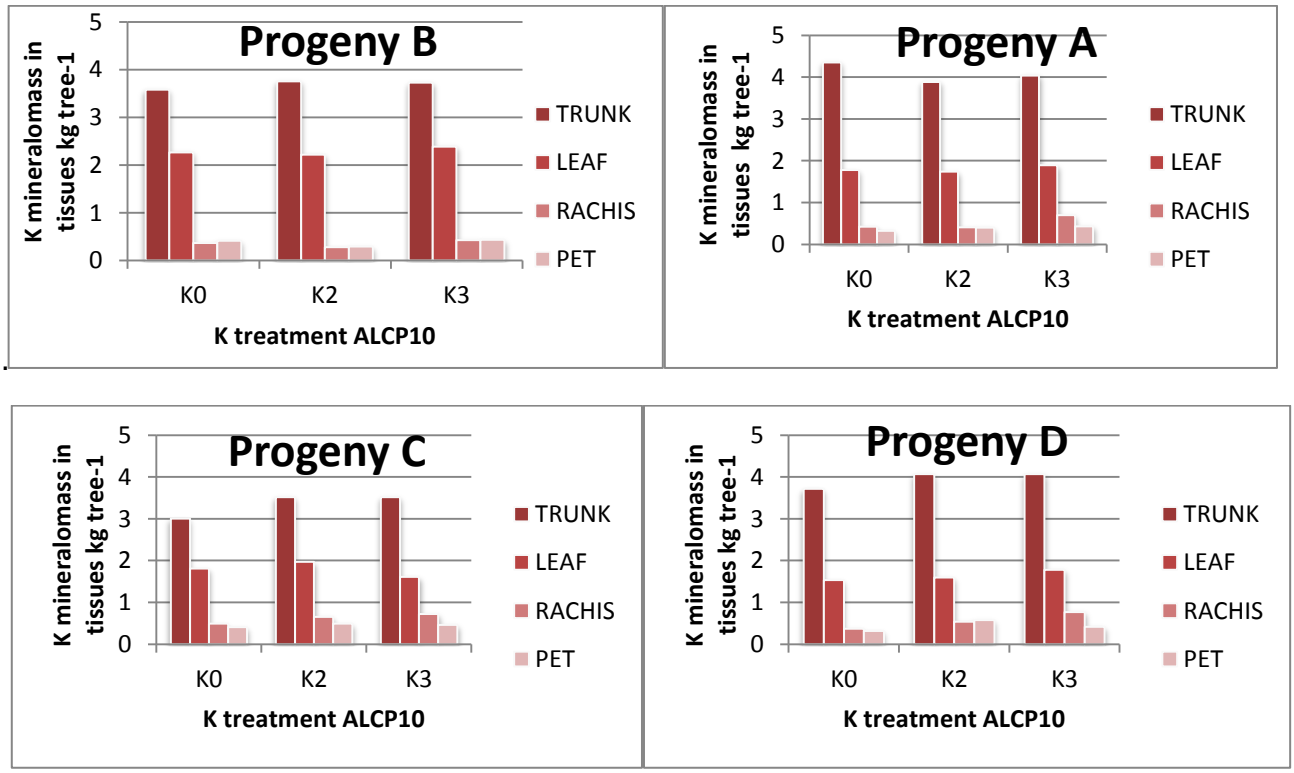


Fig. 29. Total K allocation in term of quantity for A,B,C,D in ALCP10.

The hole plant strategy for survival and development is located in the leaf and in reserve organs. **For K , allocation A and D present most contrasting one with a K reserve pool in trunk.**

If K is not directly used for photosynthetic sucrose transportation, its accumulation in heterotrophic organs maybe an indication of the adaptive strategy of the progenies.

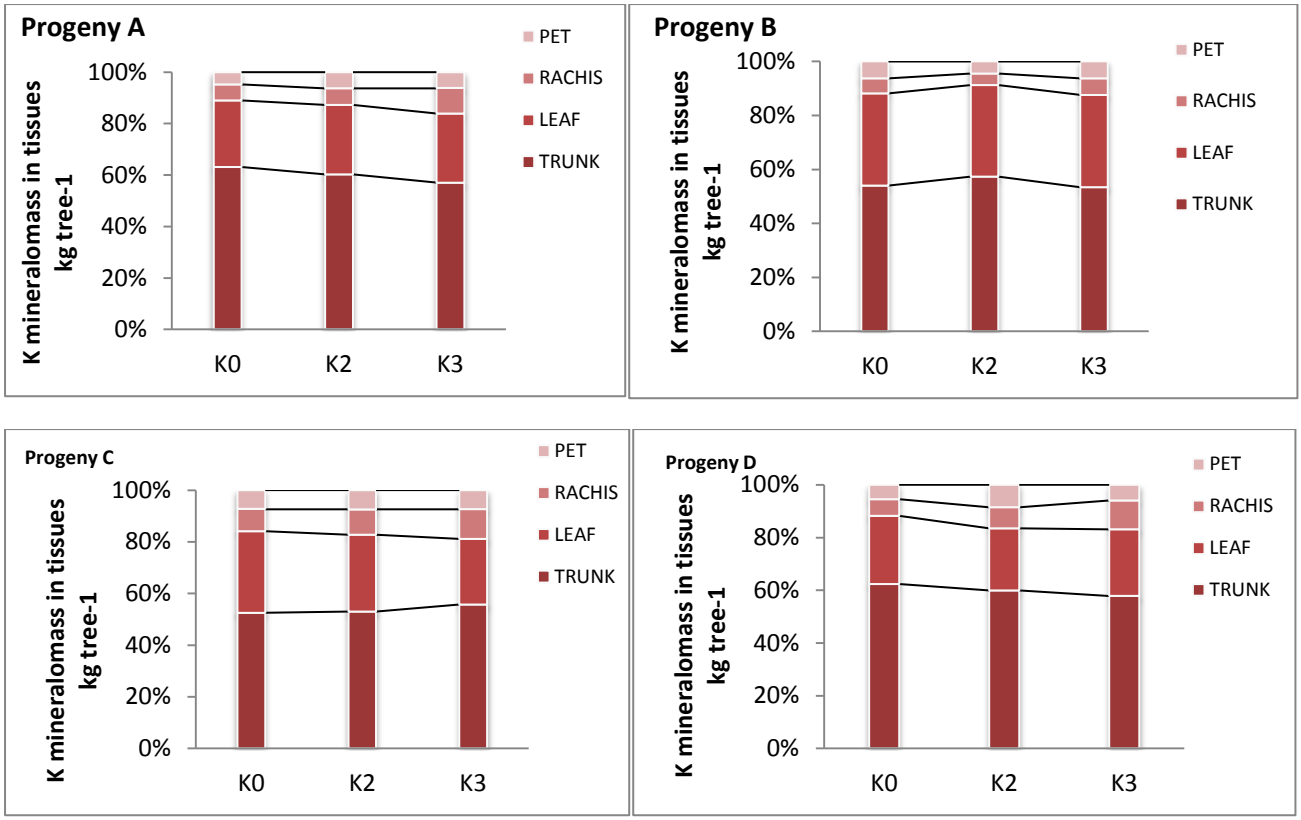


Fig.30. Allocation of K under K0,K1,K3, ALCP10, A,B,C,D progenies.

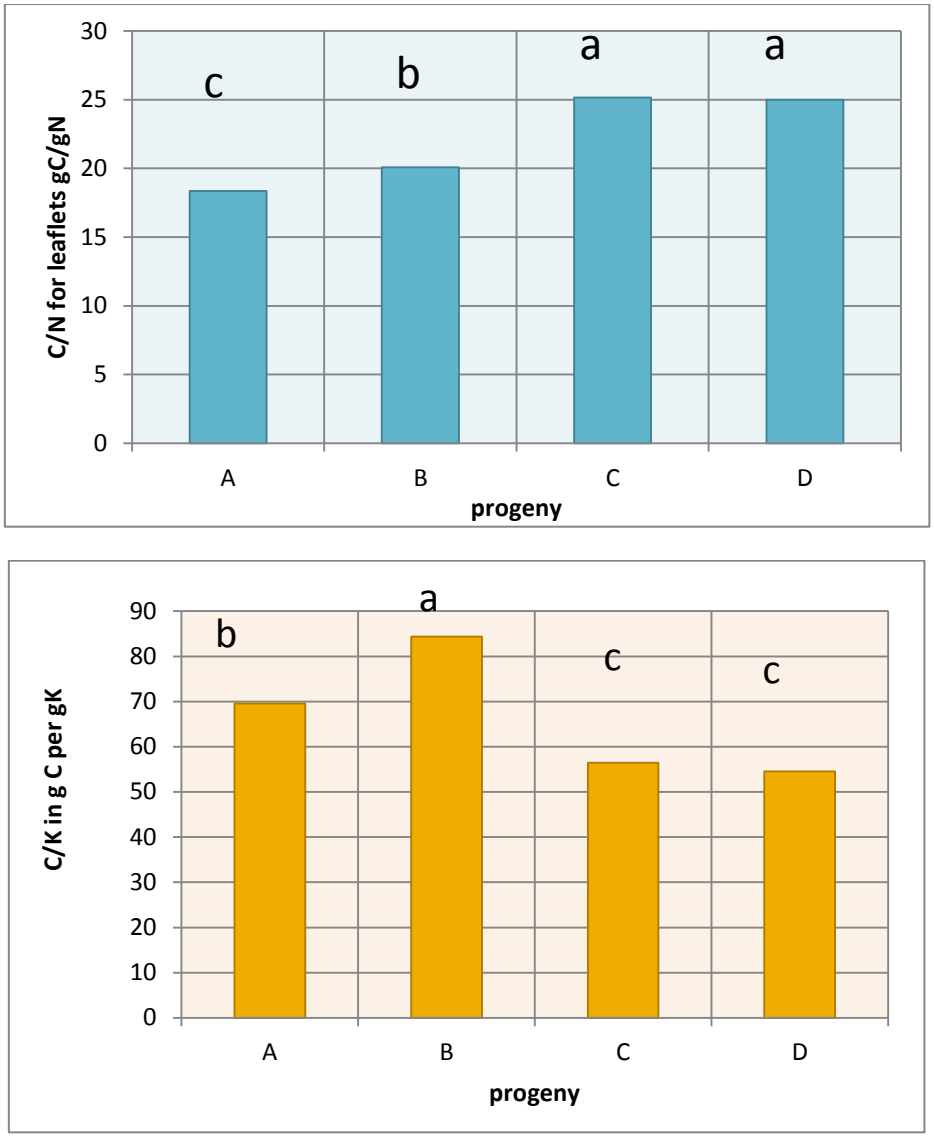
For A and D, there is under K3, a low decrease of the K allocation in trunk towards the rachis (Fig.30). Both A and D present the better production : we can observe that the shift between trunk and rachis for K accumulation maybe an interesting point to study.

Then we can look at the following ratio : C/N, C/P, C/K for above ground biomass taking into account C% variation among the organs. For leaflets it is around 45 % .

effect	DEF	F value	*Pr*<F
For C/N	2	2.59	0.0834ns
NivK	3	91.77	<0.001***
Progeny	6	0.26	0.9540ns
Nivk*Prog			
For C/K	2	0.74	0.4807ns
NivK	3	19.31	<0.001***
Progeny	6	0.61	0.724ns
Nivk*Prog			

Table 28. ANOVA for C/N and C/K variables for four progenies under K treatment in ALCP10.

There is a very strong effect of the progeny for the ratio C/N and C/K (Table 40).



Fig; 31. Variation of C/N (top) and C/K (down) for four progenies A,B,C,D in ALCP10. a,b,c means comparison Tukey 's test, 5% .

A and B progeny present the lowest C/N ratio for leaflets biomass compared to C and D. For the ratio C/K it is the other way around (Fig. 31). Maybe this ratio is a good alternative to compared progenies with minerals content.

What about the total mineralomass of the crown ? The crown of each oil palm tree is composed by the leaflets, the rachis and the petiole. For the mineralomass of the crown, the sum of all the 3 mineralomass is done. This new balance is interesting to understand the "standing" mineral quantity in individual tree depending of the progeny and the K level treatment.

5. Evolution of the production 2011/2013 on" ISOPALM" trees

The evolution of the ISOPALM trees since 2007 until 2013 shows (Fig. 32 and 33) an increase of the FFB until 2011, then after decrease, especially in 2013.

The FFB production on 2011 for Isopalm trees (ISOPALM trees are 18 x 4 oil palm trees belonging to A,B,C,D and under K0,K2 and K3 treatment) shows an effect of the progenies and not of the K treatment (Table 30). Isopalm trees is a small sample of all the trees of the Block 5. Then Isopalm trees FFB cannot be identical to the FFB of block 5. For 2011, the FFB average for the block is around 178 kg/tree. Then all Isopalm trees are in average above the mean block production.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.99	ns
NivK	2	4	0.13	ns
Progeny	3	17	7.47	0.0021**
Nivk*Prog	6	17	1.44	ns
Progeny	K0	K2	K3	Average
A (LM2T)	209.67	191.14	234.78	214.11±29.8 a
B (LM5T)	188.50	226.04	200.50	207.55±36.9 ab
C(LM5T)	187.05	168.29	180.50	177.33±52.4 b
D(LM5T)	234.78	241.79	232.83	237.83 ±27.6 a

Table 30. FFB in year 2011 for the Isopalm trees, ALCP10. *Proc mixed*, SAS.

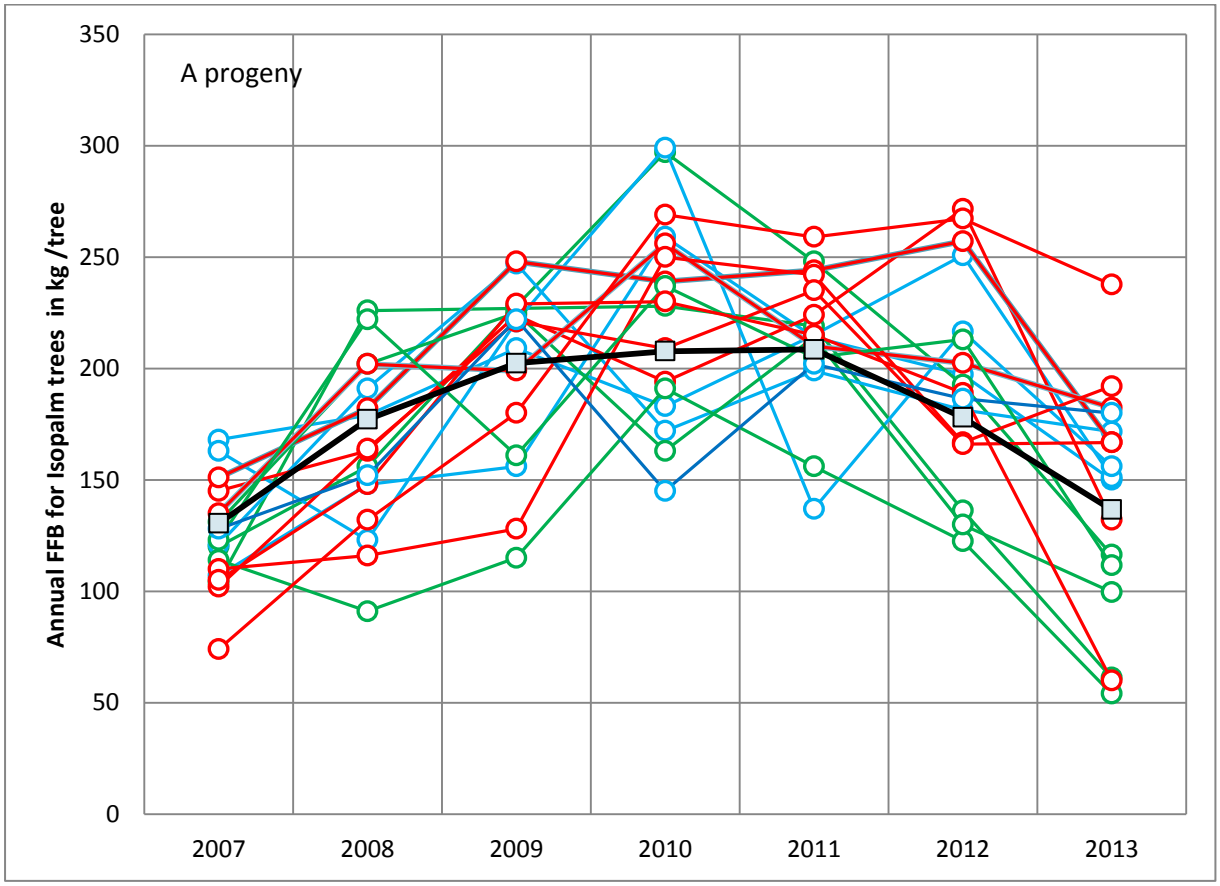


Fig. 32. Evolution of the individual production for Isopalm trees 2007-2013 , A progeny under K0 (green), K2(blue) and K3(red) treatment.

