Quantitative approach of oil palm phenology in different environments for La Mé Deli and Yangambi Deli materials. Investigations in the inflorescences cycles process.

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1998 International Oil palm Conference, September 23-25, Nusa Dua, Bali Indonesia.

Abstract

In order to get a better understanding for the oil palm of the organogenesis rhythm and sexualisation cycles, precise weekly phenological observations have been carried out during 3 to 6 years - taking into account for each palm tree : the date of leaf emission, the date of rank one, the date of anthesis, the sex of the axil inflorescence, the date of harvest ...- in Côte d'Ivoire on the control family LM2T x DA 10D and also in North Sumatra on a La Mé x Deli and a Yangambi x Deli families. It is theoretically possible through the processing of data to compare environmental effect and genetic effect on the vegetative development and the sexualisation. Interesting results have been pointed out concerning comparative rate of leaf development and inflorescence. Significant differences have been highlighted between La Mé x Deli (18.32 days) and Yangambi x Deli (15.40 days) for the time interval of the succession of the leaf rank "one" in same environment. For the female anthesis time interval, differences may be pointed out only between Côte d'Ivoire (16.59 days) and Indonesia (20.6 days). But for the time interval of the male anthesis, different situation may be observed.palm trees of Yangambi x Deli origin show first, shorter time interval (14.56 days) than La Mé x Deli (16.51 days) in potential environment whereas similar pattern are shown by both trees of La M x Deli origin in Côte d'Ivoire and Indonesia.Male flowering seems to be related to genetics and female more to environmental effect. Maturation time (time interval from anthesis to harvest) pointed out essentially environmental effect : significantly shorter in Côte d'Ivoire (161.73 days) than in Indonesia (172.94 for La Mé x Deli and 178.19 days for Yangambi x Deli). Correlation have been found between the lenght of the maturation of the inflorescences and the weight of the bunches. Significant differences may be observed between mean weight of bunches with 15.5 kg of fresh weight for LM2T x DA 10D, 19.22 kg for La Mé x Deli in Marihat and 24.28 kg for Yangambi x Deli in same conditions. Interval time between the anthesis of the inflorescence coming from the leaf axils and the same leaf fully openned at rank one is a very interesting variable : seasonnals trends may be observed for all the studied trees both in Ivory Coast and in Indonesia related to environmental factors as rainfall and radiation. For this same variable significant difference have been carried out, as far as female inflorescence are concerned, between Côte d'Ivoire (274.59 days) and Indonesia (244.77 days). For the male inflorescences, time interval is significantly shorter (Côte d'Ivoire : 257.76 days; Indonesia : 237.01 days) with same trends already observed for female inflorescence. It seems that for carbon allocation to reproductive sink , delay is much more important that any priorities rules... It seems that to fill a sink, rate of photosynthetic carbon flux is constant. The lenght of the filling period will allow differences in the elaboration of a male or a female and also for bigger bunches.

As far as leaf emission, anthesis, harvesting are concerned, strong seasonal effect for each tree and for each family in both environment, Côte d'Ivoire and Indonesia, may be pointed out. In Indonesia, leaf emission annual trend for both studied families follow quite well rainfall distribution with a peak in May but a strong decrease in September at the begining of the rainy period. Harvesting peak, in Indonesia may be observed in June/July for both studied families. For the month of male and female anthesis, in Indonesia, there is a small delay between La Mé x Deli and Yangambi x Deli (around 10 days). Sexualisation cycles have been investigated for the three families. Concerning the respective proportion of abortion (when no inflorescence is observed at the leaf axil : this one is quite constant (around 13 % on all observed inflorescences) for both environment Côte d'Ivoire and Indonesia and for all genetic origin La Mé x Deli and Yangambi.x Deli The origin La Mé x

Deli in Indonesia shows the hightest female rate (53.58%) and Yangambi x Deli , even in potential conditions, the hightest male production (57.68%). Sex ratio seems to be strongly related to genetics. Successive sexual sequences have been studied, mainly composed by 3 elements as FFF, MMM or FFM, MMF and so on. Hypothesis of dependance at first level have been tested for all studied families. Under assumptions for LM2T x DA10D, it is possible to say that the sexe of an inflorescence is strongly related to the previous one, if this one is not an abortion. For the indonesian material this dependance is only true if the previous is, in that case, an abortion. In general it is possible to consider two previous levels to be secure enough to predict the sex of the new forthcoming inflorescence. Abortion seems to play an important role, even out of drastic environmental conditions, in the regulation of the sexualisation.

