C. R. Acad. Sci. Paris, Sciences de la vie/Life sciences, 1996 ; 319 : 523-7
Biologie et pathologie végétales/*Plant biology and pathology*

Dendrochronological approach to the radial growth of okoume (Congo)

Approche dendrochronologique de la croissance radiale de l'okoumé (Congo)

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RÉSUMÉ

La croissance radiale de 4 sections d'okoumé du Congo provenant de 4 arbres différents est analysée. La présence dans la région d'au moins une saison sèche marquée permet de définir des cernes de croissance annuels. Ils sont mesurés et les courbes des largeurs de cernes sont confrontées de manière graphique afin de vérifier que l'année de formation attribuée à chaque cerne est exacte (interdatation). Le synchronisme est mauvais lorsque les courbes appartiennent à des arbres différents. Pour lever le doute quant à la validité de la délimitation des cernes annuels, une confrontation avec les enregistrements pluviométriques de Pointe Noire est tentée. Le résultat du test est positif et les limites de cernes établies au début de l'étude sont maintenues. L'approche dendrochronologique sur une espèce telle que l'okoumé est donc possible mais une vérification de l'interdatation par confrontation avec des données climatologiques est indispensable. Ce type d'approche conduisant à une datation absolue des cernes peut être d'un grand intérêt en écologie tropicale : elle permet en particulier de replacer les analyses biogéochimiques des cernes dans un cadre chronologique exact, ou encore d'apprécier la vitesse de progression des lisières forestières.▲

Mots clés : *dendrochronologie,* Aucoumea klaineana *Pierre, Congo, Afrique centrale, écologie végétale.*

ABSTRACT

The radial growth of 4 stem disks of okoume, sampled from 4 different trees in Congo, was analyzed. The presence of at least one marked dry season allowed one to describe annual growth rings. These rings were measured and the ring width curves were compared on a graph in order to check that the crossdating (1 ring corresponds to 1 year) was correct. The synchronism of the chronologies was bad when they belonged to different trees ; the limits defined for the annual rings were thus uncertain. In order to check these ring limits, the chronologies were compared with the rainfall records obtained at Pointe Noire. As the test was positive, the assumed limits of the annual rings were considered valid. Age dating seems to be possible on okoume, but the crossdating must be checked by comparing the rings chronologies with climatological data. Dendrochronology can be a very useful tool for tropical ecological studies: it enables one to place the ring biogeochemical analysis within an accurate chronological frame and to assess the speed of the forest advance over the savannah. ▲

Key words: dendrochronology, *Aucoumea klaineana* Pierre, Congo, Central Africa, ecology.

VERSION ABRÉGÉE

Une analyse dendrochronologique est menée sur 4 sections d'okoumé (*Aucoumea klaineana* Pierre) provenant de la région de Kouilou (4°03' S., 11°38' E.) dans le sud-ouest du Congo. Cette analyse, qui vise à déterminer précisément l'âge des individus abattus, s'insère dans le cadre du programme CNRS-ORSTOM ECOFIT (écologie et paléoécologie des forêts intertropicales).

La présence dans la région d'une saison sèche, fraîche et nuageuse de 4 à 5 mois permet d'espérer une périodicité de la croissance radiale. L'interdatation des sections sous loupe binoculaire (qui a pour but d'attribuer à chaque cerne de croissance l'année de sa formation) se révèle difficile. Pour vérification, les cernes définis

Note présentée par Michel Thellier.
Note remise le 16 février 1996, acceptée le 22 avril 1996.