The FFB result for the year 2013 shows for the same block 5, a strong decrease of the production from 178 kgFFB /tree in 2013 to 146 kg FFB/tree. For the Isopalm trees the total average is 156 kg FFB/tree. Then Isopalm trees production are still higher than for the block 5 average. What are the causes of the decrease in Block 5 ?

Effect	**Num DEF**	**DenDF**	**F value**	***Pr*<F**
Repet	2	4	1.03	ns
NivK	2	4	11.50	+
Progeny	3	17	7.44	0.002**
Nivk*Prog	6	17	1.45	ns
Progeny	K0	K2	K3	Average
A (LM2T)	95.8±31.4	161.7±13.34	162.5±55.3	140.06±49.5 b
B (LM5T)	102.8±35.9	145.3±52.01	147.6±28.3	133.26±44.3 b
C(LM5T)	115.6±58.2	162.4±31.3	168.4±89.6	148.8±65.1 b
D(LM5T)	160.8±51.2	176.4±50.1	272.6±54.3	203.26±70.4 a

Table 31. FFB in year 2013 for the Isopalm trees, ALCP10, *Proc mixed*, SAS.

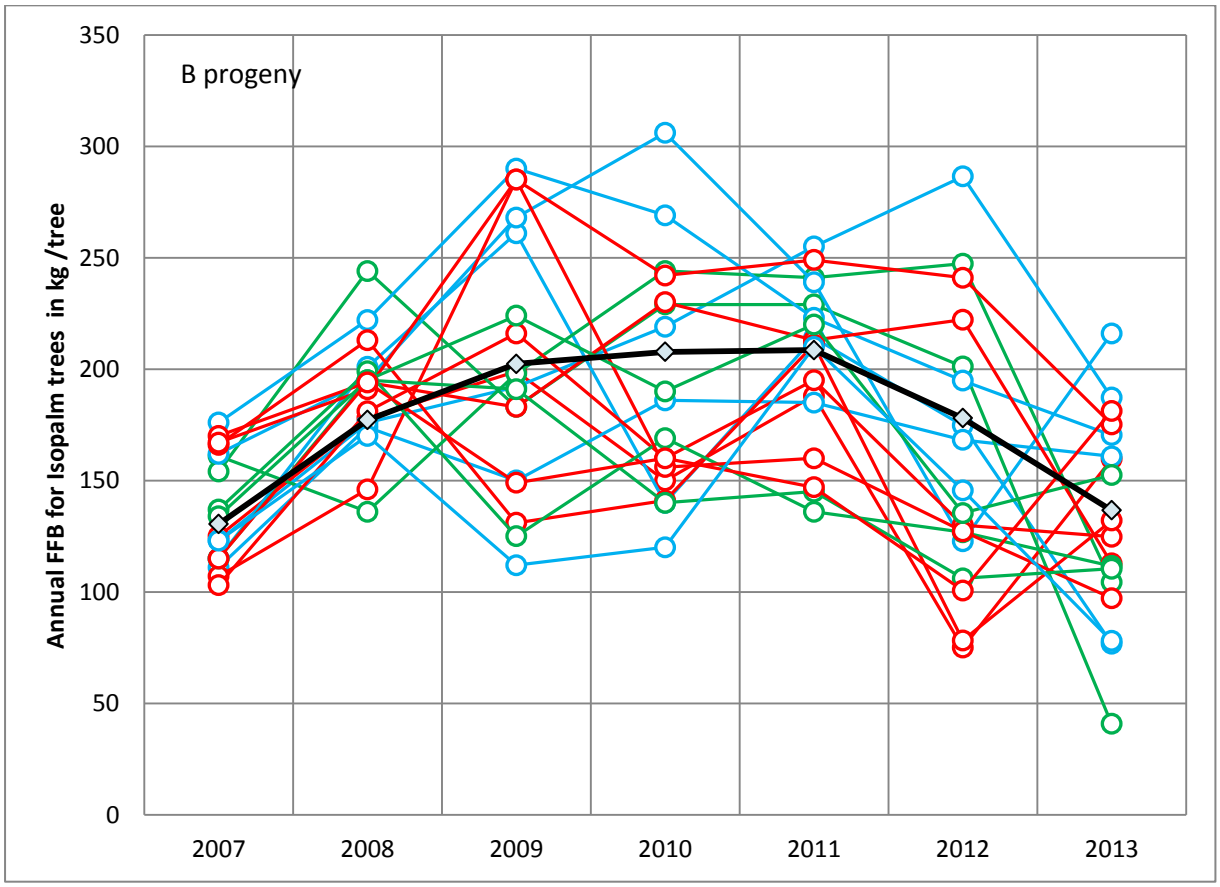


Fig. 33. Evolution of the individual production for Isopalm trees 2007-2013 , B progeny under K0 (green), K2(blue) and K3(red) treatment.

The decrease of the production in 2013 can be explained by abiotic factors changes. The Sinabung eruption in September 2013 could have change the radiation and the mean temperature due to dust in the atmosphere (Fig. 34). During this year, the rainfall distribution observed in Medan (not in Aek Loba) shows irregularity with strong dry months. The combination of these two factors may influence strongly the FFB. The beginning of the year 2013 is very hot and this can impact the stomatal conductance and decrease the amount of carbon entering in the oil palm leaves. The end of the year shows a decrease of the average monthly temperature (Fig. 34) which can affect the production metabolism.
The other cause could be a biotic factor: the roots conditions for the Isopalm trees are questionable. Then *ganoderma* infestation is suspected on the Block 5. For Isopalm trees, an effect of the sampling on FFB can be also suspected but it cannot be seen on directly on data.
When comparing the FFB of the four progenies, it is obvious that D is showed whatever the conditions, the higher production.

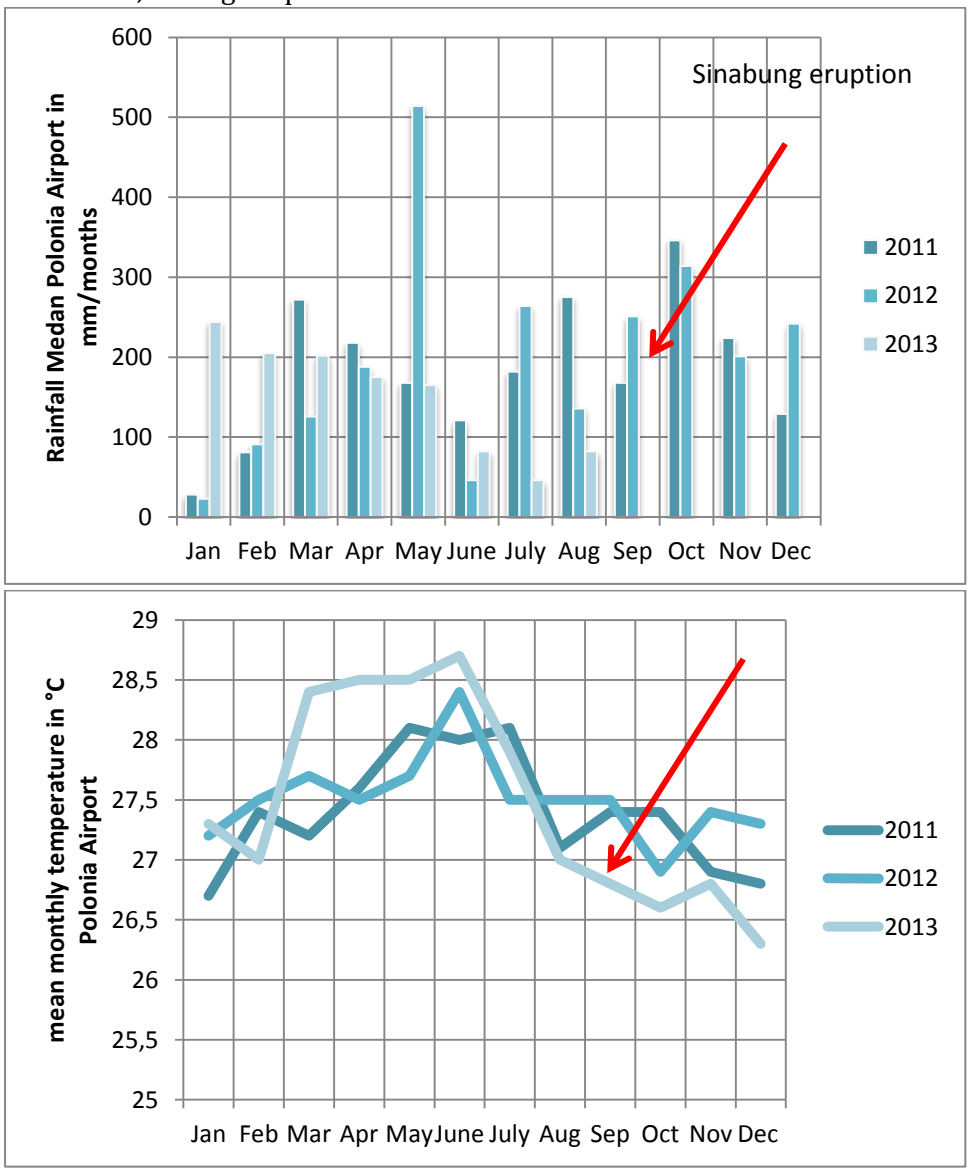


Fig. 34. Rainfall distribution (monthly records, upper graph) and mean monthly temperature (below graph) at Polonia Airport for 2011,2012 and 2013.

Concerning the relation between FFB and functional traits as LAI, LA and K status (Table 32) it is possible to see that the progeny D shows the higher K stock at individual tree level, and the bigger base trunk diameter. LAI is high as well as leaf area (LA).

progeny	FFB11 kg tree-1	FFB13 Kg tree-1	Trunk Base cm	Trunk top cm	Ktot kg K tree-1	LAI	LA m²	Total biom kg DMtree-1
A	214	140	82	53	5.49	2.81	7.03	285
B	207	133	75	49	4.97	3.94	9.85	319
C	177	148	82	57	4.55	4.29	10.72	309
D	237	203	88	55	5.77	4.12	10.31	303

Table 32. FFB, functional traits for 4 progenies in ALCP10 and K status for Isopalm trees.

There is no relation between the total biomass at individual scale and the FFB.

6. Metabolic analyses : main results

6.1. Soluble sugars on leaf : leaflets and petioles

HPLC results on leaf tissues (leaflets, rachis, petiole) shows very interesting traits for A and B progenies.

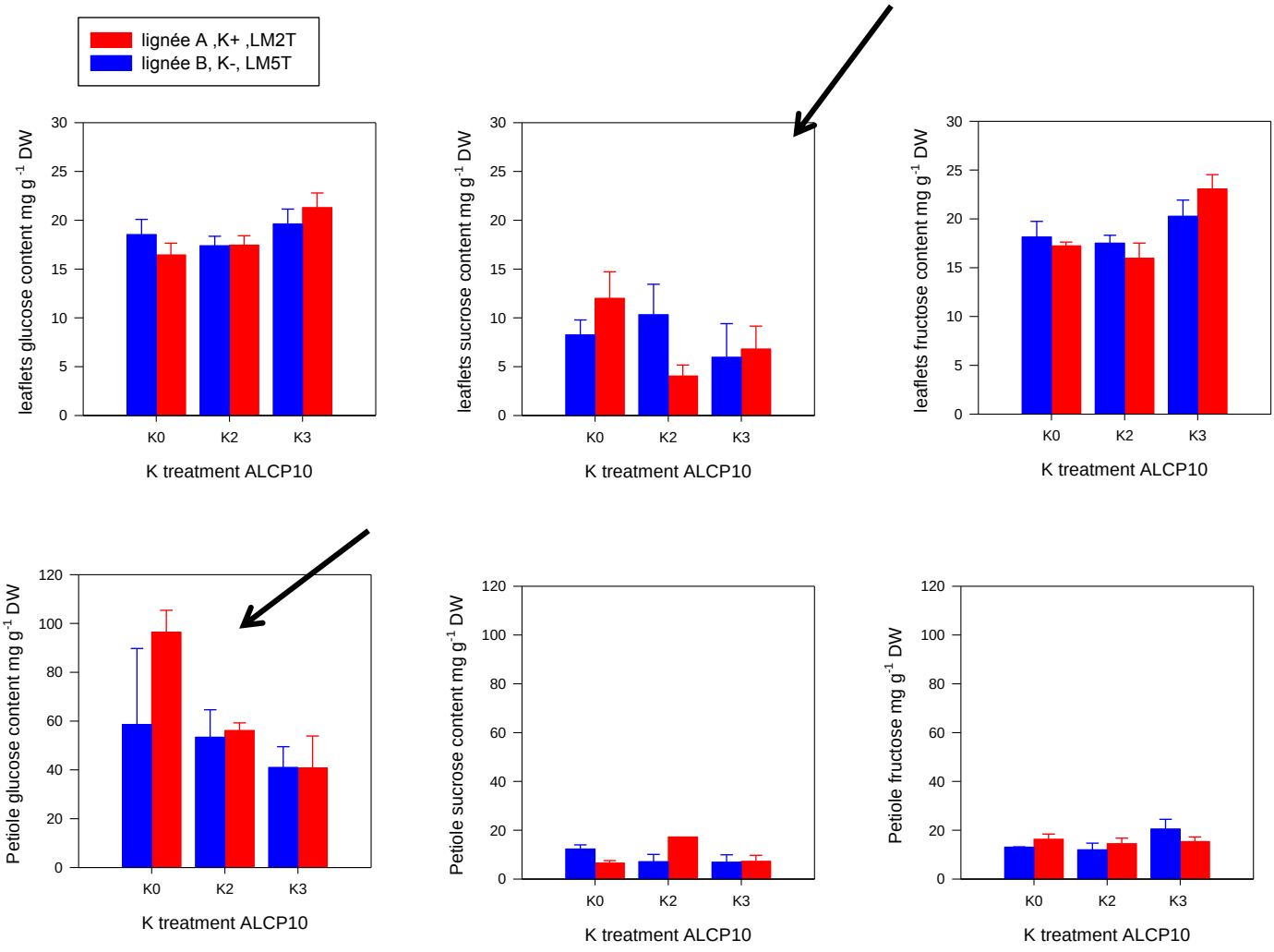


Fig. 35. Soluble sugars contents in leaflets (top) and petioles (down) for A and B progenies in ALCP10.

The very unusual point is the quantity of sucrose in leaflets (between 5 to 15 mg g^{-1} DW) especially in K0. This may be can be a sign of physiological disfunctionning because normally there is a very fast translocation of the photosynthetic products (most sucrose) to rachis and petioles (Fig. 35).

This accumulation is due to also the lack of K in leaflets and then a low transportation of sucrose is observed (K+ is transporting sucrose with H+). It is difficult to see any trends between A and B for the glucose and fructose content in leaflets. For petioles soluble sugars content, important amount of glucose is observed. The petioles are one of the carbon reserve pool as well as the trunk for oil palm. Glucose in petiole maybe not used for bunch filling (Lamade et al., 2014). It is A progeny (K+) which shows the highest glucose content compared to B progeny. There is an accumulation of glucose and K in rachis and petiole, when K is not entering leaflets tissues for sucrose translocation.

There is an increase of glucose and fructose content in leaflets under K3 application for both progenies A and B. In K3, A progeny shows higher glucose and fructose content than B. Because K is susceptible to be more related to soluble sugars than starch content, then this result is expected.