Introduction

Phenology is the study of annually reccurring phenomena in the life cycle of an organism (Kramer, 1996). The phenology of the oil palm have been investigated early in the century (Adam, 1910 quoted by Bredas and Scuvie, 1960) with a first experiment study at Gazi (Belgian Congo) an important advance in floral biology concerning the co-existence of one inflorescence at each leaf axil where already done by Rutgers (1922, quoted by Bredas and Scuvie, 1960) and Mason and Levin (1925, quoted by Hartley, 1988) and further more by Beinaert (1934). Others studies focussing with the relation between yield and rainfall (Janssens, 1955; Stoffels, 1934; Devuyst, 1948; Hemptinne and Ferwerda, 1961 quoted by Bredas and Scuvie, 1960) have pointed out good correlation between production cycle and the climatic characteristics of the 5 to 24 previous months. Broekmans, first of all, has introduced in 1957 codified field phenological observations. Corley (1976,1977) emphasised more studies on flowering cycles, sex identification at early stage, and the possible effects of both environment and cropping practices on abortion. Hartley, in an important synthesis about growth and flowering of oil palm (1988) pointed out the prime importance of studying of the variations in leaf and flower development and distinguishing the genetic and environmental causes. Nowadays, if more is known about the development of each inflorescence and each leaf, sexualisation cycles and quantitatives aspect of organogenesis rhythm in relation with environmental factors still remain in a black box. In order to identify some key processes in the phenological development of different genetical materials and to be able one days to established accurate modelling, precises phenological observations were carried out during 3 to 6 years in Côte d’Ivoire (Research Station of La Mé) and in North Sumatra (Indonesia : Research Station of IOPRI-Marihat). The first step of this study was to obtain good quantification of the respective length of the main organs successions (period between two anthesis, two leaf emission - unfolded leaf - for example) of each studied families.The second step dealed with the analysis of the possible effect of the environment and especially some climatic factors as rainfall distribution and global radiation on seasonnality of leaf and inflorescence development rhythm. At last, sexual sequences have been investigated particularly focusing on the possible abortion role in the sexual cycle regulation and the possibility to predict the sex of the newforthcoming inflorescences from the previous one. In another point of view comparisons were done within genetic origins as La Mé Deli and Yangambi Deli related to environmental effect.

Materials and methods

Ecology

* **Côte d'Ivoire**

A first set of phenological observations have been undertaken at the La Mé Oil Palm Research Station (5°25 N 3° 50 E) on the plot E70 (planting 1973) with density equal to 143 trees/ha, located on sandy ferrallitic soils representative of the tertiary sediments in that zone (Ochs, 1977). The annual rainfall is 1486 mm (upon the period 1973-1988). It can be distinguished different seasons especially two dry periods, the most important in December to March and the less prononced during August. The annual water deficit calculated with the IRHO method (IGM 12) is in average 363 mm (Guedon et al., 1995).

* **North Sumatra**

The second part of the study was conducted in the Marihat Research Station (Balai Penelitian Marihat, 99° 13' E; 2°59' N) in a genetic trial situated in Andarasi (PTP VII, Afdeling III) nearby the station. The planting density is around 128 palms/ha, the year of planting is 1986. A first study on simulation of yield (Lamade and Setiyo, 1996) has already permitted to present the studied zone and the planting material. The mean annual sunshine is 2037 hours (1984-1995) and the annual total rainfall (1972-1994) is around 2890 mm. The mean daily global radiation is 15.29 $MJ.m^{-2}.d^{-1}$. Comparing to Côte d'Ivoire there is no water deficit according the IRHO method. Soil are deep volcanic and unsaturated.

***Materials and trials**

In Côte d'Ivoire the studied material were belonged to the single family (LM2T x DA10D). Observations were made on an elementary nutrition plot E 70 on 24 palm trees from Mai 1986 to the end of 1992. In North Sumatra, same experimental design have been carried out on two contrasting families (one is "La Mé x Deli " origin : block MA008S, cross n° 4, DA128D self x LM7T self. The second one is "Yangambi" origin : block MA009S, cross n° 8 BJ13D self x BJ2 21P) with 24 studied trees per family. The total characteristics of all studied material have been reported on Table 1.

* *Observations*

Similar observations routines were carried out in both agroecological zones. For each studied tree all standing leaves have been recorded chronologically from the oldest to the youngest one. All new opened leaves were beared a new number which represented the number of observation.For each leaves, following events were quoted and codified : the date of emission of the new leaf, the date of the full development at rank one, the date of the cut of this leaf with at the same time, the measurement of the length of petiole and rachis, the sex of axil inflorescence with the date of anthesis and harvest at maturation time for the bunches. The precise fresh weight of each collected bunch have been recorded too.

** Data processing*

A very important set of informations have been collected in Côte d'Ivoire and in the North Sumatra. All data processing have been done with the SAS system (SAS inst, 1990). The following "time" variables were studied :
-" int_rank1" : the time interval in days between two successive leaves fully opened at the stage rank one on the same tree.
- "int_flow" : the time interval in days between two successive anthesis (of the same sex) inflorescences on the same tree.
-"harv_flow" : the time interval in days between the harvesting and the anthesis of all bunches on each tree.
- "flow_rank1" : the time interval in days between the full opening of one leaf and the anthesis of the inflorescence at the same axil.
Such "time" variables present particularities (partial dependance of events in a tree, partial continuous...) and classical statistical studies are not always adequate. Nevertheless, we propose in this paper to look at the observed data, as simple as possible, with bearing in mind the limit of some applications as far as statistical tests are concerned.
Respective distributions of these variables have been done before with an ANOVA on the trees effect for each family. Normality tests were done on all distributions using the "univariate" procedure (SAS system). To illustrate and compare the different patterns of the studied families , distributions of time intervals have been fitted with kernel density curves, taking into account each event median (or mean) and the standard deviation (Sokal and Rohlf, 1980). For a same "time" variable, 3 histogramms (corresponding to the 3 families) were compared , class by class graphically .
For seasonnality trends, density of all variables were calculated, per month using the same time reference as the studied family.
For the study of the sexualisation sequences, the main goal was to try to see if the sex of each inflorescence may be dependant from the sex of the previous . Data are composed of the observed following sequences established for each tree of each studied family. Observed sequences on oil palm may be like "FFFMMAFFFFAFFM...", where F is the female inflorescence, M the male inflorescence and A the aborted inflorescence (which is in all cases in this work the abscence of inflorescence at the axil of the leaf). If S is the sex of one inflorescence, S_n will be quoted for the n^{th} previous one. If we want to determine if the sex of an inflorescence is depending of the n previous one, we have to look at the sequences $S_nS_{n-1}...S_1S_0$. The number of possible sequences is 9 for n=1, 27 for n=2, 81 for n=3... When n increases, it is becoming very difficult to observe all sequences, we just considered when n= 2 the sequences $S_2S_1S_0$. The 7 sequences possibles are AAA, AAF, AAM, AFA ...MMM.