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par l'interdatation sont mesurés et les chronologies de largeurs de cernes annuels ainsi obtenues sont comparées de manière graphique. Les courbes ne sont pas toujours synchrones, en particulier quand elles appartiennent à des arbres différents. Lorsque l'arbre est jeune, la largeur du cerne annuel varie beaucoup d'un point à l'autre de la circonférence du tronc. Plusieurs hypothèses sont avancées pour expliquer l'assynchronisme des chronologies appartenant à des arbres différents, mais la validité de l'interdatation est également remise en question. Afin de vérifier ce dernier point, la chronologie de l'arbre le plus vieux est confrontée à la courbe des précipitations annuelles enregistrées à Pointe Noire. Une nette correspondance entre les courbes apparaît, si on confronte cette chronologie (K3) avec la somme des précipitations allant d'octobre de l'année (n – 1) à septembre de l'année (n). Afin de préciser quel facteur pluviométrique de l'année conditionne la variation interannuelle des largeurs de cernes, cette séquence est divisée en plusieurs périodes correspondant aux saisons. C'est la somme des précipitations comprises entre octobre (n – 1) et janvier (n) qui est la mieux corrélée avec K3.
L'okoumé semble être un piètre enregistreur des facteurs climatiques au début de sa vie (15-20 ans), mais la quantité de pluie (particulièrement celle s'étalant de la fin de la grande saison sèche à la fin de la petite saison des pluies) apparaît par la suite comme un bon facteur limitant de la croissance radiale. L'approche dendrochronologique semble donc applicable à l'okoumé dans les conditions climatiques locales, mais une vérification de l'interdatation par confrontation avec des données pluviométriques reste cependant indispensable. La dendrochronologie, parce qu'elle permet de définir l'âge des arbres, s'avère d'un grand intérêt en écologie tropicale pour toute la recherche touchant à la dynamique forestière, aux taux de croissance et de régénération, ainsi qu'à l'analyse isotopique en offrant la possibilité de travailler sur des cernes datés. ▲

Within the framework of a study carried out by CNRS-ORSTOM (ECOFIT), in the region of Kouilou (west Congo), near Kola village (4°03′ S., 11°38′ E.) 4 okoumes (*Aucoumea klaineana* Pierre) were cut down. One of the aims of the study was to describe the vegetation dynamics at the forest edge in a landscape consisting of a mosaic of savannah and forests. At the edge of the forest, okoumes are abundant and form a typical colonizing front *(Fig. 1)*. Although calibration tables established by foresters allows to estimate roughly the age of the trees [1], it appeared that the dendrochronological method can provide their exact age. The 4 stem disks were therefore prepared for tree ring analysis. In his study about the growth periodicity of tropical trees, Détienne [2] ranks okoume among the species that are more or less liable to be correctly dated (depending on the growth rate). In the study area, the dry season lasts 4 to 5 months and it is cloudier and cooler than the rest of the year; so despite the pluviometric deficit, the evapotranspiration is limited. Owing to this dry season, distinct rings were expected, allowing a dendrochronological approach to the problem [3].

Materials and method

Stem disks were cut as close as possible to the base of the trees, above the swells (up to 2-3 m), in order to know the age of the trees.
The radial growth of these trees was more or less eccentric: slightly so for disk K0 (diameter = 36 mm) and K1 (diameter = 170 mm), quite so for K2 (diameter = 400 mm) and markedly so for disk K3 (diameter = 600 mm).
For each section, 3 radii at approximately 120° from one another, were selected. But in the disk with the most eccentric radial growth (K3), the smallest and the largest radii were left aside and only 2 radii were selected.
Each radius was carefully sanded and partly coated with oil in order to intensify the contrast between clearly alternating light and dark layers.
A delimitation of annual rings was then attempted under binoculars, on the basis of Mariaux's [4] anatomical observations.
A normal annual ring should comprise: (1) a light layer; (2) a dark layer with poorly marked borders corresponding to the main dry season (from June to September); (3) a second light layer smaller than the first one; (4) a dark line with abrupt borders corresponding to the short dry season of the beginning of the year (December and January).
A normal annual ring should therefore be contained between the 2 dark lines of the short dry period. *(Fig. 5B)*.
Unfortunately such normal rings were not frequent on K0, K1, K2 and K3. According to Mariaux's tree ring typology [4], it seemed that most of the rings examined were « r » type rings in which the second light layer did not exist and the dark line was fused with the dark layer. Moreover, sometimes the dark layer showed very abrupt borders (initial or final) and this may have brought about confusion.
Other rings were rather « s » type rings with no dark line. In that case the limits between 2 annual rings were assumed to be situated in the first third of the light layer.
Some rings composed of well identified light and dark layers could be recognized on the 3 radii of the same tree. But such event years [5] were hardly recognizable when the radii belonged to different trees.
The 10-15 first years of the okoume life are known to be the period the most difficult to analyze [4, 6]. This was not the case for K3 as its rings were of « normal » type and easy to define precisely over the 10-15 first years.
Despite the helpful ring typology proposed by Mariaux, the delimitation of growth rings in the okoume (at least in our samples) appeared to be quite arbitrary in practice. So the crossdating of the radii (that is to say the determination of the year of growth corresponding to each ring) had to be checked with a graphic comparison of the ring width chronologies built for each radius: k11, k12 and k13 for tree K1, k21, k22 and k23 for tree K2 and k31 and k33 for tree K3. No chronology was built for K0 because this tree was too young (only 3-year-old).