6.2. Soluble sugars content in trunks

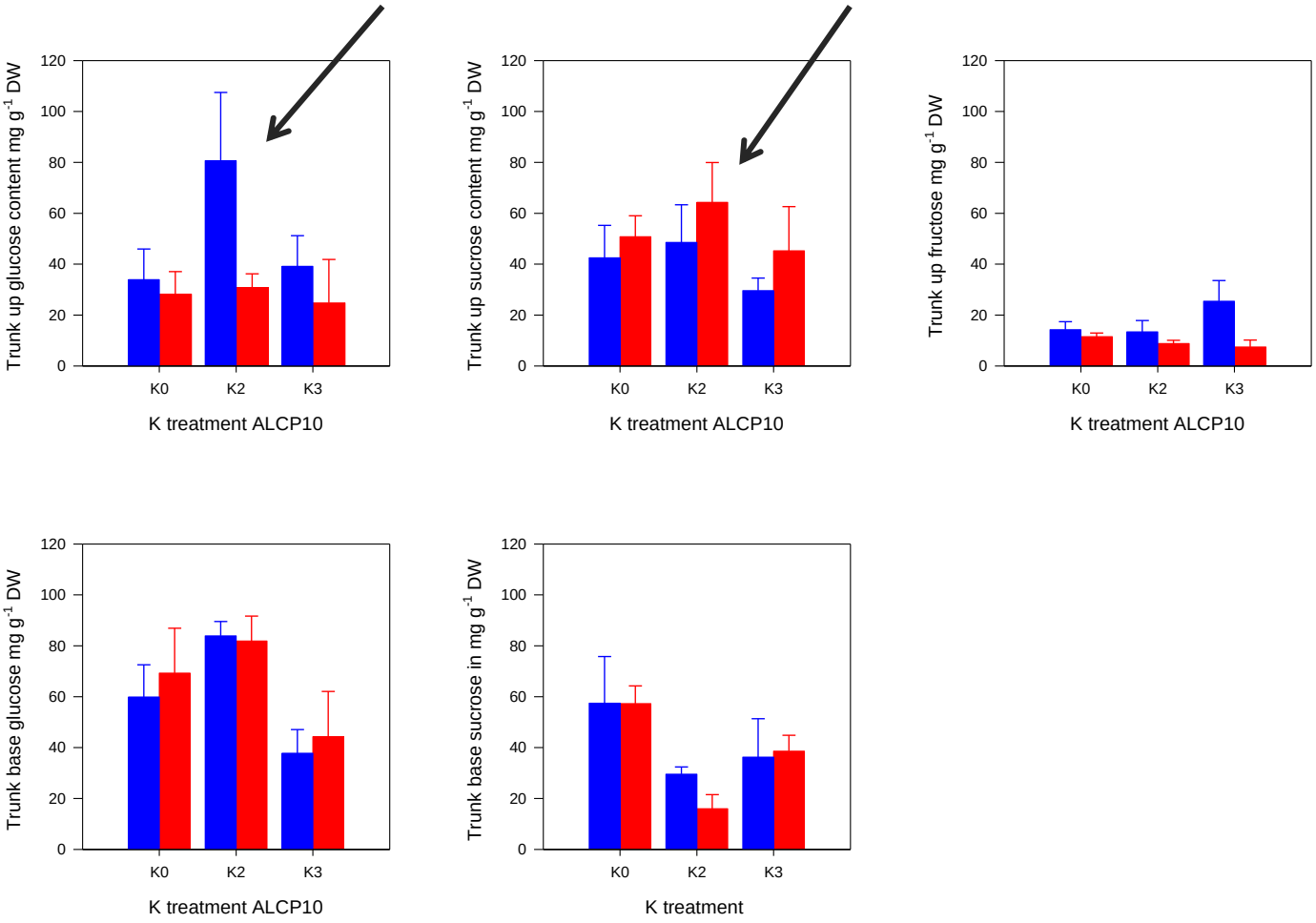


Fig. 36. Soluble sugars content (glucose, sucrose, fructose) in trunk base, middle and top part for A and B progenies in ALCP10.

The feature for sugars content in trunks for A and B is very interesting (Fig. 36). First of all we notice an important accumulation of glucose in the top of the trunk for B progeny compared to A especially for K2 treatment. It is unusual. Normally it is starch which is accumulated at the top of the trunk (Lamade

et al, 2009, Legros et al. 2009). There is another unusual feature : the important sucrose accumulation at the top of the trunk. Normally we can found sucrose in meristem only. This accumulation may be a sign of disfunctionning. A seems more affected than B under K0,K2 and K3. Even in trunk base there is an important quantity of sucrose ...for both progenies. We know that already in ALCP10, *ganoderma* is well spread and trees shows many damage signs. Then *ganoderma* infestation may be at the origin of the accumulation of sucrose in trunk base and top. This result is well known in MPOB (personal communication).

The base of the trunks is normally a zone of glucose accumulation : we see than A progeny shows higher glucose than B on this zone. When K fertilizer is applied (K3) , the glucose accumulation is less. This means that there is a mobilization of trunk glucose under K3. It can be for osmotic equilibrium or for bunch filling.

Maybe also A due to its high proportion of glucose in the base of the trunk will be sensitive to ganoderma than B. *Ganoderma* at the base of the trunk is located and developing from the glucose reserve pool. Then a way to control ganoderma development may be to reduce the glucose pool in the trunk base.

6.3. Starch content in all organs

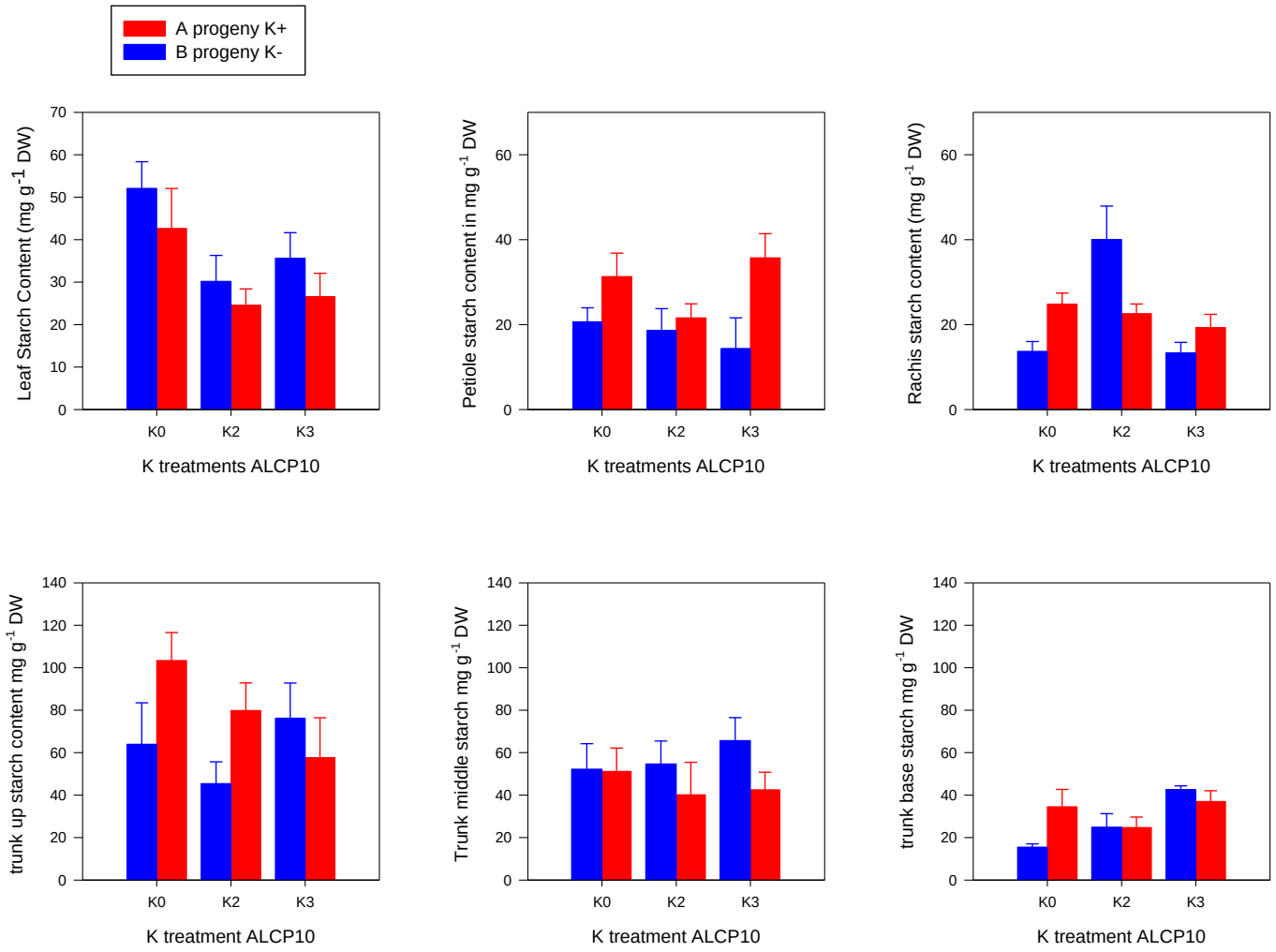


Fig. 37. Starch content in all organs for 2 progenies in ALCP10.

There is a significant difference between starch (Fig. 22) in leaflets (for A compared to B . As expected A (K+) shows lower starch content (starch-) compared to B (K-), higher starch content (starch+). This confirm the last result found on equivalent PSBB material (Lobato et al. 2012).

For leaflets (autotrophic tissues), then material K+ is glucose + and starch- compared to K- material which will be glucose – and starch+.

For heterotrophic tissues (reserve organs as trunk and petiole) it is the contrary :

A which is K+ will be starch + (glucose -) and B which is K- will be starch – (and glucose +).

The relation with FFB production is in the sense of the use of the starch located in the top of the trunk. For Legros et al., (2009), it was observed a consumption of starch during bunch development. The same is observed on temperate trees during spring and budbust (Damesin and Lelarge, 2003).

Then more observations are needed to relate starch level in the top trunk and FFB.

7. Relation between K rachis/Kleaflets and glucose/starch in leaflets : towards a new LD ?

Many investigations are bearing on the relation between the difference of K content in rachis and leaflets and some other metabolic indicator as glucose, sucrose or starch leaflets contents.

The question of the accumulation of K in some rachis (see A progeny) and the lack of K in leaflets is questionable.

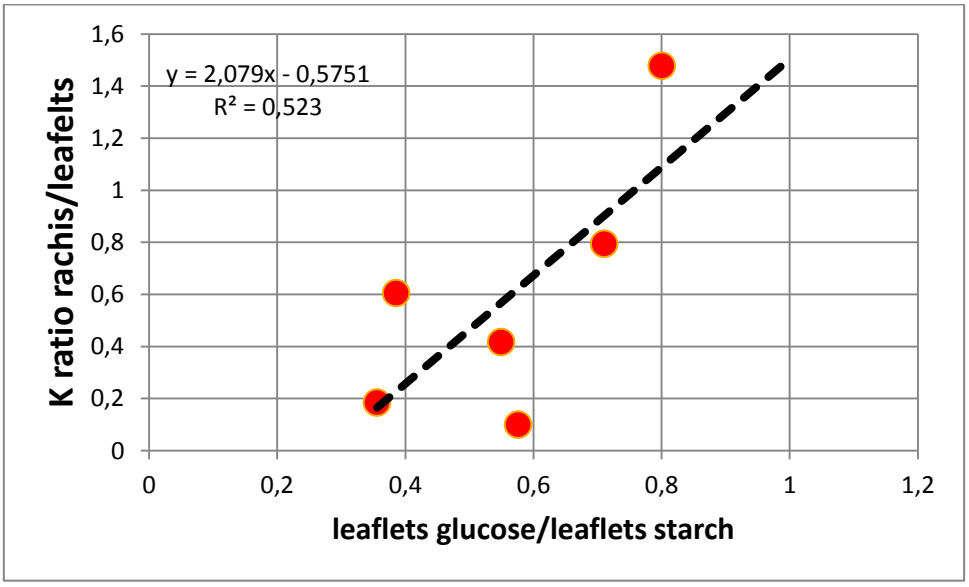


Fig. 38. Relation between the ratio (Krachis-Kleaflets/Krachis+Kleaflets) and the leaflets ratio : glucose/starch .

A relation (Fig. 38) is found between the expression of contrast between K rachis and K leaflets and the metabolic ratio between glucose and starch leaflets content. It seems that progeny effect is one of the main cause these difference towards K treatment.

8. Roots problem in ALCP10.

During roots excavation for roots biomass evaluation , it was appeared very quickly that the roots are very damaged (Photo 33-35).

Photo 33. Aspect of the primary roots for A progeny near the trunk .

Photo 34. Aspect of the primary roots in ALCP10, A progeny.

The external tissues present empty spaces and an irregular epiderm with damage spots. The central cylinder present also empty spaces. The causes maybe temporary flooding situations in the trial but

also *ganoderma.*

Photo 35. Aspect of the primary roots in ALCP10, A progeny.

The consequences of the roots conditions are huge for N,P,K allocation. The low level of K content in leaflets in this trial is maybe the consequence of the poor roots conditions.

9. First results of labelling with ^{15}N.

What is interesting is to found N in the rachis of the new leaves (Rachis n° 4). The signal is maximal there after the roots signal (see primary roots, root 1 in fig. 23). Then it can be suspected that any addition of N can benefit new leaves growth (classical result). Rachis seems to be a key organs for mineral reserves and adjustment to leaflets.

15N labelling

CONCLUSIONS

All the results are not yet ready. For example, the ^{15}N fluxes will be examined next year. Further metabolic analyses will be performed on C and D also to complete the present study.

Why A, K+ and B, K- ?

The first conclusion is about the relation between the leaf mineral contents and the functional traits. If we try to understand the physiological meaning of the high/low leaf mineral content, it can pointed out that in literature, this fact is related to the adaptative strategies of plants to survive in their environment. The leaf economic spectrum (Wright et al. 2004) will focuse on ecological meaning for a plant to present high or low foliar mineral content.

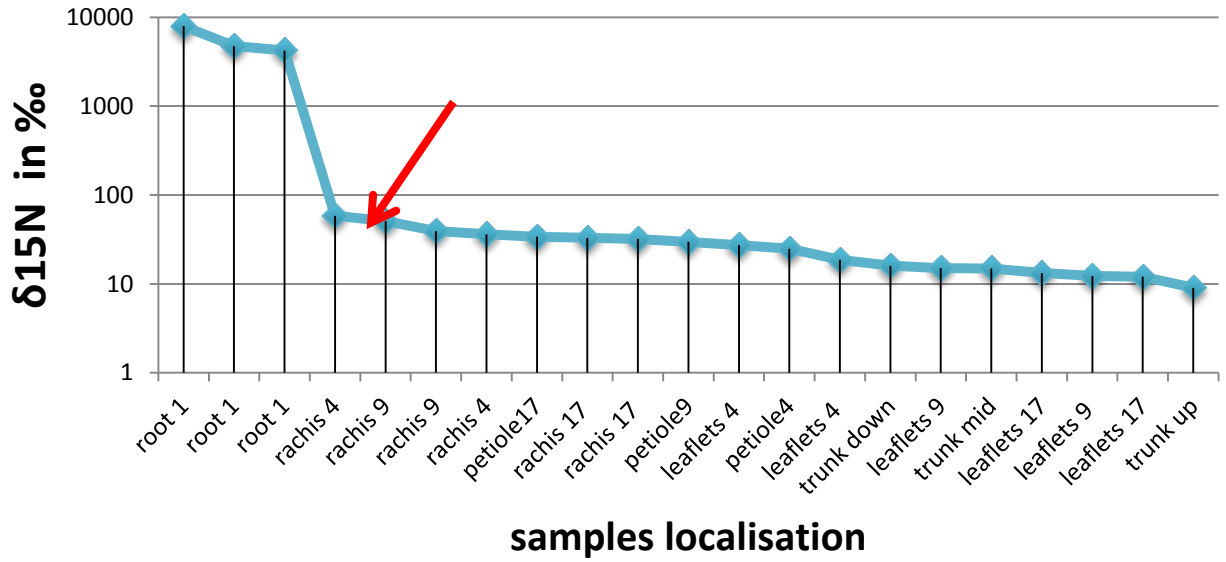


Fig. 39. Results of ^{15}N signals for Isopalm trees in ALCP10.

Normally it is generally oberved that plants presenting N+P+K+ content in leaf will also present typical morphological caracteristic as

- small leaf area,
- short life span,
- small height.
- high photosynthesis

then the metabolic turn-over between carbon/mineral investment is more fast , contrary to N-P-K- plants will present :

- big leaf area
- long life span
- high heigh
- low photosynthesis

and a slow carbon/mineral investment turn over. For oil palm is oberved that the progenies A,B,C and D seems to follow these ecological rules. Then A (LM2T) is a “quick return invest” as far as minerals is concerned compared to B,C and D (LM5T) which are “slow return invest”. Then the relation with the production and the minerals requirements as to be established for

this two ecological categories for oil palm. Normally it is expected that “quick –retrun invest “ will have high mineral requirement and will be adapt to constraint environments.”slow-return” will have low mineral requirement and will have potential development in good environment.

Relation K rachis /K leaflets

The results show a great response of rachis tissues to K application. The same observation is done with the total K amount in rachis biomass. Then K rachis mineralomass may be used for K indicator in response to K gradient.

K in rachis is mainly located in the white parenchym and is very variable along the rachis then the sampling must take into account the K repartition. K is moving with sucrose (or glucose) and H+ mainly.

The time of day when collecting rachis is important too. As well as to select only white tissue and removing the green epiderm.

Photosynthesis is very high the morning from 7 to 10, then a depletion is observed from 11 to 14h. The afternoon the photosynthesis will not be maximal any more and will be very variable. Because K is moving with the photosynthetic product it is may be better to fix the timing during the morning only.