Results

In all comments "L2T" will represent the family "LM2T x DA 10 D", "LA ME" the material "DA128D self x LM7T self" and "Yangambi" the material "BJ13D self x BJ221P".

1. Time interval of phenological events

First of all, time interval between the succession of phenological steps (as the complete opening of each leaf, the succession of anthesis of following inflorescences) have been investigated for the three different genotypes and both environmental situations. Most of the time, a strong "tree effect" has been seen in each family (Table 2). One point that should be made concerned the fact that most "time variables" do not significantly follow a normal function, as the tests involved are difficult to satisfy; Nevertheless, we have presented normal fitting just to illustrate more clearly comparisons between genetic material. The value of the Kolmogorov test was indicated for all distributions.

- For full opening of the leaves at rank one, the "Yang" material showed the shortest time interval (15.40 days between two successive full opening of leaves) in a North Sumatra environment (Table 3). "L2T" and "LA ME"which are , genetically similar showed very similar vegetative growth rates independant of the environment (18.09 days for "L2T" and 18.32 days for "LA ME". With reference to the distribution (Fig. 1 a, b, c), the histogramms presented some interesting features. For "L2T" two classes (14-17.5 and 21-24.5 ; The length of classes estimated by dividing the standard deviation by two) presented higher effectives.The same was observed for "LA ME" whereas differences can be seen with "Yangambi". The latter indicating larger effectives for classes : 7-10.5 , 10.5-14, 14-17.5. Comparisons classes for the 3 studied material highlighted the individualisation of "Yangambi" material for this variable. The different peaks observed for each family are probably due to the data collection method : the recording process in the field involves regular constraints on some days (during week end and specific time scedules..). and some observations may be not done totally on time.

In fig. 3 a, the respective normal density function (Z) of the 3 studied materials indicates a better growth regularity with "L2T".

- For the time interval between two female anthesis (Table 3), inside a female cycle (this variable is not continuous) , a strong environmental effect can be seen : "L2T" in Côte d'Ivoire presented the significant shortest time (16.59 days composed to 20.06 days for "LA ME" and 19.22 days for "Yangambi"). The histogramms (Fig. 2 a,b,c) all shows asymetrical features for L2T, LA ME and Yangambi. In all of them, a clear peak is evident for the class 10-15 days. However for the material in a North Sumatra environment, the length between two female anthesis are more variable than L2T in Côte d'Ivoire : for LA ME and Yangambi, the 15-20 days and 20-25 days period still show important effectives. Inside a female cycle the time between two successive female flowerings is shorter than that of two leaf openings for Côte d'Ivoire , the opposite being evident in North Sumatra. In fig. 3 c, it is possible to see that, in North Sumatra, different genetic material shows the same pattern with a spread of the length of the time between two successive anthesis until 25-30 days. This may be due to the fact that there are some some preferential gathering of female anthesis in Côte d'Ivoire caused by the seasonnality of the climatology.

- different features are observed for the male anthesis. For all studies , the time between two male anthesis is shorter than between two female (Table 3) . "LA ME" material has the significantly longest time interval (16.51 days) (Fig. 3 b). All studied material shows bigger strenght for the 3 following classes : 10-15 days, 15-20 days, 20-25 days (Fig. 2 d, e, f) , although the "LA ME" family shows different distributions (Fig. 3 b). This may be due to the low male rate for this family.

- another interesting variable is the time between full opening at rank one and the anthesis of the inflorescence at the axil of the same leaf (flow_rank1). For both sex, there is a complete segregation between both environments; "Côte d'Ivoire" and "North Sumatra" (Fig. 3 e, f). The longest (Table 3) time can seen with "L2T" (Female : 274.59 days; Male 257.76 days) compared to "LA ME" (Female : 244.7 days ; Male : 237.01 days) and "Yangambi (Female : 244.8 days; Male : 234 days). For the females, histogramms show that "L2T" indicated numerous strenght for 4 classes : 240-250 days, 250-260 days, 260-270 days and 270-280 days. For both families in North Sumatra, numerous strenght may be seen for the classes 230-240 days, 240-250 days and 250-260 days. For the male, histrogramms highlighted shorter numerous strenght zone (from 220-230 days to 230-240 days) for the North Sumatra material whereas , "L2T" shows different distribution (very asymetrical) with a peak from class 210-220 to 240-250 days. Finally, if female and male distributions are compared for all families, as far as the time variable flow_rank1 is concerned, the time interval between the full opening of the leaf and the anthesis of the axil inflorescence is significantly shorter when the axil inflorescence is male as opposed to female (Fig. 3 g, h, i). This is apparent in all shown environments.