Results

Visual comparison of the chronologies of the radii for each tree *(Fig. 2, A, B and C)*

The curves of trees K1 and K2 are badly synchronized over the 15-20 first years. After 20-year-old, some good event years (the years for which all the curves of the graphic vary

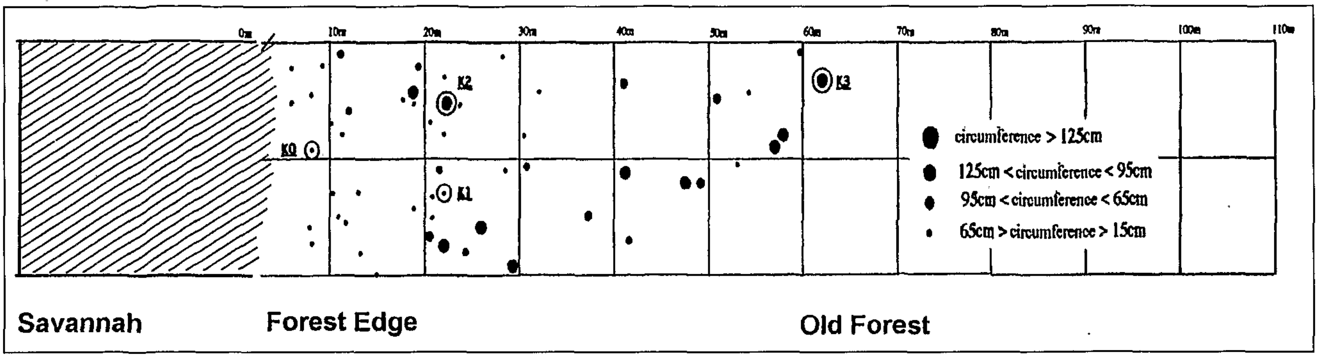

Figure 1. ***Distribution of the okoume trees from the savannah and the edge of the forest to the heart of the forest.*** *K0, K1, K2 and K3 are the sampled trees.*

obviously in the same way) testify to the good synchronism of the chronologies.
The synchronism is good throughout the chronologies for K3.

Visual comparison of the mean chronologies *(Fig. 3)*

A mean individual chronology was built for each tree including the different chronologies of the different radii.
The graphic comparison of the chronologies shows that K2 and K3 are badly synchronized except over the 10 last years and that K1 is synchronized neither with K2 nor K3.