When a big difference is observed between K rachis and K leaflets with a very low K content in the leaflets, a dysfuntionning can be suspected. In case of ALCP10, the primary roots are in a very poor conditions. This may be due to the important *ganoderma* development around the plot. But also the fluctuation of water table, which is very near the soil surface may provoks anaerobic reactions and roots hypoxia.

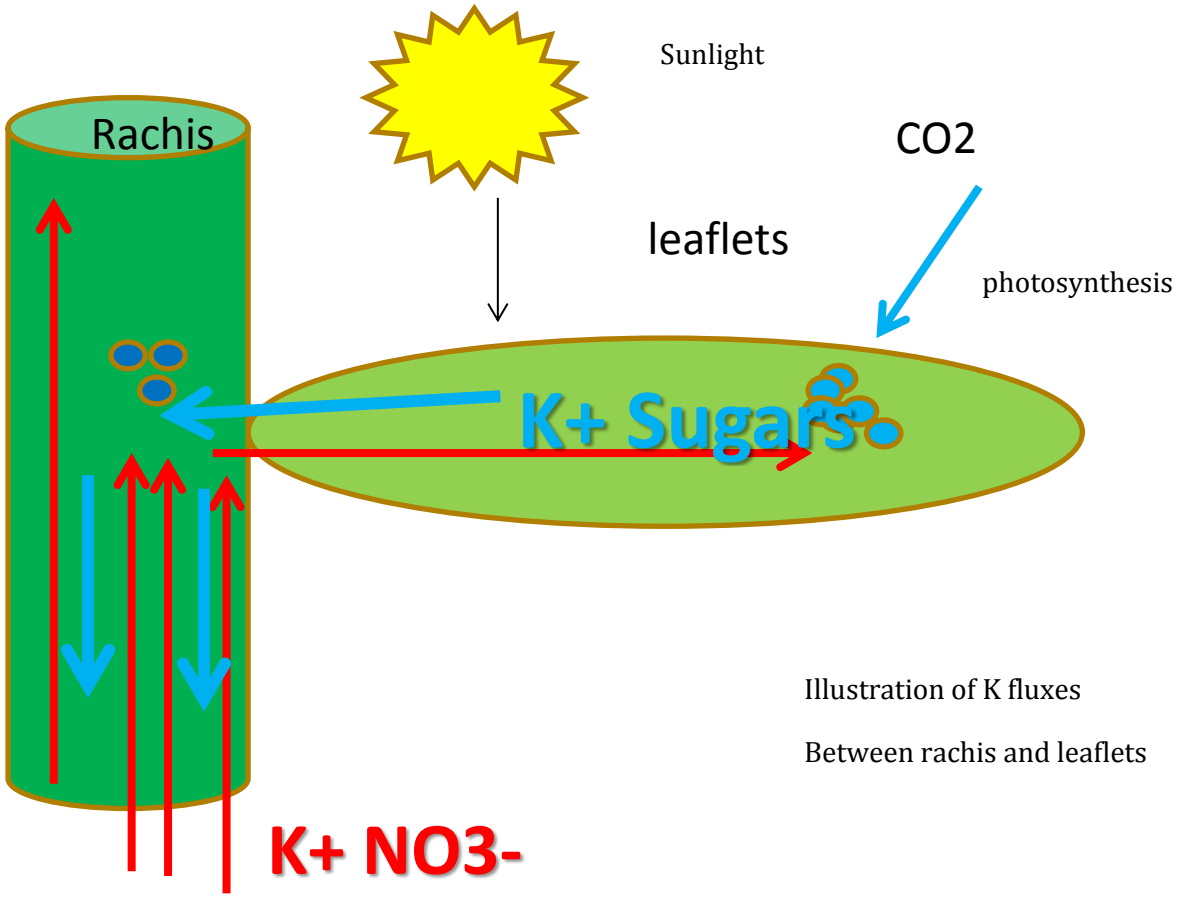


Illustration of K fluxes

Between rachis and leaflets

The accumulation of K in rachis under K treatment may be due also to the fact that K+ in the leaflets is not used for sugars transportation (see diagram above). The reasons can be multiple. One reason can be that the sugars, in the leaflets are not produced in enough quantity and then there is too much K+ compared to soluble sugars amount. We see that this K accumulation in rachis is higher for some progenies. A relation between the ratio glucose/starch in leaflets and the rachis-leaflets K differential has been found**.**

K is then highly under the dependence of the "sink-source carbon system" at tree scale. To adjust the LD, a supplement knowledge of the carbon leaflets metabolism is a key to improve this method.

Effect (LA)	Num DEF	DenDF	F value	Pr<F
Repet	2	4	6.43	0.0563+
NivK	2	4	2.19	0.2284 n.s.
Progeny	3	13	53.03	<0.001 ***
Nivk*Prog	6	13	1.3	0.3234n.s.
progeny	K0	K2	K3	average
A (LM2T)	6.80±045	7.43±0.44	6.99±0.30	7.033±0.52 a
B (LM5T)	10.18±040	9.73±0.35	9.90±0.32	9.85±0.88 bc
C(LM5T)	10.37±0.37	11.12±0.44	10.82±0.34	10.72±1.14 d
D(LM5T)	9.23±0.42	10.78±0.39	10.63±0.37	10.31±1.21 cd

Tab.1 . LA response to K0,K2,K3 treatment in ALCP10. Test on means : Tukey test at 5% (SAS , version 2009).

Effect slw	Num DEF	DenDF	F value	Pr<F
Repet	2	4	0.29	0.76 ns
NivK	2	4	0.78	0.51 n.s.
Progeny	3	12	3.69	0.04 **
Nivk*Prog	6	12	0.56	0.75 ns
progeny	K0	K2	K3	average
A (LM2T)	294.21±13.19	313.67±12.19	307.61±9.67	305.70±14.93 ad
B (LM5T)	305.73±11.38	317.46±10.69	315.65±10.01	312.385±18.07 a
C(LM5T)	290.18±11.75	281.74±13.27	278.74±13.12	285.93±2.74 bc
D(LM5T)	287.51±12.64	314.82±12.25	297.55±10.94	302.72±29.16 cd

Tab. 2. SLW responses to K0,K2, K3 treatments in ALCP10.

Effect (rachis L)	Num DEF	DenDF	F value	Pr<F
Repet	2	4	4.23	0.103 ns
NivK	2	4	0.36	0.716 n.s.
Progeny	3	13	18.79	<0.0001 ***
Nivk*Prog	6	13	2.48	0.0802 ns
progeny	K0	K2	K3	average
A (LM2T)	541.75±33.39	534.50±14.47	530.30±16.68	533.77±20.08 a
B (LM5T)	610.40±34.03	576.85±18.14	608.12±32.74	597.75±31.48 d
C(LM5T)	593.00±31.92	597.40±30.97	593.57±24.04	594.36±27.36 cd
D(LM5T)	532.40±52.22	587.00±25.32	585.83±23.35	570.52±41.18 b

Tab. 3. Rachis length responses to K0,K2,K3 treatments in ALCP10.

Effect	Num DEF	DenDF	F value	Pr<F
Repet	2	4	2.37	0.209 ns
NivK	2	4	2.74	0.178n.s.
Progeny	3	13	10.73	<0.0008 ***
Nivk*Prog	6	13	0.93	0.504 ns
Progeny	K0	K2	K3	average
A (LM2T)	82.38±3.41	75.65±3.37	85.28±2.14	82.50±6.12 a
B (LM5T)	77.05±3.01	75.07±2.57	73.29±2.38	75.10±5.14 b
C(LM5T)	81.17±2.62	78.75±3.14	84.10±2.54	81.74±8.44 a
D(LM5T)	87.78±3.08	85.39±2.84	90.55±2.76	87.77±7.60 a

Tab. 4. Diameter of the base of the trunk along K0, K2 and K3 in ALCP10.

Effect	Num DEF	DenDF	F value	Pr<F
Repet	2	4	0.86	0.488 ns
NivK	2	4	2.36	0.2102 n.s.
Progeny	3	13	1.83	0.1918 ns
Nivk*Prog	6	13	2.21	0.1086 ns
Progeny	K0	K2	K3	average
A (LM2T)	59.24±2.23	57.96±2.020	60.31±1.40	59.55±3.71
B (LM5T)	56.99±1.97	57.66±1.68	55.64±1.55	56.00±2.40
C(LM5T)	57.81±1.71	54.26±2.05	64.33±1.66	59.28±7.30
D(LM5T)	56.75±2.01	58.28±1.86	56.93±1.80	57.35±3.83

Tab. 5. Diameter in the middle of the trunk along K0,K2 and K3 treatments in ALCP10.

Effect	Num DEF	DenDF	F value	Pr<F
	2	4	3.74	0.121 ns
	2	4	0.32	0.745 n.s.
	3	13	10.50	0.0009 ns
	6	13	0.79	0.5927 ns
progeny	K0	K2	K3	average
A (LM2T)	54.25±3.50	55.50±3.87	53.10±4.45	53.10±4.45 b
B (LM5T)	50.60±2.96	50.14±2.26	48.87±4.18	48.87±4.18 a
C(LM5T)	57.35±1.71	55.80±4.76	55.80±4.76	57.54±5.31 b
D(LM5T)	52.80±4.08	52.75±2.89	55.35±2.89	55.35±4.70 b

Tab. 6. Diameter at the top of the trunk along K0,K2 and K3 in ALCP10.

Effect	DEF	F value	*Pr*<F	
NivK	2	1.22	ns	
Progeny	3	2.22	ns	
Nivk*Prog	6	5.19	***	
Progeny	K0	K2	K3	average
A (LM2T)	137.70±14.3	143.9±18.6	155.64±23	146.40±19.8
B (LM5T)	146.1±12.2	168.7±22.6	121.9±30.2	148.812±29.4
C(LM5T)	127.56±18.3	120.30±22.5	150.7±10.1	132.90±21.3
D(LM5T)	141.15±20	134.05±13.4	162.8±29.3	146.01±24.1

Table 8. Trunk biomass depending on progenies (A,B,C,D) and K0,K2,K3.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.63	0.3 ns
NivK	2	4	1.14	0.4 n.s.
Progeny	3	17	14.29	<0.0002* **
Nivk*Prog	6	17	1.53	1.53 ns
Progeny	K0	K2	K3	average
A (LM2T)	71.86±10.6	72.33±6.22	75.77±8	73.51±8.3 a
B (LM5T)	100.2±15.6	96.9±14.08	100.9±14.7	99.11±14.0 b
C(LM5T)	97.7±19.8	109.9±19.62	91.37±20.5	99.72±20.4 b
D(LM5T)	80.7±8.98	93.37±13.15	99.13±6.42	91.09±12.2 b

Table 9. leaf biomass depending on progenies (A,B,C,D) and K0,K2, K3. Proc mixed SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.84	0.49 ns
NivK	2	4	0.58	0.59 n.s.
Progeny	3	17	9.96	<0.0005* **
Nivk*Prog	6	17	1.31	0.3 ns
Progeny	K0	K2	K3	Average
A (LM2T)	40.61±3.05	36.78±7.05	40.65±3.01	39.56± 4.56 b
B (LM5T)	51.22±8.65	48.81±8.36	50.35±4.86	50 ±7.26 a
C(LM5T)	48.98±11.59	49.26±10.71	48.45±7.65	48.89±9.51a
D(LM5T)	34.57±8.22	43.86±4.76	45.57±3.41	41.33±7.39 b

Table 10. Rachis biomass depending on progenies and K treatment , ALCP10. Proc mixed , SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.75	0.53 ns
NivK	2	4	0.07	0.93 n.s.
Progeny	3	17	6.23	<0.004 **
Nivk*Prog	6	17	1.19	0.3 ns
progeny	K0	K2	K3	Average
A (LM2T)				25.61± 2.91 bc
B (LM5T)				28.54 ±3.52 a
C(LM5T)				27.03±3.55 bc
D(LM5T)				24.48±2.32 c

Table 11. Petiole biomass depending on progenies and K treatment , ALCP10. Proc mixed, SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.69	0.29 ns
NivK	2	4	0.19	0.83 n.s.
Progeny	3	15	39.95	0.0001***
Nivk*Prog	6	15	0.48	0.81 ns
progeny	K0	K2	K3	Average
A (LM2T)	1.35±0.12	1.34±0.14	1.41±0.12	1.27 a
B (LM5T)	0.92±0.12	1.13±0.12	0.92±0.14	0.99 b
***C(LM5T)**	0.39±0.16	0.31±0.14	0.55±0.16	0.39 c
***D(LM5T)**	0.31±0.13	0.38±0.13	0.31±0.12	0.33 c

Table 14. Total N in trunk . For C and D , a problem was pointed out for Sumbio analyses , then results are not very accurate for N trunk. (**)

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.58	0.60 ns
NivK	2	4	0.48	0.64 ns
Progeny	3	15	0.65	0.59ns
Nivk*Prog	6	15	0.59	0.73 ns
progeny	K0	K2	K3	average
A (LM2T)	4.35±0.52	3.89±0.57	4.04±0.49	4.10 ns
B (LM5T)	3.58±0.52	3.76±0.52	3.73±0.52	3.67 ns
C(LM5T)	3.006±0.63	3.52±0.59	3.52 0.59	3.67 ns
D(LM5T)	3.717±0.53	4.07±0.53	4.07±0.53	4.00 ns

Table 15. Total K in trunk for A,B,C and D progenies . *Proc mixed,* SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.94	0.25 ns
NivK	2	4	0.62	0.58 ns
Progeny	3	15	6.23	0.0059**
Nivk*Prog	6	15	1.31	0.313 ns
Progeny	K0	K2	K3	average
A (LM2T)	0.179±0.023	0.169±0.02	0.181±0.021	0.177 b
B (LM5T)	0.149±0.023	0.176±0.02	0.148±0.025	0.157 c
C(LM5T)	0.233±0.029	0.197±0.02	0.298±0.029	0.237 a
D(LM5T)	0.194±0.023	0.220±0.02	0.2038±0.023	0.205 a

Table 16. P total in trunk for A,B,C and D. Prox mixed SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.32	0.74 ns
NivK	2	4	0.15	0.86 ns
Progeny	3	15	1.31	0.30 ns
Nivk*Prog	6	15	0.78	0.59 ns
Progeny	K0	K2	K3	average
A (LM2T)	0.408±0.05	0.395±0.061	0.407±0.05	0.404
B (LM5T)	0.341±0.056	0.396±0.056	0.273±0.06	0.339
C(LM5T)	0.288±0.069	0.317±0.065	0.357±0.07	0.328
D(LM5T)	0.447±0.058	0.347±0.058	0.341±0.034	0.375

Table 17. Ca total in trunk for A,B,C,D progenies in ALCP10. *Proc mixed,* SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.77	0.51 ns
NivK	2	4	0.33	0.73 ns
Progeny	3	17	37.18	0.0001 ***
Nivk*Prog	6	17	0.75	0.61 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.103±0.012	0.119±0.013	0.0958±0.01	0.105 b
B (LM5T)	0.147±0.013	0.12±0.012	0.124±0.01	0.129 a
C(LM5T)	0.044±0.012	0.0494±0.004	0.0398±0.01	0.044 c pb
D(LM5T)	0.030±0.01	0.041±0.012	0.0473±0.01	0.038 c pb

Table 29. Effect of K level treatment on N petiole mineralomass for A,B,C,D in ALCP10.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.97	0.25 ns
NivK	2	4	0.08	0.92 ns
Progeny	3	17	3.87	0.028+
Nivk*Prog	6	17	0.76	0.61 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.011±0.002	0.013±0.002	0.0103±0.01	0.0117 b
B (LM5T)	0.018±0.002	0.013±0.002	0.02±0.01	0.0174 a
C(LM5T)	0.010±0.002	0.0114±0.002	0.0106±0.01	0.0110 b
D(LM5T)	0.0122±0.002	0.0112±0.002	0.012±0.01	0.0119 a b

Table 30. Effect of K level treatment on P petiole mineralomass for A,B,C,D in ALCP10.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.56	0.316 ns
NivK	2	4	1.27	0.375 ns
Progeny	3	17	0.83	0.495 ns
Nivk*Prog	6	17	1.31	0.306 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.3313±0.07	0.406±0.07	0.437±0.06	0.393
B (LM5T)	0.414±0.07	0.292±0.07	0.433±0.07	0.375
C(LM5T)	0.415±0.07	0.494±0.07	0.467±0.07	0.459
D(LM5T)	0.323±0.07	0.581±0.07	0.421±0.07	0.442

Table 31. Effect of K level treatment on K petiole mineralomass for A,B,C,D in ALCP10.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.20	0.829 ns
NivK	2	4	0.29	0.765 ns
Progeny	3	17	2.19	0.126 ns
Nivk*Prog	6	17	0.31	0.924 ns
progeny	K0	K2	K3	Average
A (LM2T)	0.0253±0.005	0.0205±0.005	0.0232±0.004	0.0233
B (LM5T)	0.0321±0.005	0.0287±0.005	0.0387±0.005	0.0329
C(LM5T)	0.0280±0.005	0.0298±0.005	0.0298±0.005	0.0287
D(LM5T)	0.025±0.005	0.0243±0.005	0.0243±0.005	0.0255

Table 32. Effect of K level treatment on Mg petiole mineralomass for A,B,C,D in ALCP10.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.16	0.4004 ns
NivK	2	4	1.47	0.3314 ns
Progeny	3	17	6.60	0.0037 ns
Nivk*Prog	6	17	0.45	0.834 ns
progeny	K0	K2	K3	Average
A (LM2T)	0.082±0.016	0.0957±0.017	0.0084±0.015	0.089 b
B (LM5T)	0.1047±0.0162	0.1317±0.016	0.1309±0.017	0.121 ab
C(LM5T)	0.1280± .001	0.158±0.0163	0.161±0.018	0.149 a
D(LM5T)	0.125±0.01	0.116±0.0163	0.143±0.017	0.127 ab

Table 33. Effect of K level treatment on Ca petiole mineralomass for A,B,C,D in ALCP10.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.53	0.627 ns
NivK	2	4	1.20	0.390 ns
Progeny	3	17	13.82	<0.001 ***
Nivk*Prog	6	17	0.76	0.608 ns
progeny	K0	K2	K3	Average
A (LM2T)	2.0176±0.157	2.003±0.17	2.124±0.146	2.055 a
B (LM5T)	2.535±0.173	2.495±0.157	2.645±0.17	2.551 a
C(LM5T)	1.664±0.158	2.129±0.158	1.792±0.17	1.862 b (pb)
D(LM5T)	1.596±0.158	1.755±0.160	1.9133±0.17	1.746 b (pb)

Table 34. Effect of K level treatment on N crown mineralomass for A,B,C,D in ALCP10. *Proc mixed*, SAS.

Effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	3.25	0.145 ns
NivK	2	4	1.90	0.263 ns
Progeny	3	17	15.22	<0.001 ***
Nivk*Prog	6	17	1.09	0.406 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.136±0.011	0.144±0.012	0.145±0.010	0.142 b
B (LM5T)	0.195±0.011	0.188±0.011	0.215±0.012	0.198 a
C(LM5T)	0.194±0.011	0.209±0.011	0.190±0.013	0.197 a
D(LM5T)	0.161±0.011	0.183±0.011	0.204±0.012	0.181 a

Table 35. Effect of K level treatment on P crown mineralomass for A,B,C,D in ALCP10. *Proc mixed*, SAS.

Effect	Num DEF	DenDF	*F* value	*Pr*<F
Repet	2	4	1.81	0.275 ns
NivK	2	4	5.26	0.075 TENDANCY
Progeny	3	17	12.33	<0.0002 ***
Nivk*Prog	6	17	2.15	0.1005 ns
Progeny	K0	K2	K3	Average
A (LM2T)	1.173±0.159	1.281±0.175	1.663±0.147	1.393 b
B (LM5T)	1.350±0.175	0.839±0.139	1.447±0.175	1.1304 c
C(LM5T)	1.740±0.175	2.0341±0.160	1.982±0.164	1.926 a
D(LM5T)	1.389±0.160	1.892±0.160	2.029±0.159	1.770 a

Table 36. Effect of K level treatment on K crown mineralomass for A,B,C,D in ALCP10. *Proc mixed*, SAS.

effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.4	0.345 ns
NivK	2	4	1.46	0.333 ns
Progeny	3	17	10.53	0.0004 ***
Nivk*Prog	6	17	3.42	0.0211 ns
progeny	K0	K2	K3	Average
A (LM2T)	0.1335±0.02	0.131±0.022	0.143±0.022	0.136 b
B (LM5T)	0.267±0.02	0.162±0.018	0.237±0.022	0.214 a
C(LM5T)	0.246±0.022	0.227±0.02	0.170±0.021	0.213 a
D(LM5T)	0.172±0.020	0.196±0.02	0.217±0.021	0.195 a

Table 37. Effect of K level treatment on Mg crown mineralomass for A,B,C,D in ALCP10. *Proc mixed*, SAS.

effect	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.73	0.537 ns
NivK	2	4	0.49	0.642 ns
Progeny	3	17	5.35	0.008 ***
Nivk*Prog	6	17	1.14	0.379 ns
progeny	K0	K2	K3	Average
A (LM2T)	0.7556±0.134	0.768±0.145	0.900±0.128	0.814 b
B (LM5T)	1.182±0.134	1.081±0.124	1.423±0.145	1.172 a
C(LM5T)	1.078±0.145	1.262±0.137	0.917±0.148	1.078 ab
D(LM5T)	0.885±0.137	0.969±0.137	1.076±0.134	0.979 ab

Table 38. Effect of K level treatment on Ca crown mineralomass for A,B,C,D in ALCP10. *Proc mixed*, SAS.

ANNEXE 2

SCHEDULE MISSION 19 DECEMBER-8 JANUARY 2014

Schedule	mission	E Lamade	19 dec	8 january	2014
Physiology of mineral nutrition			ALCP10		
Days	LOCATION	BIOMASS		soil/root	others
19	PSBB	Aek Loba			PSBB
20	Aek Loba	pheno			
21	Aek Loba	trunk density		Voronoi /roots	C
22	Aek Loba	trunk density		Voronoi /roots	C
23	Aek Loba	trunk density		Voronoi /roots	C
24	Aek Loba	rachis sampling		Voronoi /roots	D
25	Aek Loba				
26	Aek Loba	rachis sampling		Voronoi /roots	D
				dutch auger	C
27	Aek Loba	rachis sampling		Voronoi /roots	
				dutch auger	C
28	Aek Loba	missing trees	samplings	total (leaf/rachis/petiola….)	
				dutch auger	D
29	Aek Loba				
30	Aek Loba	missing trees	samplings	total (leaf/rachis/petiola….)	
31	Aek Loba	roots sampling	sugars	height trees	A
1	Aek Loba				
2	Aek Loba	roots sampling	sugars	height trees	B
3	Aek Loba	diameter tree		height trees	C
4	Aek Loba	diameter tree		petiole lenght	a,b,c,d
5	Aek Loba	diameter tree		petiole lenght	a,b,c,d
6	Aek Loba	isotope trees	soil sampling	pheno	
7	Aek Loba	samples conditionning		pheno	
8	winup		PSBB		meeting
Requirements					
	Liquid nitrogen		PSBB	on arrival	
	ladder		ALSP	on arrival	
	envelops		ALSP	on arrival	
	plastic bags		ALSP	on arrival	
	an others as usual (dutch auger, bore …..)				

ANNEXE 2 LISTE RACHIS, ANALYSIS N PSBB

AMBIL RACHIS

No	Baris	pokok	rank	
1	62	11	17	B
2	62	10	17	B
3	62	12	17	C
4	62	13	17	C
5	63	10	17	D
6	64	11	17	D
7	67	10	17	C
8	67	5	17	C
9	67	7	17	D
10	67	6	17	D
11	67	4	17	C
12	68	10	17	C
13	69	12	17	D
14	69	13	17	D
15	81	23	17	C
16	82	18	17	C
17	83	12	17	D
18	83	23	17	A
19	83	13	17	D
20	83	4	17	C
21	83	18	17	D
22	83	5	17	C
23	83	6	17	D
24	83	19	17	D
25	84	6	17	D
26	99	25	17	C
27	99	24	17	C
28	101	6	17	C
29	101	7	17	C
30	101	5	17	D
31	101	4	17	D
32	102	22	17	D

No	Baris	pokok	rank
1	62	13	17
2	62	12	17
3	63	10	17
4	64	11	17
5	67	10	17
6	67	4	17
7	67	5	17
8	67	6	17
9	67	7	17
10	68	11	17
11	69	12	17
12	69	13	17
13	81	23	17
14	81	19	17
15	82	23	17
16	82	18	17
17	82	10	17
18	82	11	17
19	83	24	17
20	83	19	17
21	83	18	17
22	83	12	17
23	83	13	17
24	83	4	17
25	83	5	17
26	83	6	17
27	84	25	17
28	84	6	17
29	99	25	17
30	99	24	17
31	101	22	17
32	101	4	17
33	101	5	17
34	101	6	17
35	101	7	17

RACHIS

No	Baris	Pokok
1	68	13
2	82	12
3	83	23

37	102	22	17
38			

ANNEXE 3 OTHER FILES

AMBIL RACHIS

					5 cm kanan		5 cm kiri	
No	**Baris**	**pokok**	**rank**	**panjang daun**	**Berat basah gr 1**	**Berat kering gr 1**	**Berat basah gr 2**	**Berat kering gr 2**
1	62	13	17	613	6		6,1	
2	62	12	17	610	5,4		5,8	
3	62	11	17	640	8,1		5,6	
4	63	10	17	550	4,65		4,8	
5	64	11	17	590	7		7,55	
6	67	10	17	587	6,6		6,6	
7	67	4	17	592	6,15		6,25	
8	67	5	17	646	7,6		7,9	
9	67	6	17	620	8,75		7,1	
10	67	7	17	620	5,85		5,7	
11	68	11	17	630	6,4		6,2	
12	69	12	17	620	5,15		5,4	
13	69	13	17	606	5,9		5,2	
14	81	23	17	650	6		6,25	
15	81	19	17	650	8,4		8	
16	82	23	17	630	6,2		6,3	
17	82	18	17	6,6	7,9		7,5	
18	82	10	17	675	7,7		6,2	
19	82	11	17	606	5,6		6	
20	83	24	17	625	6,3		6,45	
21	83	19	17	610	5,75		5,9	
22	83	18	17	590	6,2		6,25	
23	83	12	17	620	6		6,5	
24	83	13	17	680	6,55		7,05	
25	83	4	17	572	5,1		4,9	
26	83	5	17	600	600		5,4	
27	83	6	17	566	4,8		4,9	
28	84	25	17	595	6,8		6,95	
29	84	6	17	633	6		5,7	
30	99	25	17	648	7,3		6,95	
31	99	24	17	604	6,55		7	

32	101	22	17	657	7,05		7,05	
33	101	4	17	635	8,4		7,9	
34	101	5	17	648	8,1		8,5	
35	101	6	17	665	6,8		6,4	
37	101	7	17	675	6,7		7	
38	102	22	17	657	7,5		7	

Missing trees

AMBIL SEMUA SAMPEL

NO	BARIS	POKOK	RANK	STIPA					
				Atas		tengah		bawah	
				Basah	Kering	Basah	Kering	Basah	Kering
1	67	12	17						
2	67	13	17						
3	69	6	17						
4	81	12	17						
5	81	23	17						
6	82	23	17						
7	82	18	17						
8	83	24	17						
NO	**BARIS**	**POKOK**	**RANK**	**RACHIS**		**PETIOLA**		**DAUN**	
				Basah	**Kering**	**Basah**	**Kering**	**Basah**	**Kering**
1	67	12	17						
2	67	13	17						
3	69	6	17						
4	81	12	17						
5	81	23	17						
6	82	23	17						
7	82	18	17						
8	83	24	17						

time schedule **October**
ISOPALM **2012**

Days	location	biometry	Phenology	samplings	data meteo	soil
Monday 15	arrival Medan					
	Visit Socfindo	departure for Aek Loba				
	Stop PS BB Nitrogen					
Tuesday 16	start at ALCP10	LA - Height 33	control A/B	roots A/B		
	control	A/B	missing data	starting		
Wednesday 17	ALCP10 K0	trunk density A/B	PHENO A/B	roots A/B		
		sampling canopy	observations	biomass		
Thursday 18	ALCP10	trunk density A/B	PHENO A/B	roots A/B		
		sampling canopy	observations	biomass		
Friday 19	ALCP10	LA - Height 33	SLW/SPAD	roots A/B	meteo WachDog	
		C/D		biomass	control sensors	
Saturday 20	ALCP10	LA - Height 33	SLW/SPAD	roots A/B		
		C/D		biomass		
Sunday 21	ALCP10	LA - Height 33	SLW/SPAD	roots A/B		
		C/D		biomass		
Monday 22	ALCP 10	LA - Height 33		roots A/B		
		C/D diameter		biomass		
Tuesday 23	ALCP10	LA - Height 33		roots A/B		
		C/D diameter		biomass		
Wednesday 24	ALCP10	LA - Height 33		roots A/B		
		sampling canopy		biomass		
Thursday 25	ALCP10	LA - Height 33		roots A/B		
		sampling canopy		biomass		
Friday 26	ALCP10	LA - Height 33		roots A/B	meteo WachDog	
		sampling canopy		biomass	control sensors	
Saturday 27	ALCP10	LA - Height 33		roots A/B		
		sampling trunk		biomass		
Sunday 28	ALCP10	LA - Height 33		roots A/B		
		sampling trunk		biomass		
Monday 29	ALCP10	LA - Height 33		roots A/B		
		sampling roots		biomass		
Tuesday 30	ALCP10	LA - Height 33		roots A/B		
		samplings roots		biomass		
Wednesday 31	ALCP10	LA - Height 33		roots A/B		
		samplings roots		biomass		
Thursday 1	visit Sumbio			roots A/B		
				biomass		
Friday 2	Meeting Aek Loba			roots A/B		
				biomass		
Saturday 3	departure for Pekanbaru					

Short memento for ISOPALM Activities during Mission 15 October to 3 nd November 2012 Aek Loba . ALCP10.

Emmanuelle Lamade, November 2012

This last mission has been devoted to the roots system studies for two progenies A and B. Others measurements concerning the vegetative and the reproductive have be done on C and D following same methodology used before for A and B.
All activities programmed have been achieved.

Part 1
A and B progenies in ALCP10.

36 (+2) trees are under mineral and vegetative survey specific to Isopalm.

List of the trees studied.

61/11; 61/10; 63/13; 63/12; 67/13; 67/12; 68/13; 68/12; 69/11; 69/10; 69/7; 69/6; 69/5; 70/4; 81/24; 82/25; 81/16; 82/17; 81/12; 82/12; 81/7; 81/6; 81/5; 81/4 ; 83/23; 84/23; 83/16; 84/17; 83/11; 83/10; 99/22; 100/23; 101/24; 102/25; 99/7; 100/6; 100/5; 100/4.

Phenology.

Normally 72 (A and B progenies) were under phenological observations since february 2011. Each tree were recording at least once a month. In way to improve the accurency and the frequency of the routine observations, 36 trees (on the list up) were re-selected for the second part of this programmation. A new regular routine based on bi-monthly recording is instaured to get better precision on anthesis date and leaf emission date.

Then following recommendations are given : All the 36 trees were checked for leaf numerotation. They are fully ready for new observations. These observations will be :

- Tangal rank 1 : the date of each leaf rank 1 must be quoted with precision each 15 days.
- Tangall potong pelapah : at each harvesting bunch, at least one or two leaves are cut. The date of the cutting must be quoted on the form.
- Kelamin : each bud will be quoted at its apparition at the axis of each leaf (some are aborted). Then the sex of the new inflorescence will be identified as “M” for male, “F” for female and “A” for aborption. (also “H” for hermaphrodite).
- Tangall anthesis : it can occur that anthesis of male or female inflorescences can be observed with small delay (2 or 3 days accepted) if not on time on the observation day.

- Tangall panen : because the harvest quotation is done every Saturday, it is easy to re-write this information (as well as the bunch weight) on the form every month.

Then each tree can be computed on specific phenological file (on file per tree).
Every 15 days, a complete rotation has to be done : new numerotation for new leaf rank one (around N° 80 by now).

Biometry

1. Trunk height (from base trunk to leaf 33)

Last year some data were missing especially for trunk height. This year all trees A and B chozen (see list behind) were measured again firstly to estimate the annual growth rate and to complete measurements from last year.

2. Diameter at 3 different heights : (i) 50 cm from base, (ii) at half height, (iii) at the base of petiole leaf 33.

To measure trunk diameter, a special calliper was built in ALSP to avoid petiole base :

It is a non destructive method for trunk biomass evaluation but still the remaining petiole base on trunk must be estimated too.