- The pattern of the time variable, "harvest_flow", show both environmental and genetic effects on the lenght of the duration of the bunches. In Côte d'Ivoire the duration of maturation is significantly shorter due to seasonnality, 161.73 days against 172.94 days for "LA ME" and 178.19 days for "Yangambi" (Table 3 and Fig. 3 d). A correlation may be found between the length of maturation and the fresh weight of the final bunch. "Yangambi" shows the highest mean bunch weight (Table 3) with 24.28 kg compared to "L2T" (15.5 kg) and "LA ME" (19.23 kg).

2. Seasonnals trends

When the phenological events were examined month by month, very clear annual rhythm (already very well known) may be pointed out. On Fig. 4a and 4b, the probability (density) of each phenological event by family and by month was plotted with the mean annual rainfall distribution. Without taking into account the exact delayed effect of rainfall or water deficit upon 5 months to 24 months, which is not our purpose yet, phenological peaks were examined for all studied material in both environment "Côte d'Ivoire" and "North Sumatra". As it can be expected, in Côte d'Ivoire, in relation with the contrasted bimodal rainfall distribution, clear individualisation of phenological peaks are pointed out. For harvesting peak, March and April are the highest one. Logically same annual variation may be observed for the leaf cutting (Fig. 4 a) which correspond to the prunning during harvesting. A very interesting seasonnal variation is observed for the leaf emission which seems to follow rainfall distribution excepted for July where the rainfall is over 400 mm. For the full opening of the leaf at rank one ther is two levels of stability with one before July and one higher just after. But the most interesting feature is observed for the inflorescence anthesis. In Côte d'Ivoire , for the male anthesis, it is possible point out another very important peak from December to January with two months delayed compared to the female anthesis. In North Sumatra (Fig. 4 b) it can be seen a less constrasting feature in relation with a lack of specific climatic distribution. Harvesting peaks for both studied material "LA ME" and "Yangambi" are situated during the "dry period" from June to August. Same feature is found for the date of leaf cutting. On that last variables there are no difference between both genetic origins. For the leaf development sequences (emission and full opening), the same trend is seen for "Côte d'Ivoire" environment with the rainfall distribution : nevertheless an important unexpected peack can be noticed for the leaf emission in May for both genetic material "LA ME" and "Yangambi" in North Sumatra environment. For "LA ME" it is also in May that a real peak of full opening of leaves at rank one could be noticed. For the respective anthesis of female inflorescences it is interesting to notice the delay between both genetic material with a female flowering peak in December for " LA ME" and in March for "Yangambi". But for the male anthesis both flowering peaks are in May for "LA ME" and "Yangambi".

3. Special remarks on annual growth rhythm fluctuation

With a plot of the time variable, flow-rank1, against the number of leaf observations (this may be a complete chronological reference), regular fluctuations appear for all trees and all environments (Fig. 5). To avoid confusion, only one tree per family is shown. All studied trees presented similar kinds of fluctuations, but are not synchronised. For "L2T", it is clear that these fluctuations are regular, occuring every 20-25 leaves, meaning that the fluctuations are in relation to the seasonnality of climatology. What is more surprising, the trees also present fluctuations in a North Sumatra environment (Fig. 5) more or less every 20-25 leaves for both "LA ME" and "Yangambi" , representing approximatively one year. However these cases, fluctuation rhythms are less obvious and further investigations are required in order to find the periodicity of some growth events;
Concerning the tree synchronisation, for vegetative growth as the leaf emission for example it seems that there are very regular fluctuations, the same for all trees within the same family in both Côte d'Ivoire and North Sumatra. All trees are fluctuat in a similar pattern.

4. Sex sequences study

a-Comparison of sequences within trees

The number of available sequences $S_2S_1S_0$ for one tree are, most of the time, not enought to allow statistic test. To gather for a same family all trees toghether, following tests are required as to test if the probability to get S_0 after S_2S_1 is the same for all trees and this whatever the value of S_0, S_1, S_2. This hypothesis can be tested with a Chi-2 test on effectives of one table by crossing trees of the same family with the respective sequences S_2S_1 A, S_2S_1F and S_2S_1 M . Due to low number of sequences only partial tests were realized on sequences FFF and FFM, in one part and MMF and MMM in other part which are the most numerous for all trees. The Chi-2 test is not significant in 5 cases on 6 (Table 4), and this allow to put all sequences $S_2S_1S_0$ togheter within a family. Only for "LA ME" the Chi-2 test is significant on MMF/MMM sequences: all results on that family have to be considered very carefully.

b-Study of sequences S_1S_0 by family

The sex S_0 of one inflorescence is independant from the previous one if the probability to get S_0 is the same whatever the sex of S_1. This hypothesis was tested for each family by a Chi-2 test on contengency table S_1/S_0 (Table 5). For the all three families , the Chi-2 is hightly significant and gives the opportunity to say that the sex of one inflorescence is hightly dependant from the previous one.

c-Study of sequences $S_2S_1S_0$ by family

If the sex S_0 of one inflorescence is only depending on S_1 the previous one, this process may be assimilate to a Markov chain (Guedon et al., 1995) at first order. This hypothesis (probability to get S_0 when S_1 is fixed is the same whatever S_2) was tested for each family by Chi-2 test (df equal to 4) on three contengency tables (Table 6) S_2A/ S_0, S_2F/S_0 and S_2M/S_0 . The dependance seems to be different within families. For "L2T" the dependance between S_0 and S_2 is only significant if S_1 is not an aborted inflorescence. On 9 tests, 4 are highlty significant. It seems that we may consider in conclusion that the sex of one inflorescence is depending from the sex of the two previous one .