Discussion

The only hypothesis that can explain the asynchronism of radial chronologies in the youth of the tree *(Fig. 2)* is the unevenness of the ring-width on the whole circumference [2]. When the tree is young, the interannual variation of ring-width is different from one radius to the other.
Several hypotheses were put forward to explain the poor synchronism of the mean individual chronologies *(Fig. 3)*: (1) the analyzed trees were too young and were therefore bad recorders of the surrounding factors; (2) none of the climatic factors was limiting enough to be recorded in the same way by all the trees (but only 3 trees were studied here...); (3) young trees grow at the edge of the forest, and hence in an anisotropic surrounding whereas oldest trees are deeper in the forest, and hence in an isotropic surrounding; (4) mistakes in the identification of the annual ring and in the definition of its limits led to distortions in the crossdating.
In the absence of a larger tree ring data-set, only the second and the fourth hypotheses can be tested. In tropical area, temperatures are quite constant throughout the year *(Fig. 5A)*. Therefore it can be assumed that the interannual variability of ring-widths can only be linked to the interannual variability of precipitation (this includes annual precipitation, length and intensity of the dry periods and also variations in cloudiness). So, the mean chronology of K3 (the longest one) was compared with different summations of monthly precipitation recorded at Pointe Noire from 1924 to 1991 [7, 8].
Unfortunately, if the occurrence of periodical growth zones can be undoubtedly associated to the physiological response of the tree to changing environmental conditions, we have no idea about the timing of cambial activity at the study site.
According to Mariaux's tree ring typology, one can consider that the annual ring ends with the dark line corresponding to the short dry period (January or February). Interannual variability of total ring-width can therefore potentially be correlated to the precipitation of a period prior to these months. For the period 1924-1991, different combinations of monthly precipitation have been tested against the ring-width chronology *(Fig. 5C)*. Synchronism between the precipitation and the tree ring chronologies is tested through cross-correlation and visual matching of the corresponding curves.
As most of the rings encountered are « r » type rings (see above), the ring of the year (n) is compared with the precipitation rate between October (n – 1) and September (n) *(Fig. 5)*. Despite the great distance between the site and the meteorological station, the 2 chronologies were well synchronized *(Fig. 4)*. Assuming that a narrow ring corresponds to a dry year, the sampling of the trees may be dated to 1994. This date was confirmed by the persons who did the fieldwork.
However in the chronology of K3, 2 periods were distinguished: (1) from 1924 to 1944, *i.e.* the youth period, the curves are badly synchronized; (2) after 1945, the curves are well synchronized except during the period from 1972 to 1985 *(Fig. 4)*.
In contrast, comparison between the chronology of K2 and the rainfall curve showed that for the period from 1972 to 1985, the synchronism of the curves is quite correct.
But the sequence corresponding to the youth of K2 (1940-1960) is not synchronized either with the precipitation rates.
The K3 chronology is long enough to enable a calculation of correlation with precipitation chronologies. Owing to the singularity of this chronology for the period 1972-1985, the latter was not included in the calculation, neither was the youth period.
The results obtained for different periods of the year from October (n – 1) to December (n), show that significant correlation is obtained only for the sequences October (n – 1)-September (n) and October (n – 1)-January (n). As the second period is included in the first one, much of the ring-width interannual variability is explained by the precipitation of October (n – 1) to January (n), which corresponds to the main wet season *(Fig. 5)*.