Roots biomass

Roots biomass has been studied for the total 36 trees chosen belonging to A and B progenies. Because it is a hard work, a specific methodology was used derived from Pobè s 'study (Ph.D. Thesis). A simplified

Voronoï trench plot design is done for each tree. Then a first sampling is done with a dutch auger as follow :

Depth : 15 cm /30 cm
A zone : 1 location sampling , 2 depths
B zone : 1 location sampling, 2 depths
C zone : 3 locations samplings , 2 depths
+ 1 control for soil bulk density
Direction : one trench towards the harvest path , one towards the windrows (or frond pile)
Total : 22

When the total soil is collected from zone A, zone B and zone C at two different depth

Part 2

C and D characterisation in ALCP10

36 trees were chosen in ALCP10 belonging to C and D progenies. The list of the trees chozen :

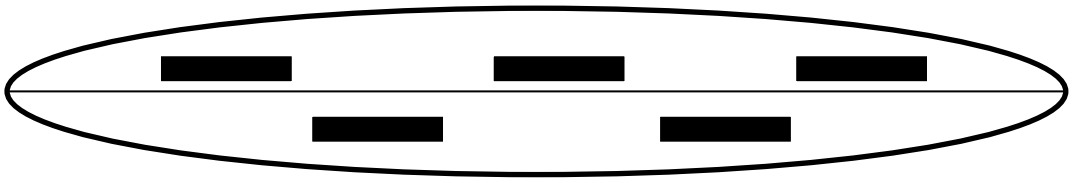
62/13 ; 62/12; 63/10; 64/11; 67/10; 63/11; 67/4; 67/5; 67/6; 67/7; 69/12; 69/13; 81/23; 82/23; 81/19; 82/18; 82/10; 82/11; 83/24; 84/25; 83/19; 83/18; 83/12; 83/13; 83/4; 83/5; 83/6; 84/6; 99/25; 99/24; 101/22; 101/4; 101/5; 101/6; 101/7; 102/22.

Biometry

Leaf area, leaf rank 17

Following the method Ballo Koffi and Tailliez 's 1992, the leaf area of leaf rank 17 was measured for each tree (see procedure on ISOPALM report) as for progeny A and B before. At the same time SLW (Specific Leaf Weight) was evaluated as follow :

with 5 repetitions per leaflets and 10 leaflets per tree.



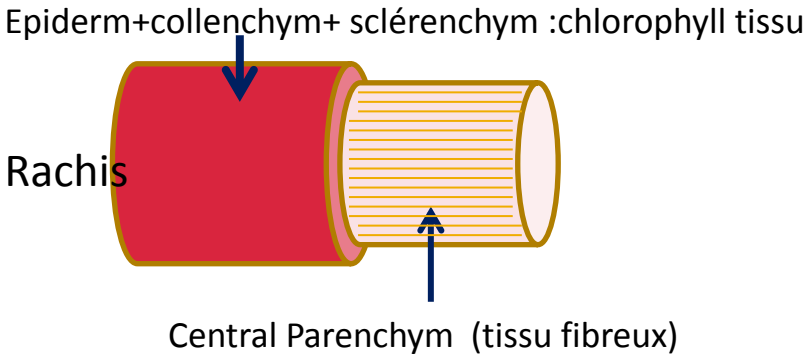
Small samples have a constant area : 5 x 2 cm
They are dried and weighed.

During LA measurements, petiole lenght as well as rachis is recording then their volume are also estimated. The total number of leaves for each trees studied is directly numered.

Trunk height and diameter
As well as for A and B progenies before, trunk height and diameter were measured precisely for the 36 trees.
Trunk height : from base to the leaf rank 33 (petiole)
Trunk diameter : (i) at 50 cm of the base, (ii) at the middle height, (iii) at the top of the trunk (leaf 33).
Trunk density : this was done with the Pressler Auger (at 3 different height also) , diameter 5mm, 45 cm long.

Samplings for mineralomass :

- Leaflets : rank 17, along rachis
- Rachis : rank 17, (5 cm), only white part before B point
- Petiole : 5 cm, only white part



- Trunk samplings : 3 locations (20g minimum) with the Pressler auger. (i) 50 cm from base, (ii) at half height, (iii) at the base of petiole leaf 33.

All samples collected in this part have been send to Bah Lias after drying under 60°C.

24/10/2012	83	19	BRONDOLAN	
22/10/2012	63	10	BRONDOLAN	
24/10/2012	83	6	BRONDOLAN	
23/10/2012	63	11	BRONDOLAN	
24/10/2012	83	18	BRONDOLAN	
28/10/2012	101	7	BRONDOLAN	
27/10/2012	83	12	BRONDOLAN	
27/10/2012	99	25	BRONDOLAN	
27/10/2012	83	13	BRONDOLAN	
25/10/2012	99	24	BRONDOLAN	
23/10/2012	67	6	BRONDOLAN	
27/10/2012	101	4	BRONDOLAN	
27/10/2012	101	6	BRONDOLAN	
25/10/2012	101	22	BRONDOLAN	

25/10/2012	82	11	BRONDOLAN	
28/10/2012	101	5	BRONDOLAN	
23/10/2012	69	10	DAUN	1
24/10/2012	83	11	DAUN	25
24/10/2012	70	4	DAUN	10
22/10/2012	68	13	DAUN	33
24/10/2012	82	17	DAUN	9
23/10/2012	61	10	DAUN	17
20/10/2012	83	12	DAUN	17
22/10/2012	68	13	DAUN	1
20/10/2012	83	5	DAUN	17
22/10/2012	68	13	DAUN	25
22/10/2012	101	6	DAUN	17
22/10/2012	68	23	DAUN	1
22/10/2012	68	12	DAUN	9
21/10/2012	101	22	DAUN	17
24/10/2012	69	5	DAUN	1
21/10/2012	101	4	DAUN	17
21/10/2012	83	24	DAUN	17
22/10/2012	68	13	DAUN	9
22/10/2012	68	13	DAUN	17
21/10/2012	84	25	DAUN	17
21/10/2012	99	24	DAUN	17
20/10/2012	83	13	DAUN	17
22/10/2012	83	19	DAUN	17
21/10/2012	102	20	DAUN	17
20/10/2012	83	6	DAUN	17
21/10/2012	99	25	DAUN	17
20/10/2012	84	16	DAUN	17
24/10/2012	83	11	DAUN	17
22/10/2012	68	12	DAUN	25
24/10/2012	81	5	DAUN	25
24/10/2012	81	5	DAUN	17
24/10/2012	81	5	DAUN	17
24/12/2012	82	12	DAUN	17
23/10/2012	61	11	DAUN	18
23/10/2012	69	10	DAUN	9
23/10/2012	69	10	DAUN	25
23/10/2012	69	11	DAUN	25
24/10/2012	69	6	DAUN	26
24/10/2012	69	7	DAUN	18
23/10/2012	61	11	DAUN	2
23/10/2012	61	10	DAUN	25
23/10/2012	61	11	DAUN	10

23/10/2012	69	11	DAUN	1
24/10/2012	81	16	DAUN	17
24/10/2012	83	11	DAUN	1
24/10/2012	81	5	DAUN	33
24/10/2012	69	6	DAUN	22
24/10/2012	69	7	DAUN	26
24/10/2012	83	10	DAUN	2
24/10/2012	81	5	DAUN	1
24/10/2012	69	5	DAUN	17
24/10/2012	69	6	DAUN	10
24/10/2012	69	5	DAUN	25
24/10/2012	83	10	DAUN	18
24/10/2012	83	10	DAUN	10
24/10/2012	81	12	DAUN	9
24/10/2012	69	7	DAUN	2
24/10/2012	83	11	DAUN	9
24/10/2012	81	12	DAUN	1
24/10/2012	82	17	DAUN	25
23/10/2012	69	10	DAUN	17
23/10/2012	69	12	DAUN	17
23/10/2012	61	10	DAUN	1
23/10/2012	61	10	DAUN	10
25/10/2012	99	7	DAUN	9
25/10/2012	100	6	DAUN	33
20/10/2012	99	4	DAUN	9
23/10/2012	69	11	DAUN	10
22/10/2012	83	18	DAUN	17
20/10/2012	81	4	DAUN	17
17/10/2012	63	13	DAUN	1
19/10/2012	62	10	DAUN	17
17/10/2012	63	12	DAUN	25
24/10/2012	81	5	DAUN	1
24/10/2012	69	7	DAUN	10
22/10/2012	101	5	DAUN	17
24/10/2012	70	4	DAUN	26
19/10/2012	81	19	DAUN	17
17/10/2012	63	13	DAUN	17
17/10/2012	63	12	DAUN	17
25/10/2012	99	7	DAUN	1
18/10/2012	67	5	DAUN	17
18/10/2012	67	7	DAUN	17
18/10/2012	67	10	DAUN	17
18/10/2012	67	4	DAUN	17
18/10/2012	67	6	DAUN	17

19/10/2012	82	23	DAUN	17
19/10/2012	62	11	DAUN	17
22/10/2012	101	7	DAUN	17
17/10/2012	62	12	DAUN	17
17/10/2012	63	13	DAUN	25
18/10/2012	68	11	DAUN	17
23/10/2012	61	11	DAUN	26
24/10/2012	81	16	DAUN	1
17/10/2012	64	11	DAUN	17
17/10/2012	63	13	DAUN	32
17/10/2012	63	12	DAUN	9
17/10/2012	62	13	DAUN	17
25/10/2012	100	6	DAUN	1
24/10/2012	100	5	DAUN	25
24/10/2012	82	17	DAUN	17
17/10/2012	63	12	DAUN	1
19/10/2012	82	18	DAUN	17
19/10/2012	81	23	DAUN	17
22/10/2012	68	12	DAUN	17
24/10/2012	70	4	DAUN	18
25/10/2012	100	5	DAUN	17
24/10/2012	81	12	DAUN	17
25/10/2012	99	7	DAUN	25
17/10/2012	63	13	DAUN	9
24/10/2012	81	5	DAUN	9
25/10/2012	100	5	DAUN	1
24/10/2012	82	12	DAUN	9
24/10/2012	82	17	DAUN	1
25/10/2012	99	7	DAUN	17
25/10/2012	100	5	DAUN	9
18/10/2012	69	13	DAUN	17
25/10/2012	100	6	DAUN	17
25/10/2012	100	6	DAUN	9
24/10/2012	82	12	DAUN	1
24/10/2012	81	16	DAUN	9
24/10/2012	81	5	DAUN	9
24/10/2012	69	5	DAUN	9
24/10/2012	83	10	DAUN	26
24/10/2012	69	6	DAUN	18
24/10/2012	70	4	DAUN	2
23/10/2012	99	4	DAUN	1
18/10/2012	69	12	DAUN	17
18/10/2012	63	10	DAUN	17
23/10/2012	99	4	DAUN	17

20/10/2012	83	5	PETIOLA	17
21/10/2012	99	25	PETIOLA	17
22/10/2012	101	7	PETIOLA	17
20/10/2012	63	12	PETIOLA	17
20/10/2012	84	6	PETIOLA	17
21/10/2012	102	22	PETIOLA	17
21/10/2012	101	22	PETIOLA	17
21/10/2012	84	25	PETIOLA	17
22/10/2012	83	18	PETIOLA	17
21/10/2012	83	24	PETIOLA	17
21/10/2012	101	4	PETIOLA	17
22/10/2012	101	5	PETIOLA	17
22/10/2012	101	6	PETIOLA	17
20/10/2012	83	6	PETIOLA	17
20/10/2012	83	13	PETIOLA	17
22/10/2012	83	19	PETIOLA	17
21/10/2012	99	24	PETIOLA	17
19/10/2012	81	19	PETIOLA	17
18/10/2012	67	10	PETIOLA	17
19/10/2012	62	11	PETIOLA	17
18/10/2012	67	4	PETIOLA	17
19/10/2012	82	18	PETIOLA	17
18/10/2012	67	6	PETIOLA	17
18/10/2012	67	7	PETIOLA	17
18/10/2012	69	13	PETIOLA	17
19/10/2012	62	10	PETIOLA	17
18/10/2012	63	10	PETIOLA	17
20/10/2012	83	4	PETIOLA	17
18/10/2012	69	12	PETIOLA	17
18/10/2012	68	11	PETIOLA	17
17/10/2012	62	12	PETIOLA	17
19/10/2012	82	23	PETIOLA	17
18/10/2012	67	5	PETIOLA	17
17/10/2012	84	11	PETIOLA	17
19/10/2012	81	23	PETIOLA	17
17/10/2012	62	13	PETIOLA	17
19/10/2012	62	11	RACHIS	17
19/10/2012	62	10	RACHIS	17
17/10/2012	62	12	RACHIS	17
21/10/2012	99	25	RACHIS	17
20/10/2012	83	12	RACHIS	17
20/10/2012	101	6	RACHIS	17
18/10/2012	63	10	RACHIS	17
18/10/2012	69	12	RACHIS	17

18/10/2012	67	10	RACHIS	17
18/10/2012	67	5	RACHIS	17
22/10/2012	101	7	RACHIS	17
21/10/2012	83	24	RACHIS	17
21/10/2012	84	25	RACHIS	17
19/10/2012	81	19	RACHIS	17
21/10/2012	101	20	RACHIS	17
20/10/2012	84	6	RACHIS	17
19/10/2012	82	18	RACHIS	17
19/10/2012	83	23	RACHIS	17
18/10/2012	68	11	RACHIS	17
21/10/2012	102	22	RACHIS	17
22/10/2012	101	5	RACHIS	17
19/10/2012	81	23	RACHIS	17
18/10/2012	69	13	RACHIS	17
18/10/2012	67	7	RACHIS	17
18/10/2012	67	6	RACHIS	17
20/10/2012	83	4	RACHIS	17
22/10/2012	83	18	RACHIS	17
17/10/2012	64	11	RACHIS	17
20/10/2012	83	5	RACHIS	17
20/10/2012	83	6	RACHIS	17
23/03/1900	83	13	RACHIS	17
17/10/2012	62	13	RACHIS	17
18/10/2012	67	4	RACHIS	17
22/10/2012	83	19	RACHIS	17
21/10/2012	99	24	RACHIS	17
21/10/2012	101	4	RACHIS	17
24/10/2012	83	19	SPIKLET	
23/10/2012	67	6	SPIKLET	
23/10/2012	67	7	SPIKLET	
24/10/2012	83	4	SPIKLET	
23/10/2012	67	5	SPIKLET	
22/10/2012	62	12	SPIKLET	
22/10/2012	68	11	SPIKLET	
23/10/2012	67	4	SPIKLET	
22/10/2012	67	10	SPIKLET	
23/10/2012	69	12	SPIKLET	
24/10/2012	69	13	SPIKLET	
22/10/2012	64	11	SPIKLET	
24/10/2012	82	10	SPIKLET	
25/10/2012	82	11	SPIKLET	
23/10/2012	81	19	SPIKLET	
24/10/2012	83	13	SPIKLET	

24/10/2012	83	6	SPIKLET	
24/10/2012	84	6	SPIKLET	
24/10/2012	83	5	SPIKLET	
24/10/2012	83	24	SPIKLET	
22/10/2012	63	10	SPIKLET	
28/10/2012	101	5	SPIKLET	
25/10/2012	99	24	SPIKLET	
27/10/2012	99	25	SPIKLET	
28/10/2012	101	4	SPIKLET	
25/10/2012	84	25	SPIKLET	
27/10/2012	83	13	SPIKLET	
27/10/2012	101	6	SPIKLET	
28/10/2012	101	7	SPIKLET	
27/10/2012	83	12	SPIKLET	
25/10/2012	101	22	SPIKLET	
25/10/2012	102	22	SPIKLET	
22/10/2012	62	13	STIPA	BAWAH
22/10/2012	62	13	STIPA	BAWAH
25/10/2012	102	22	STIPA	BAWAH
24/10/2012	83	18	STIPA	BAWAH
22/10/2012	67	10	STIPA	BAWAH
23/10/2012	81	19	STIPA	BAWAH
23/10/2012	67	5	STIPA	BAWAH
22/10/2012	64	11	STIPA	BAWAH
24/10/2012	83	19	STIPA	BAWAH
24/10/2012	83	24	STIPA	BAWAH
24/10/2012	84	6	STIPA	BAWAH
24/10/2012	82	10	STIPA	BAWAH
24/10/2012	83	4	STIPA	BAWAH
23/10/2012	99	24	STIPA	BAWAH
23/10/2012	69	13	STIPA	BAWAH
23/10/2012	69	12	STIPA	BAWAH
23/10/2012	67	6	STIPA	BAWAH
22/10/2012	62	12	STIPA	BAWAH
25/10/2012	62	11	STIPA	BAWAH
23/10/2012	67	4	STIPA	BAWAH
29/10/2012	67	6	STIPA	BAWAH
25/10/2012	101	22	STIPA	BAWAH
22/10/2012	68	11	STIPA	BAWAH
22/10/2012	62	12	STIPA	ATAS
22/10/2012	67	10	STIPA	ATAS
23/10/2012	81	19	STIPA	ATAS
23/10/2012	69	13	STIPA	ATAS
22/10/2012	62	13	STIPA	ATAS