d-Abortion role

When we look the different proportions when there is an abortion in male or female sequence, it is clear that the result is depending on the "position" of this abortion in the sequence. For "Yangambi" (Table 6) it can be noticed that there is a probability of 0.79 to get a M after MM After AM this proportion increase to 0.85, but go down to 0.57 after MA. Same feature can be noticed for "LA ME" and "L2T". The abortion stage "A" may indicated in all case a change in the sex of the following inflorescence and may play a role in the apparition of a new sexual cycle. Abortion may be important in the regulation of the palm tree. The respective abortion proportion (Table 7) for all the studied families is around 0.14 for all whatever the genetic origin or the environment .

Conclusion

Unquestionably, as far as the phenology of the oil palm is concerned, the work of Bredas and Scuvie (1960) has bring the first important results on that field. Their main conclusions were dealing with the co-occurrence at each leaf axil of an inflorescence which may abort 4 to 9 months before anthesis. If, as a consequence in their sense, the yield may be related to the number of emitted leaf during the year. The last result of their work is the clear relation, between female abortion and the effect of a dry period 19 to 20 months before harvesting. The first result of this present work is related to the genetic dependance of the full development rhythm of the leaves at rank1 because similar families L2T and LA ME are presented quite equal leaf emission (20.17 leaf per year for L2T and 19.92 for LA ME) in different environment. This point refutes what it is generally admitted in litterature where the leaf production is related to the climate. But our results confirm emission rate found in Sumatra by Fickendey and Blommendaal (1929, quoted by Hartley, 1988), between 20-24 leaves per year and in West Africa with 18-27 leaves per year (Hartley, 1988). An important point to add is the obervation of the regular variation of leaf emission inside the year due to rainfall distribution in both environments Africa and Sumatra and for all families. If some autors already emphased the effect of dry period to restrict leaf opening, recurring variations and typical periodicity of the leaf development inside years have been not pointed out yet. According Corley (1977), we have to expect same rhythm between leaf emission and inflorescence flowering. Our results show, firstly, a difference, inside a same family, between male and female for the time between two successive flowering. The time of successive male

anthesis is always shorter than the time of successive female anthesis in any kind of environment. What is more surprising is the difference, inside a family, between the leaf emission rhythm and the anthesis rhythm.With respective sex ratio, these rates may be equilibrated for “LA ME” and “YANG”. For L2T, the anthesis rhythm is always shorter than the leaf emission : at the year’s scale, both rhythms may be equilibrated due to the strong seasonnality effect on anthesis in West Africa and abortion rate. For the time between the full opening of the leaf at rank1 and the anthesis of the axil inflorescence, same reccuring variations along year may be pointed out. This time seems to be totally environment dependant. This time is always shorter when the axil inflorescence is a male than when it is a female. A shorter time between the leaf opening and the anthesis of the axil inflorescence seems to be related with a good production. But the contrary is observed for the time between anthesis and harvesting. This time is both under genetic and environmental dependance. An interesting correlation may be found between the length of this period (ripening) and the weight of the bunch. In Côte d’Ivoire the ripening length is shorter due to environmental constraint and regular water deficit.
The observation of seasonnal peaks shows constrated feature in Côte d’Ivoire related to the typical rainfall distribution. Leaf emission seems positively in relation with the rainfall until a sum of 1200 mm. In Côte d’Ivoire , female and male anthesis peaks differed from two months but both occurs out of the long wet season. In Marihat, in a North Sumatra environment similar relation with the leaf emission and the rainfall can be pointed out : it is an interesting result. In this environment, it can be observed also a delay of two months between female flowering of “LA ME” and “yangambi” material. The study of the regular fluctuations and theirs similarities within the trees of the development of the leaf inside a year was not clearly identified before : it has to be emphased in the future.
The study of sexual sequences composed by 3 successive inflorescences F (female) , M (male) or A(aborted) has permit to establish that sexual cycles are not following markovien process at first level due to the change in probability when there is an aborted inflorescence in the sequence. In clear, abortion mostly appears as a way for each tree to regulate the sex ratio and to establish a good concordance between leaf and inflorescence growth rhythm at annual level.

Acknowledgements

We are grateful for the phenological data set, coming from Côte d’Ivoire provided by the staff of the Agronomy Service (CIRAD-CP) and for the help of the staff of Marihat during measurements .

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Contribution à l’étude de la sélection de l’Elaeis guineensis à Sumatra.B.A.C.B. n° 1.

Table 1. Vegetative and reproductive characteristics of the three studied families. Respective standing biomass are in DM.