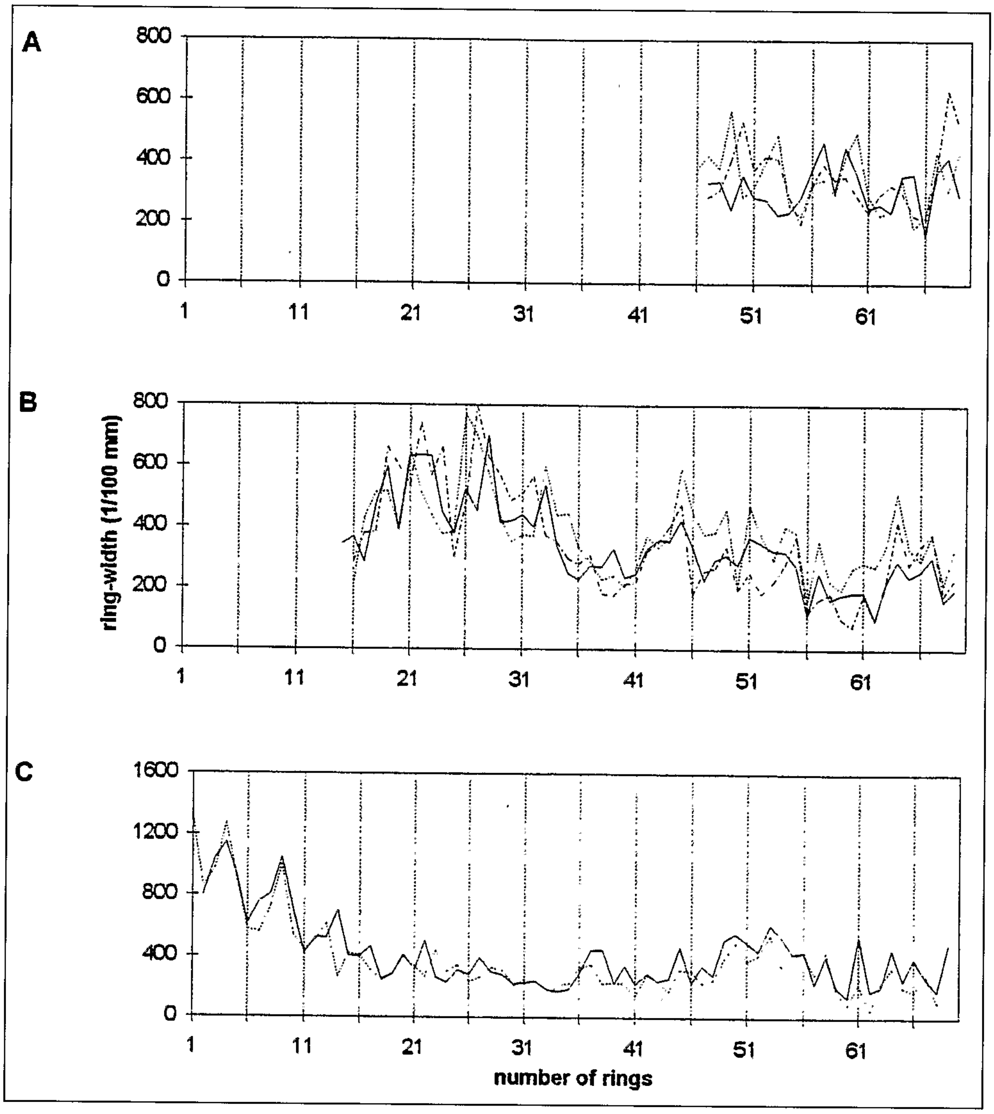

Figure 2. ***Comparison between the elementary chronologies (radii) of the trees. (A)*** *For tree K1.* ***(B)*** *For tree K2.* ***(C)*** *For tree K3.*

These results allowed one to conclude that: (1) the hydric factor is limiting enough to be recorded in the interannual variations of the radial growth of the tree; (2) the dating of the rings is correct for K3 and K2, and the ring limits are considered valid; (3) the okoume really reacts in an anarchic way to rainfall when it is young (the lack of synchronism between K3 and rainfall cannot be attributed to a bad crossdating over that period as in K3, the rings limits were obvious over the 15-20 first years); (4) the radial growth chronologies of the okoume sometimes show disturbance episodes, probably due to intrinsic and/or local factors temporarily more limiting than the surrounding ones (regional rainfall). If such episodes occur between 2 well synchronized sequences, the crossdating of the wood sample can be considered correct.

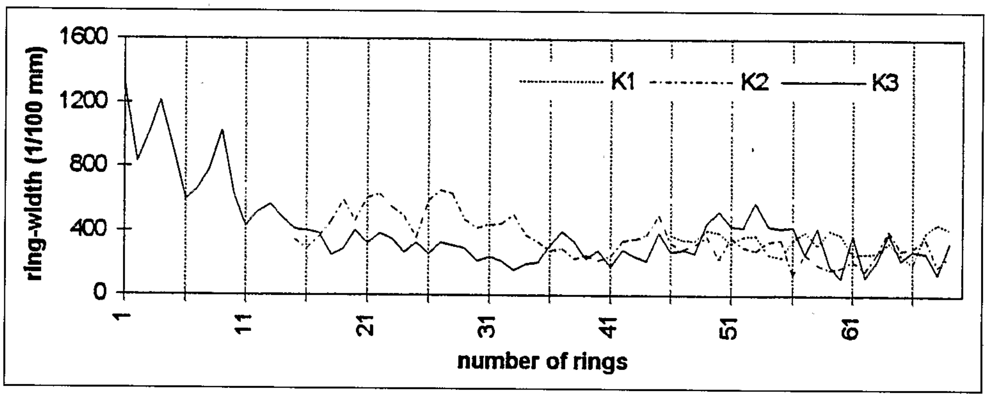

Figure 3. ***Comparison between the individual (the mean of the 3 radius) chronologies of the trees (K1, K2 and K3).***