22/10/2012	68	11	STIPA	ATAS
23/10/2012	67	4	STIPA	ATAS
25/10/2012	84	25	STIPA	ATAS
24/10/2012	83	19	STIPA	ATAS
24/10/2012	82	10	STIPA	ATAS
24/10/2012	83	4	STIPA	ATAS
23/10/2012	69	12	STIPA	ATAS
23/10/2012	67	6	STIPA	ATAS
23/10/2012	67	5	STIPA	ATAS
23/10/2012	67	7	STIPA	ATAS
24/10/2012	83	14	STIPA	ATAS
24/10/2012	83	6	STIPA	ATAS
24/10/2012	83	5	STIPA	ATAS
24/10/2012	83	18	STIPA	ATAS
22/10/2012	63	10	STIPA	ATAS
22/10/2012	64	11	STIPA	ATAS
24/10/2012	84	6	STIPA	ATAS
25/10/2012	99	24	STIPA	ATAS
22/10/2012	62	12	STIPA	TENGAH
23/10/2012	67	4	STIPA	TENGAH
22/10/2012	68	11	STIPA	TENGAH
24/10/2012	85	5	STIPA	TENGAH
22/10/2012	63	10	STIPA	TENGAH
22/10/2012	64	11	STIPA	TENGAH
22/10/2012	67	10	STIPA	TENGAH
24/10/2012	84	6	STIPA	TENGAH
24/10/2012	83	6	STIPA	TENGAH
24/10/2012	83	4	STIPA	TENGAH
23/10/2012	67	6	STIPA	TENGAH
24/10/2012	83	19	STIPA	TENGAH
23/10/2012	67	5	STIPA	TENGAH
23/10/2012	81	19	STIPA	TENGAH
22/10/2012	62	13	STIPA	TENGAH
23/10/2012	69	12	STIPA	TENGAH
25/10/2012	101	22	STIPA	TENGAH
23/10/2012	67	7	STIPA	TENGAH
25/10/2012	102	22	STIPA	TENGAH
24/10/2012	83	24	STIPA	TENGAH
23/10/2012	69	13	STIPA	TENGAH
24/10/2012	83	6	STIPA	TENGAH
28/10/2012	101	4	STIPA	TENGAH
27/10/2012	99	25	STIPA	TENGAH
25/10/2012	84	25	STIPA	TENGAH
27/10/2012	83	12	STIPA	TENGAH

28/10/2012	101	5	STIPA	TENGAH
25/10/2012	82	11	STIPA	TENGAH
25/10/2012	99	24	STIPA	TENGAH
27/10/2012	101	6	STIPA	TENGAH
27/10/2012	83	13	STIPA	TENGAH
27/10/2012	83	13	STIPA	BAWAH
28/10/2012	101	4	STIPA	BAWAH
27/10/2012	83	12	STIPA	BAWAH
27/10/2012	99	25	STIPA	BAWAH
28/10/2012	101	5	STIPA	BAWAH
27/10/2012	101	6	STIPA	BAWAH
27/10/2012	101	7	STIPA	BAWAH
25/10/2012	84	25	STIPA	BAWAH
27/10/2012	101	6	STIPA	ATAS
27/10/2012	83	13	STIPA	ATAS
25/10/2012	102	22	STIPA	ATAS
27/10/2012	83	12	STIPA	ATAS
25/10/2012	82	11	STIPA	ATAS
27/10/2012	99	25	STIPA	ATAS
28/10/2012	101	4	STIPA	ATAS
25/10/2012	101	22	STIPA	ATAS
28/10/2012	101	5	STIPA	ATAS
24/10/2012	83	18	STIPA	TENGAH
24/10/2012	82	10	STIPA	TENGAH

CONTRASTED MINERAL POTASSIUM SIGNATURE (K ++ K--) FOR TWO OIL PALM GENOTYPES (*Elaeis guineensis* Jacq.) IN NURSERY STAGE: Preliminary results

Maria do Rosario Lobato Rodrigues[1], Emmanuelle Lamade[2], Jean Ollivier[2], Bernard Dubos[2], Jaleh Ghashghaie[3]

[1]Brazilian Agricultural Research Corporation – Embrapa Western Amazon, C.P. 319, 69010-970-Manaus, AM, Brasil. Email: rosario.lobato@cpaa.embrapa.br; [2]CIRAD/Persyst-UP34, 34398-Montpellier Cedex France. Email: emmanuelle.lamade@cirad.fr; [3]Université de Paris XI, CNRS –UMR 8079, Orsay Cedex 91.405, France

Introduction

Oil palm production depends upon three main factor groups: (i) the genetic potential of the planting material, (ii) the biophysical environment and (iii) the technical quality of the agronomical practices during the establishment, the maintenance of the plantation and the adequate input level (as fertilizers, pesticides..). Recently, some researchers focus on the identification of planting material presenting a better efficiency towards nutrient applications and consumptions. Our work is focusing on the internal functioning of the mineral reserves of the plant, especially the absorption processes and the remobilization of some nutrients essential to oil palm as potassium, in addition with nitrogen, in relation with the carbon allocation (soit allocation soit metabolism soit les deux avec and) metabolism in different plant organs.

Material and Method

An experimental trial has been conducted in greenhouse (CIRAD, Lavalette center, Montpellier, France), aiming to study the effect of potassium gradient on the mineral allocation at the plant scale and to compare two different genotypes (V1 and V2) presenting contrasting leaf potassium content (V1 will be characterized as K– and V2 as K++). Pre-germinated seeds originated from SOCFINDO (PSBB center, North Sumatra, Indonesia) were planted in plastic pots with sandy substrate, then transferred to bigger pots (capacity of 6 kg) filled with a substrate composed of 50 % sand and 50 % vegetal commercial compost. The plants were submitted to 4 K level (K0, K1, K2, K3) and 2 N levels (N1, N2), with 3 repetitions. A first set of measurements started in 09/2011, a second in 02/2012 on 36 plants by progeny (V1 and V2) belonging to N1K0, N1K1, N1K2, N1K3 N2K0 and N2K3 treatments. In 06/2012 was applied a solution containing heavy stable isotopes (^{41}K, ^{15}N, ^{13}C) to compare ^{85}Rb and ^{41}K flow ? and determine the metabolic basis of the relationship between K and carbohydrates (soluble sugars and starch) in oil palm.

A - Pre-germinated seed plantation in plastic pots with sandy substrate

B - Transplantation to bigger pots

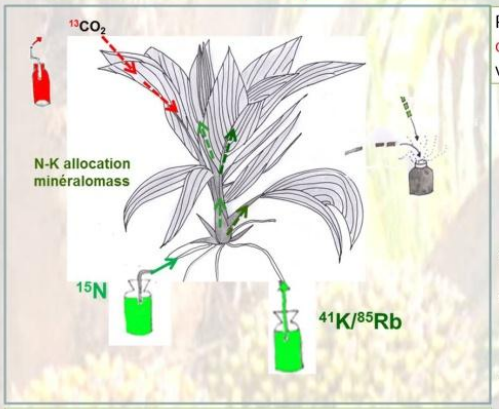
C - Sampling to determine leaf mass area

D - Sampling to determine dry biomass and nutrient contents (leaves, roots and collect)

E – Labelling of the plants with stable isotopes

F – Gas exchange measurements

Labelling of the plants with heavy stable isotopes

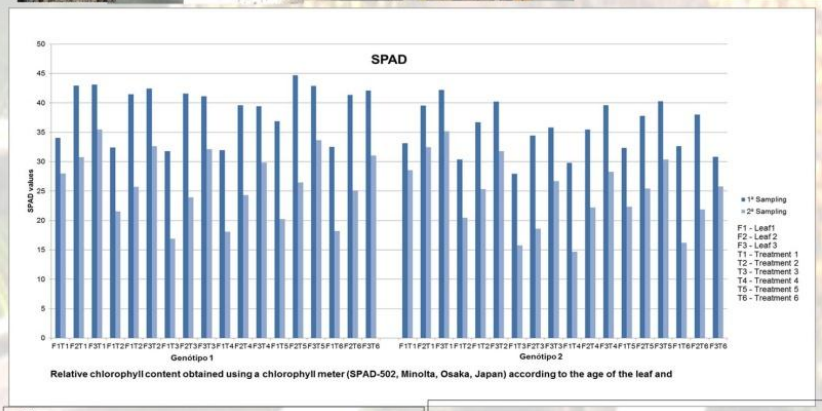


Labelling scheme of plants with stable isotopes by E. Lamade and R. Lobato

Physiological comparison of two varieties (K++,K--)

What is the role of K for the transport of assimilates (sugars and starch)?

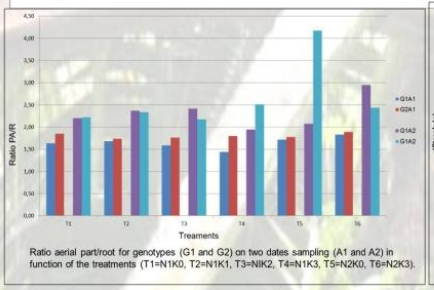
What are the mechanisms of the allocation of NK relations with those of carbon? (mode of transport of assimilates to other organs such as heterotrophic stem, root)



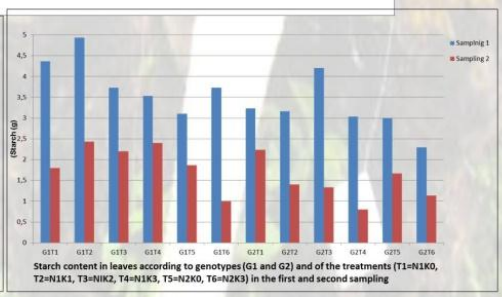
Relative chlorophyll content obtained using a chlorophyll meter (SPAD-502, Minolta, Osaka, Japan) according to the age of the leaf and

Preliminary Results

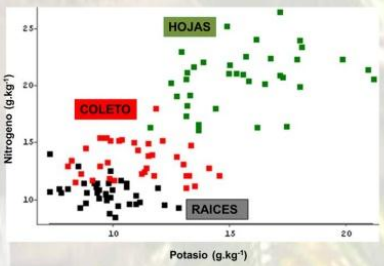
The first results concerning the foliar mineral analyses pointed out high levels for nitrogen (N), potassium (K) and magnesium (Mg) for V2 genotype. The results are: N%=2.26 (±0.17), K%=1.64 (±0.21), Mg%=0.476 (±0.04) for V2 and for V1: N%=1.89 (±0.20), K%=1.478 (±0.24), Mg%=0.394 (±0.04). Others measurements, performed with the SPAD 502 (Minolta) on the three youngest leaves of each plant, show an increase of the chlorophyll content from leaf rank 1 to leaf rank 3. The chlorophyll content is higher in K- - leaves than in K++ ones for the two first measurement dates (Sep/11 and Feb/12). The first results concerning the biomass show differences among genotypes all along the plant growth. Foliar and root biomass are higher for V1 than for V2 at both dates of samplings. V1 and V2 show contrasted "aboveground/root" ratios which increase during plant growth (first sampling of V1=1.65 (±0.21) and V2=1.80 (±0.19), second sampling V1=2.18 (±0.40) and V2=2.63 (±0.78).

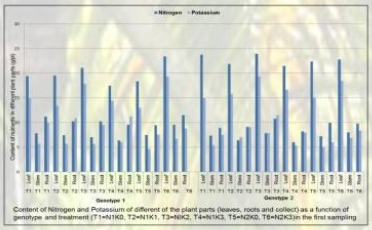


Ratio aerial part/root for genotypes (G1 and G2) on two dates sampling (A1 and A2) in function of the treatments (T1=N1K0, T2=N1K1, T3=NIK2, T4=N1K3, T5=N2K0, T6=N2K3).



Starch content in leaves according to genotypes (G1 and G2) and of the treatments (T1=N1K0, T2=N1K1, T3=NIK2, T4=N1K3, T5=N2K0, T6=N2K3) in the first and second sampling





Clues? Indicative? The first investigations undertaken just after germination stage for the two genotypes do confirm their potassium characterization K- - for V1 and K++ for V2. Does this difference between these two crosses could indicated any relation with the plant genome? (je suggère: could be a genetical characteristic?)

ANNEXE 5

Variations of carbon content among oil palm organs in North Sumatra conditions. Implication for carbon stock estimation at plantation scale.

Emmanuelle Lamade1 and Indra Eko Setiyo 2

CIRAD- UR 34- Performance of Perennial Cropping Systems, 34 398 Montpellier Cedex France, emmanuelle.lamade@cirad.fr

IOPRI,

ICOPE 2010

ABSTRACT

Most of the models which convert the standing biomass to equivalent carbon stock are depending upon the choice of a good estimation of the carbon content of oil palm biomass. Most of the time, rates comprised between 40 % and 45 % are used assumptionally. In order to examine the validity of such rates, an important set of carbon content analyses (920) were performed on dry matter samples collected in Aek Pancur (Indonesian Oil Palm Research Institute, 3°30' N, 98°48' E ; 25 m above sea level) on *Deli X La Mé* material (LM007T x DA 128D clonal material, MK60) between 2003 and 2004. Sampling was done on 10 trees, respectively on the above part (leaflets, rachis, petiole, trunk) and below root system (roots I,II and III+IV) as well as reproductive parts (fruits, bud, stall, spikelets). Carbon composition of bulk organic matter was determined (at the same time with ^{13}C composition) using an NA-1500 elemental analyzer (Carlo-Erba, Milan, Italy) coupled to an isotope ratio mass spectrometer (VG Optima, Micromass, Villeurbanne, France). Then results were double with, in one hand, the carbon composition in % of the sample and, in other hand, the delta ^{13}C (already published Lamade et al., 2009). Important variations were observed in leaflets, rachis and petiole depending on the leaf rank and also among all organs as trunks and roots. For leaflets, a maximum was quoted at leaf rank 3 (47.4 % ± 0.2 n = 20) and a minimum at leaf rank 57 (41.8 % ± 0.7 , n= 7) with a total average of 45.2 % ± 0.03 (n= 479). For the rachis and petioles, carbon content is lower than for leaflets with an average of 41.2 % ± 0.2 (n=84) for rachis and 41.8 % ± 0.3 (n=55) for petioles . Trunk dry matter showed an average of 40.8 % ± 0.3 (n= 35) and roots 42.08 %± 1.06 (n= 14). The new total average can be estimated at 41.8 % (including all ponderations for vegetative parts), when it is 45.7 % for reproductive parts. The carbon content of fruits is highly related to their maturation stages : 43 % ± 0.6 (n=28) the first month after anthesis until 57 % ± 2.7 (n=9).at maturation stage. As a consequence of these observed rates, our new estimation for *Deli x La Mé* material in North Sumatra conditions will be equal to 25.4 t C ha^{-1} of standing biomass for the vegetative part and 6.5 t C ha^{-1} for the reproductive one.Then the difference from our former rate of 45%, will be around 2 t of C per ha. It is not that much, but if calculation is done over 100 000 ha, this make a difference of 2 $*10^5$ t of C which is not negligeable. In conclusion, such analyses must be done more frequently for different planting materials and different ecologies to get adequate carbon stock for oil palm.

INTRODUCTION

Nowadays many estimations of the carbon stock are done for oil palm plantations mainly due to the controversial position of this crop towards international environmental concern. The estimation of the carbon stock at the tree scale (or plantation scale) is very related to an important parameter : the exact carbon content of the biomass. Most of the time values between 40 to 45 % are used for oil palm (Lamade et al, 1996; Lamade et Bouillet 2005). Concerning the direct measurement of the carbon content of oil palm biomass, few data seems to be available. It is the reason why we decide to publish the second part of our results obtained in North Sumatra during ^{13}C content exploration in oil palm biomass (Lamade et al., 2009). Aware about this lack of data, Lamlom & Savidge (2003) measured important variations within american trees from 46 % of C for *Ulmus* to 55 % for *Sequoiadendron giganteum* L. There is also carbon content variation within organs. This carbon content is depending of the development stage (age) and upon metabolic components. Lignin and cellulose content makes this rate contrasted within species. For oil palm biomass one precise estimation has been given by Syahrinudin (2005 quoted by Germer and Sauerborn, 2008) with 40.4% .

MATERIALS AND METHODS

Genetic material and environment

An important collecting of biomass samples was done (Lamade et al., 2009) between 2003 and 2004 in North Sumatra (Aek Pancur Research Station from the Indonesian Oil Palm Research Institute – 3°30'N, 98°48' E; 25 m above sea level). Ten oil palm trees, considered to be adult, were selected in a genetic trial planted in 1995 belonging to the clonal material : *Dura x Pisifera - Deli x La Mé* type - MK60 : LM007T x DA 128 D. Climatic characteristics in this area are near to the potential for oil palm. During that period, the solar radiation was over 16 MJ m^{-2} day^{-1}, the annual rainfall around 2800 mm well distributed along the year. Leaves, trunks, roots, bunches components, buds were sampled as well. The leaves were sampled from rank -6 to rank 57 (comprised each one petiole and one rachis). Because oil palm leaves are large (6 m^2 for this material) they were divided in 10 segments following the method of Tailliez and Koffi (1992) for leaf area determination. Aliquots belonging from all the 10 segments were mixed together before analyses to get a representative sample of the total leaf.