	L2T (Ivory Coast)	LA ME (Marihat)	YANG (Marihat)
leaflets (t.ha-1)	4.95	6.25	10.69
petiole (t.ha-1)	8.97	10.93	20.14
rachis (t.ha-1)	6.05	8.31	13.60
trunk (t.ha-1)	21.75	21.23	39.30
roots (t.ha-1)	31.48	14.12	9.69
FFB (t.ha-1)	cf Dufrêne (1989)	24.02	16.89

Table 2. ANOVA on studied variables for the tree effect within families. D.F. : degree of freedom. Results of the Fisher tests are done with indication of the level significance ; P < 0.001 : ***, P< 0.01 : **, P<0.05 : +, n.s. : non significant.

variable	material	D.F.	Fisher test	variable	material	D.F.	Fisher test
int_rank1	L2T LAME YANG	22 19 20	** + n.s.	int_flow	L2T LAME YANG	22 19 20	+ n.s. n.s.
flow_rank	L2T LAME YANG	22 19 20	*** *** ***	FFB	L2T LAME YANG	22 19 20	** *** ***
harvest_flow	L2T LAME YANG	22 19 20	*** *** ***				

Table 3.Time interval study for all phenological variables . Meaning of abreviation : Int_rank1 : time interval between two successive full opening of leaves on the same tree. Int_flow : time interval between two successive anthesis (male and female). Flow_rank1 : time interval between anthesis of the inflorescence which is at the axil of one leaf which is at the full opening at rank one. Harvest_flow : time interval between the flowering of the inflorescence and its harvesting when mature. ANOVA have been done with SAS system to compare variance of respective variable for each studied material “L2T”, “LA ME” and “Yangambi”. *** :significant under 0.001. S.d. standard deviation , N : number of observation.

variable		L2T	LA ME	YANG	test Fisher
int_rank1 along year	mean(days) s.d. N	18.09 6.43 2268	18.32 8.19 1106	15.40*** 7.21 1369	74.56 P<0.0001
int_flow in a female cycle	mean(days) s.d. N	16.59*** 8.96 836	20.06 11.60 417	19.22 12.09 286	18.05 P<0.0001
int_flow in a male cycle	mean(days) s.d. N	15.90 8.21 1106	16.51 10.25 296	14.56*** 8.46 634	6.88 P<0.011
flow_rank1 femelle	mean(days) s.d. N	274.59*** 31.07 718	244.77 24.57 387	244.89 25.18 308	196.92 P<0.01
flow_rank1 male	mean (days) s.d. N	257.76*** 29.01 1004	237.01 26.01 310	233.81 23.10 575	171.37 P<0.001
harvest_flow	mean(days) s.d. N	161.73*** 10.68 815	172.94*** 14.09 374	178.19*** 13.38 283	237.8 P<0.0001
FFB	mean(kg) s.d. N	15.53*** 5.02 895	19.226*** 5.90 511	24.284*** 8.08 414	321 P<0.0001

Table 4. Sequences study for “L2T” “LA ME” and “Yangambi”. Chi-2 on partial $S_2S_1S_0$ sequences to test trees effect within studied families.

material	sequences	Chi-2	ddl	Proba
L2T	FFF/FFM	25.55	22	0.272
	MMF/MMM	9.14	22	0.993
LA ME	FFF/FFM	28.51	22	0.159
	MMF/MMM	45.36**	21	0.002
Yangambi	FFF/FFM	20.06	21	0.517
	MMF/MMM	21.91	21	0.405

Table 5. Markov chain on sexual sequence , test on dependance level for each studied family “L2T” “LA ME” and “Yagambi”. Chi-2 test for ckecking for each family if the dependance of the sex is at first order.

material	S1	Chi-2	Prob
L2T	A	5.109	0.276
	F	40.592**	0.001
	M	20.576**	0.001
LA ME	A	19.165**	0.001
	F	3.388	0.495
	M	2.328	0.676
Yangambi	A	47.412**	0.001
	F	8.149	0.086
	M	3.473	0.482

Table 6. Abortion role . Study for each studied families “L2T” “LA ME” and “Yagambi”.

	L2T	LA ME	YANGAMBI
S0	M	M	M
MM (S2S1) AM MA	0.79 0.68 0.26	0.65 0.66 0.44	0.79 0.85 0.57
	F	F	F
FF AF FA	0.72 0.70 0.19	0.75 0.77 0.34	0.59 0.54 0.26

Table 7. Respective proportion of female , male and aborted inflorescences for all studied families.