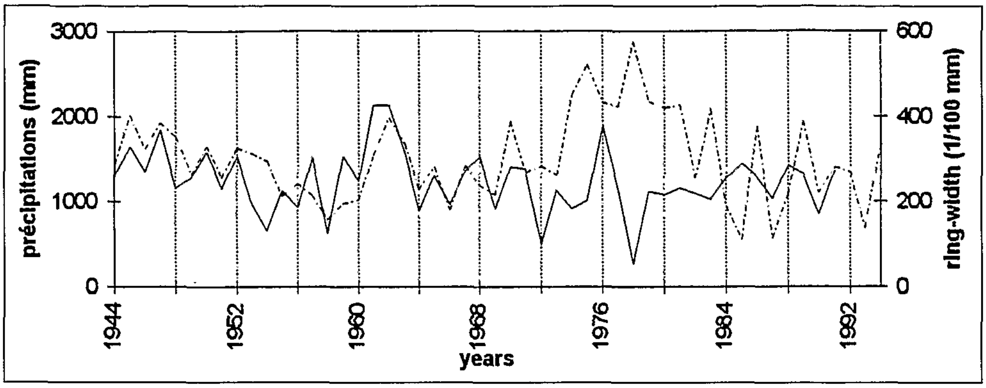

Figure 4. ***Confrontation of the mean chronology of K3 (dotted line) and the curve of the precipitation from October of the year (n – 1) to September (n) at Pointe Noire (solid line), over the period 1944-1991.***

Conclusion

The 4 okoumes studied were 3-(K0), 24-(K1), 55-(K2) and 69-(K3) year-old in 1994 when they were cut. (The ages given for K0 and K1 cannot be absolutely certain as these trees are very young and there is no synchronism between their chronologies and the rainfalls curve.)

In view of the uncertainties in the reading of the okoume ring series, the age proposed after the crossdating needs to be checked thanks to a comparison with climatological data. In the event of negative results it would be risky to give a chronological conclusion.

Nevertheless, the age dating of trees is very important for the tropical ecological research dealing with increment rates, regeneration patterns and stands dynamics as for instance the measure of the speed of the forests advance over the savannah, which is a widely spread phenomenon in southern Congo [9]. If the interannual variability of the ring width is proved to be sufficiently correlated to precipitation, tentative dendroecological and dendroclimatological approaches [10-12] can be made. Such studies would focus in a first step, on areas where the dry season is well defined [13]. Moreover even though correlation between ring-width and precipitation is not strong enough to enable a reconstruction, the identification and dating of annual rings make it possible to use tree rings in biogeochemical and isotopic analyses. ▼

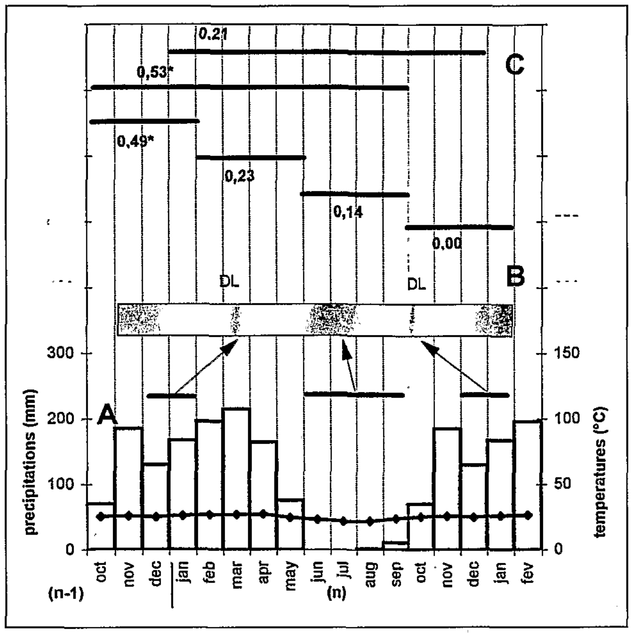

Figure 5. ***Synthetic graph of the study.*** ***(A)*** *Ombrothermic diagram of the region (Pointe Noire - 1935-1981).* ***(B)*** *Relation between the formation of the normal annual ring and the seasons of the year (DL means dark line).* ***(C)*** *Correlation coefficients between ring-width chronologies and precipitation series obtained by adding up monthly values over different periods. * Correlation significant at the level 99%.*

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