For the trunks, sampling were done at 3 different levels (i) at the base (ii) at the middle part considering the height (iii) at the upper part (near the petiola base of leaf rank 33). Additional samplings were done in the meristem zone and in the terminal bud. For the bunches: sampling were done on fruits every month since the pollination. Spikelets and stalls were sampled too (at least one bunch per tree). Roots were also investigated by category (I,II,III+IV). All samples were all disinfected by ozone, put into liquid nitrogen then dried directly during at minimum 2 days just below 80°C.

Carbon analysis

The carbon composition (as the same time with the carbon isotope composition $^{13}C/^{12}C$) of bulk organic matter of the leaves (rachis, petioles, leaflets), the trunk (up, middle, base, meristem and terminal bud), the bunches (fruits, spikelets, stalls) and the roots (I,II,III+IV) was determined with an NA-1500 elemental analyser (Carlo-Erba, Milan, Italy) coupled to an isotope ratio mass spectrometer (VG Optima, Micromass, Villeurbanne, France). The carbon content is given in % of MS as the same time with the $\delta^{13}C$*. A total of 920 analyses were done in IBP Plateforme Métabolisme-Métabolome www.pmm.u-psud.fr (France).

RESULTS

The "source" organs : the leaves

For the leaflets, an increase is observed from the very young leaves, still at the heterotrophic stage as spear leaf, to the leaflets belonging to the rank 3 (Fig. 1a) which showed a maximum value (47% DW ± 0.2, n = 20). After rank 3, the carbon content is around 45 % DW until the leaf rank 33. After the rank 33, there is a very clear decrease of the carbon content until the leaf rank 57 (41.8 % ± 0.7, n = 7). The total average over all ranks is 45.2 % ± 0.03 (n = 479).
For the rachis, very variable trends are observed (Fig. 1b). Then it is difficult to give an interpretation of what was found. The carbon content of the rachis is in average (41.2 % ± 0.22, n = 84) lower than for the leaflets with a minimum around rank 15 (35% DW) and a maximum at rank 9 (46% DW). For the petioles (Fig.1c), a decrease was observed from the youngest leaves (rank 5) with a value around 43 % DW and the oldest one (rank 57) with a value around 37% DW. The average values for the carbon content in petioles was measured at 41.8 %± 0.3 (n= 55).

The "sink" organs : the trunks, the roots, the bunches

For the carbon content, no difference was observed along the trunks (Fig. 2a) from the upper part (42.12% DW± 0.3, n=11), the middle (41.54% DW ± 0.6 n = 10) and the base (42.14 DW ± 0.8 n = 6). It is interesting to notice that heterotrophic tissues present always a lower carbon content that the full active photosynthetically one (see leaflets at 45 %) : the meristem zone showed lowest carbon content with a mean value of 38.14% DW ± 0.8 (n = 3).

Concerning the roots, the variations observed were related to their category and functions. The secondary roots (Fig. 2c), which are responsible for the expansion of the root system, with a short turn-over, showed a lowest content than both others categories (I, and III+IV) with a mean value of 37.6 % DW ± 1.5 (n = 5). Primary and absorbent roots did not presented any significant difference with a mean value equal to 43.28 ± 1.2 (n = 4) for the roots I and 45.32 ± 2.5 (n = 5) for the roots III+IV (Fig. 2c).

An interesting feature was found for the fruits during their maturation (Fig. 2b). During the 4 first stages (4 months) the carbon content of young fruits (at this stage full of soluble sugars and starch) presented an average of 42.6 % DW, then during the last month, corresponding to the oleosynthesis process, a significant increase was observed with a value equal to 46.47 % DW ± 0.9 until 57.02 % DW ± 2.7 (n = 9).

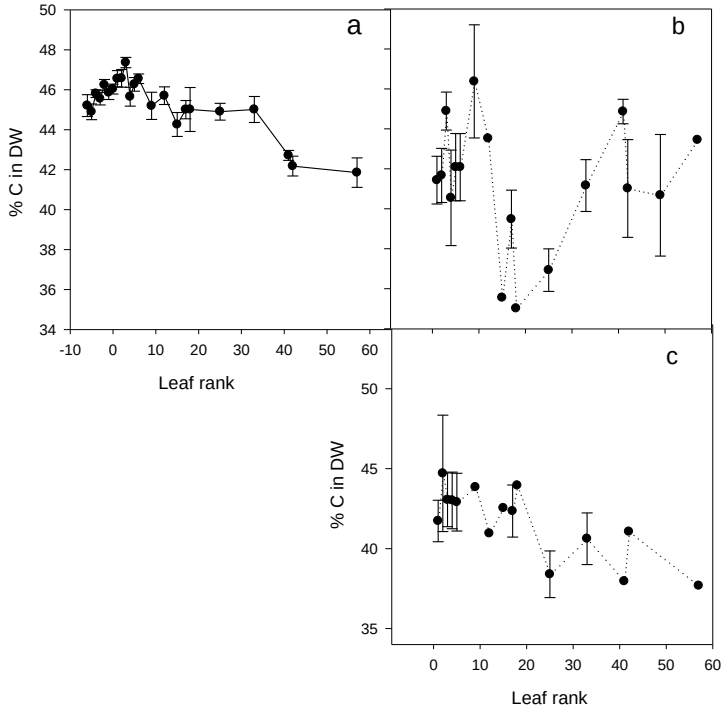


Fig. 1 a,b,c .(a)Variation along leaf rank of the carbon content in % of DW of the leaflets. Data points correspond to the mean values and the error bars to the ± SD (n = 479). (b) Variation along the leaf rank of the carbon content of the rachis in % of DW. Data points correspond o the mean values and the error bars to the ± SD (n = 84) .(c) Idem for the petioles with n = 55.

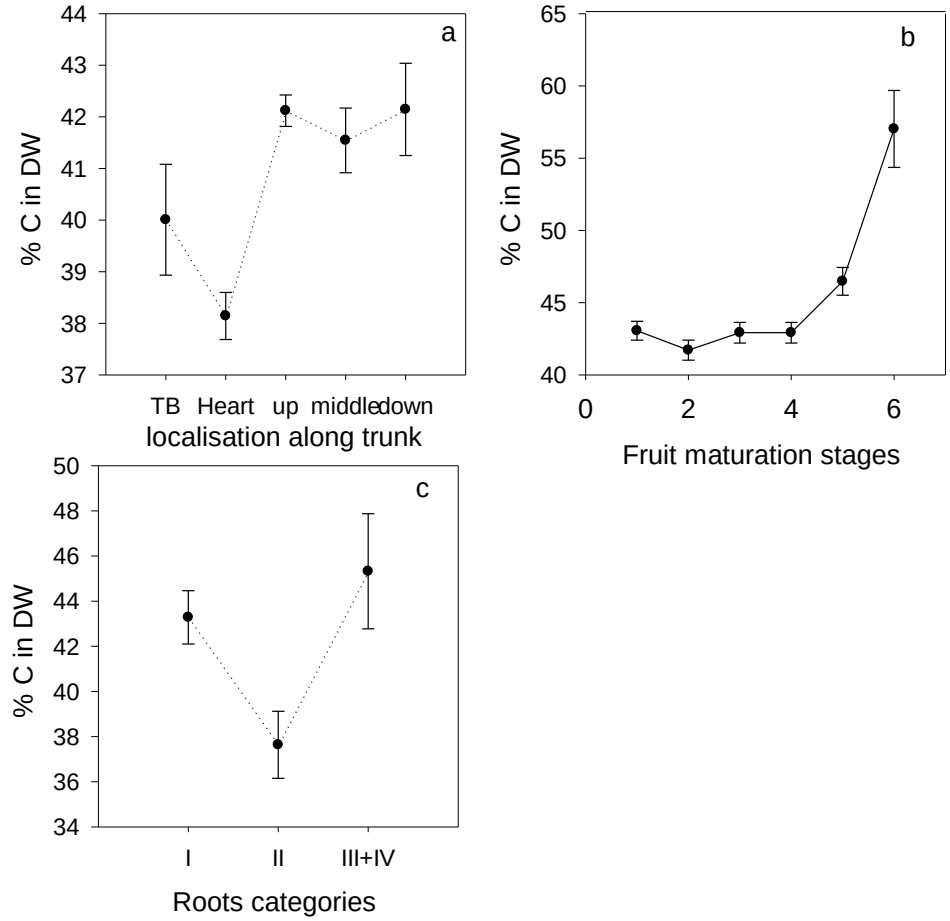


Fig. 2 a,b,c (a) Carbon content variations along the trunk with TB as terminal bud, Heart (meristem), up : the upper part of the trunk, middle : at the half height, down : the base of the trunk. (b) variation of the carbon content during the fruit maturation from pollination to harvesting time. (c) Difference of the carbon content within roots categories with I as primary roots, II as secondary roots, III+IV as tertiary and quaternary roots. Data points correspond o the mean values and the error bars to the ± SD for (a) n = 35, (b) n = 44 , (c) n= 14.

Estimation of carbon stock for two different genetic materials

To give a new estimation of the carbon stock from our previous one (Lamade and Bouillet 2005), the same measurements of the standing biomass (Lamade et al. 1998) is used again because there were very near (ecologycally and genetically) of the material sampled for carbon analysis. These measurements were done on two genetic material (*La Mé* x *Deli* : DA18D self x LM7T self and *La Mé x Yangambi* : BJ 3 D self x BJ 21 P). Vegetative and reproductive caracteristics are shown on Table 1.

organs	D x L (biomass)	D x Y (biomass)	D x L (carbone)	D x Y (carbone)
Leaflets ($t.ha^{-1}$)	6.25	10.69	2.83	4.83
Rachis ($t.ha^{-1}$)	10.93	20.14	4.50	8.30
Petioles ($t.ha^{-1}$)	8.31	13.6	3.48	5.69
Trunks ($t.ha^{-1}$)	21.23	39.3	8.66	16.03
Roots 1 ($t.ha^{-1}$)	5.71	4.11	2.47	1.77
Roots 2 ($t.ha^{-1}$)	3.88	3.73	1.46	1.4
Roots 3 +4 ($t.ha^{-1}$)	4.53	1.84	2.053	0.83
(FFB)	(24.02)	(16.8)	(4.55)	(2.34)

Total t.ha^{-1}			**25.45**	**38.87**

Table 1. Vegetative and reproductive caracteristics for two materials studied in Marihat Research Station (IOPRI). Estimations of carbon stock for two different genetic material (with their biomass measured) with the measured carbon content in North Sumatra conditions.

For buds, carbon contents were observed at a mean of 40.7 % . If we applied the new rate – 41.8 % DW – which is the result of a mean ponderation upon all the organs biomass to evaluate new carbon stock at the plantation scale (Table 1) we obtained 25.4 t C ha^{-1} for Deli x *La Mé* material (when bunches are removed) and 38.9 t C ha^{-1} for *Deli x Yangambi* . The difference with the former estimations (D x L : 27.1 t C ha^{-1}; D x Y : 41. 1 t C ha^{-1} in Lamade and Bouillet 2005) is around 2 t C ha^{-1}.

CONCLUSION

The exact evaluation of the carbon stock at plantation for oil palm is well done with firstly the measurement of the carbon content of the oil palm tissues composing all the standing biomass. For our estimations in 2005 we did not have such analyses. The difference is around 2 t C ha-1. It is not that much but if this new rate is apply upon 1000 ha, the implication is an error of 2000 t C already. Then our conclusion is that precise direct field studies with organs samplings and carbon analysis on different oil palm tissues are more than necessary also because genetic and ecology will change this rate as well as planting ages.

ACKNOWLEDGEMENTS

We do acknowledge the Indonesian Oil Palm Research Institute staff and especially researchers based in the Marihat Research Station. We thanks more than other the regretted Ing. Polin Marbun who help us during years for ecophysiological data acquisitions. We thanks also Jaleh Ghashghaie from the University of Paris XI, France.

REFERENCES

Germer,J. and Sauerborn, J. 2008. Estimation of the impact of oil palm plantation establishment on greenhouse gas balance. Environ Dev Sustain, vol. 10 : 697-716.

Lamade, E., Bonnot, F., Kabul Pamin and Setiyo I E. 1998. Quantitative approaches of oil palm phenology in different environments for the *La Mé x Deli* and *Yangambi* materials. Investigations in the inflorescences cycle process. 1998 International Oil Palm Conference : commodity of the past, today and the future, september 23-25, Bali Indonesia. AG/14. 23p.

Lamade, E and Bouillet, J.P. 2005. Carbon storage and global change : the role of oil palm. Oléagineux, Corps Gras, Lipides. Vol. 12, n° 2, 154-60, Dossier : recherche palmier à huile et développement durable.

Lamade, E. Djegui N and Leterme P. (1996). Estimation of carbon allocation to the roots from soil respiration measurements of oil palm. PlantSoil : 181 : 329-39.

Lamade , E. , Setiyo, I.E., Girard, S. and Ghashghaie, J. 2009. Changes in $^{13}C/^{12}C$ of oil palm leaves to undestand carbon use during their passage from heterotrophy to autotrophy. Rapid communication in Mass Spectrometry, vol. 23, issue 16 : 2586-2596.

Lamlom, S.H. and Savidge R.A. 2003. A reassessment of carbon content in wood : variation within and between 41 North American Species.Biomass and Energy, vol. 25, issue 4 : 381-388.

Tailliez, B and Koffi B. C. (1992). Une méthode de mesure de la surface foliaire du palmier à huile. Oléagineux, vol. 47 , n°8-9 : 537-545.

Table 1. general results on N,P,K total mineralomass

N mineralomass	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.20	0.824 ns
NivK	2	4	1.16	0.401 ns
Progeny	3	17	41.86	0.0001 ***
Nivk*Prog	6	17	0.39	0.87 ns
Progeny	K0	K2	K3	Average
A (LM2T)	3.287±0.192	3.24±0.211	3.433±0.178	3.331 a
B (LM5T)	3.427±0.211	3.678±0.211	3.529±0.145	3.545 a
C(LM5T)	1.924±0.194	2.38±0.194	2.120±0.215	2.142 b
D(LM5T)	2.008±0.194	2.134±0.194	2.245±0.211	2.120 b
P mineralomass	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	0.63	0.579 ns
NivK	2	4	0.37	0.711 ns
Progeny	3	17	1.42	0.271 ns
Nivk*Prog	6	17	0.08	0.997 ns
Progeny	K0	K2	K3	Average
A (LM2T)	0.316±0.036	0.308±0.039	0.329±0.035	0.319
B (LM5T)	0.344±0.036	0.364±0.036	0.362±0.039	0.356
C(LM5T)	0.319±0.039	0.360±0.037	0.348±0.042	0.346
D(LM5T)	0.364±0.037	0.969±0.037	0.381±0.039	0.380
K mineralomass	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.50	0.326 ns
NivK	2	4	1.81	0.275 ns
Progeny	3	17	2.38	0.105
Nivk*Prog	6	17	0.43	0.84 ns
Progeny	K0	K2	K3	Average
A (LM2T)	5.529±0.599	5.049±0.65	5.782±0.557	5.49±1.05
B (LM5T)	4.902±0.658	4.848±0.59	5.181±0.658	4.97±1.12
C(LM5T)	3.655±0.65	4.795±0.605	5.140±0.624	4.55± 1.75
D(LM5T)	5.088±0.605	5.830±0.605	6.41±0.599	5.77±1.69
Mg mineralomass	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.11	0.414 ns
NivK	2	4	0.23	0.80 ns
Progeny	3	17	2.78	0.072+
Nivk*Prog	6	17	0.45	0.836ns

progeny	K0	K2	K3	Average
A (LM2T)	0.541±0.06	0.5204±0.06	0.554±0.06	0.541
B (LM5T)	0.608±0.06	0.6103±0.06	0.512±0.06	0.579
C(LM5T)	0.422±0.06	0.480±0.06	0.430±0.07	0.448
D(LM5T)	0.626±0.08	0.5344±0.06	0.558±0.06	0.571

Ca mineralomass	Num DEF	DenDF	F value	*Pr*<F
Repet	2	4	1.16	0.326 ns
NivK	2	4	2.06	0.242 ns
Progeny	3	17	16.94	<0.0001 ***
Nivk*Prog	6	17	1.66	0.192 ns

progeny	K0	K2	K3	Average
A (LM2T)	0.864±0.088	0.873±0.097	1.008±0.081	0.923 c
B (LM5T)	1.295±0.088	1.489±0.08	1.5063±0.097	1.422 a
C(LM5T)	1.145±0.097	1.336±0.088	1.004±0.091	1.159 b
D(LM5T)	0.987±0.08	1.074±0.088	1.183±0.088	1.081 b