%	A	F	M
L2T	13.19	37.72	49.09
LA ME	14.24	32.18	53.58
YANGAMBI	13.04	29.29	57.68

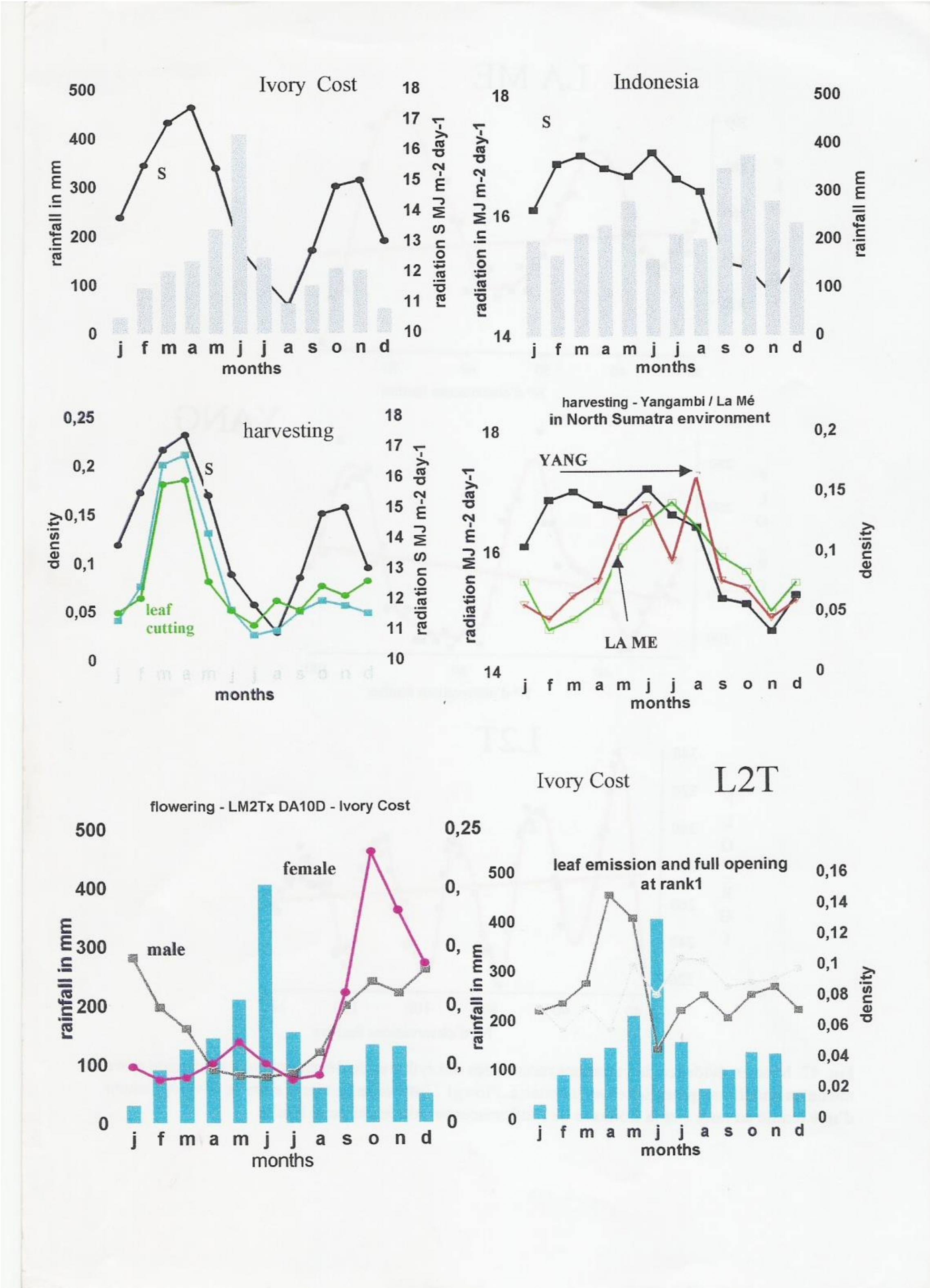

Fig. 1. General overview phenological and climatic results for L2T, Lame and Yangmabi materials under Ivory Coast and Sumatra environment.

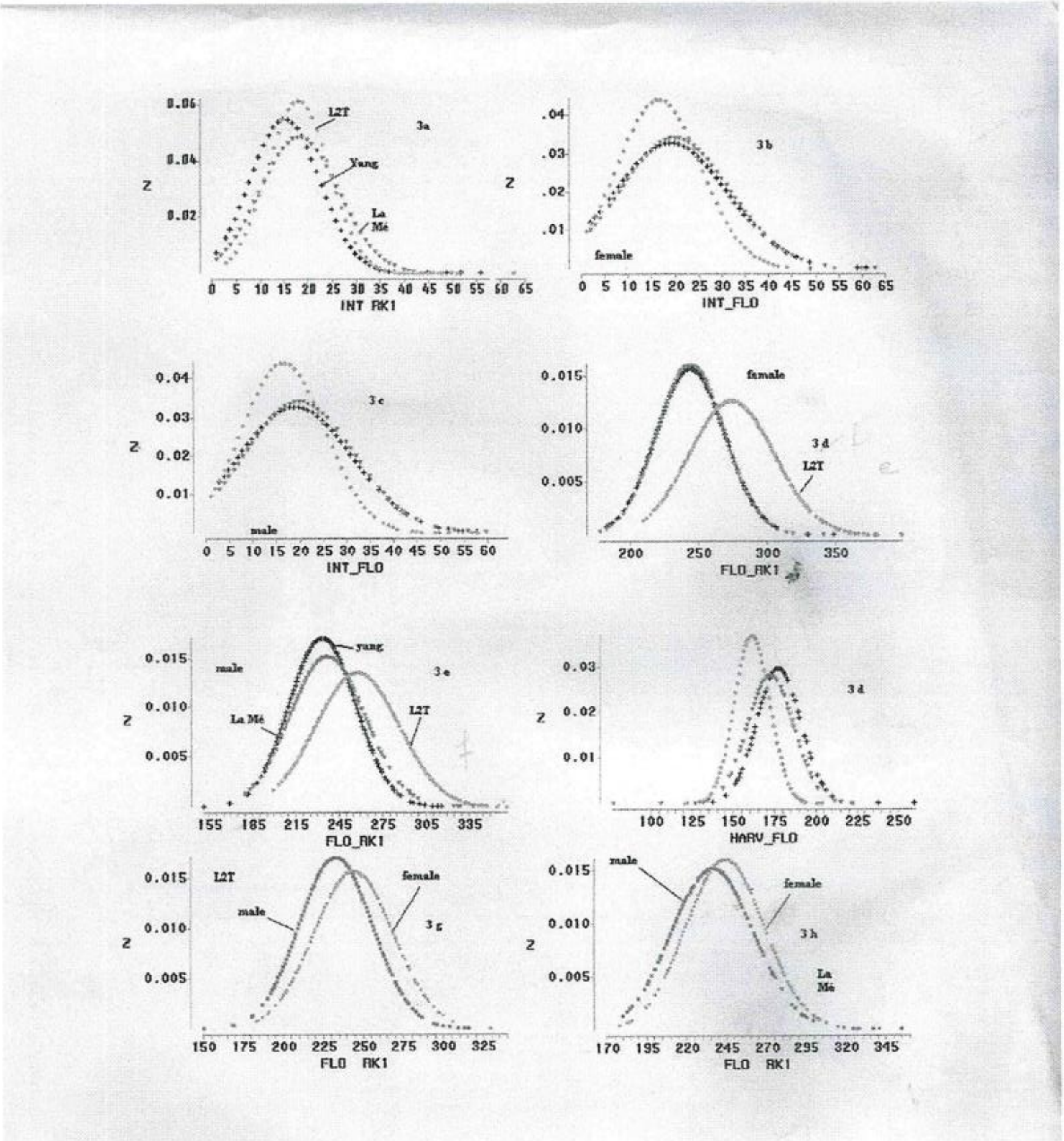

Fig. 2 . Comparison of distribution and average for phenological variables (INT-RK1…) for 3 different matérials.

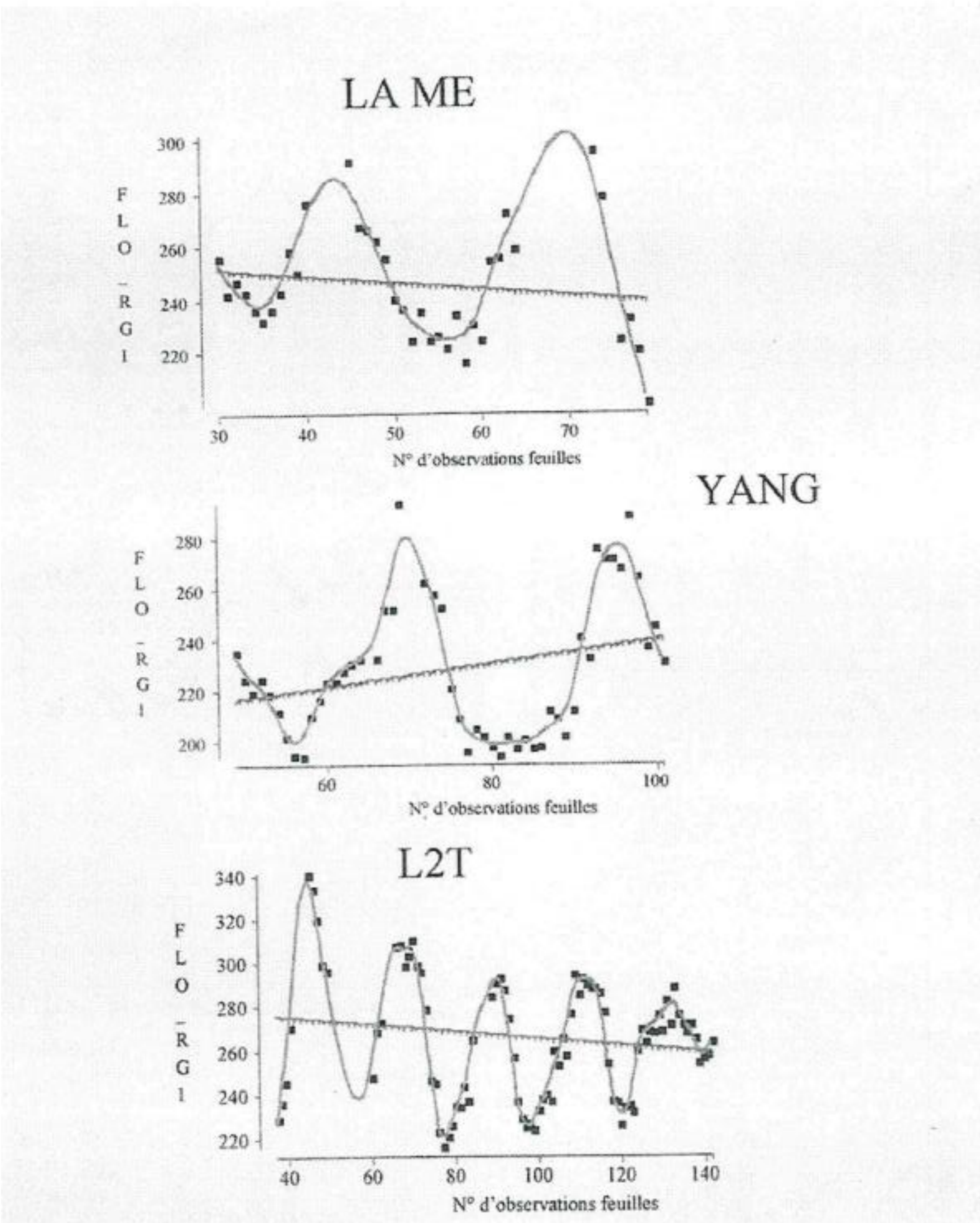

Fig. 3. Seasonnal variations of the length of the period between leaf emission and flowering stage of the inflorescence axilled by the leaf for 3 materials and 2 locations Lame and Yang in Sumatra (Indonesia) and L2T in Ivory Coast.