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PATTERNS OF FLOWERING IN SOME INDIGENOUS TREE SPECIES IN THE HUMID LOWLANDS OF CAMEROON

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Abstract

Studies were conducted on eight plant species of the humid forest of Cameroon from July 1989 to June 1991. The objective was to evaluate the effect of exogenous factors on the flowering patterns of these species. Flowering phenology was monitored in two sites of the humid lowlands of Cameroon. The experimental design was a split-split-plot with three replicates. The species was considered as main plot whereas sites and years represented the sub- and sub-sub plot, respectively. The experimental unit was made up of seven individual trees. The results showed that the mean period and the range of flowering of the species varied. They were also influenced by the pedoclimatic conditions of the sites. Two categories of the species were distinguished: the species which flowered early in October (*Alstonia boonei*) and that which flowered in mid February (*Ricinodendron heudelotii*). According to the range of flowering, *Alstonia boonei* was classified amongst the plants with brief flowering whereas *Pycnanthus angolense* belonged to the group of extended flowering. Concerning the flowering frequency, species noticed with regular flowering include *Cordia plathyrsa, Pycnanthus angolense, Ricinodendron heudelotii, Milicia excelsa* and *Terminalia superba,* and irregular flowering species include of *Alstonia boonei* and *Ceiba pentrandra. Ricinodendron heudelotii, Cordia plathyrsa* and *Milicia excelsa* were dioecious.

Résumé

MAPONGMETSEM PIERRE MARIE, NKONGMENECK BERNARD ALOYS & DUGUMA BAHIRU: *Modéles de floraison en quelques espèces d'arbre indigène dans les plaines humides de Cameroun.* Des études se déroulaient sur huit espèces de plantes de la forêt humide de Cameroun de juillet 1989 à juin 1991. Le but était d'évaluer l'effet de facters exogènes sur les modèles de floraison de ces espèces. La phénologie de floraison était surveillée à deux sites des plaines humides de Cameroun. Le dessin d'expèrience était un lot-divisé-divisé avec trois replicatifs. Les espèces étaient considérées le lot principal alors que les sites et les années représentaient respectivement la subdivision et le lot-subdivisé-subdivisé. L'unité expérimentale comprenait sept arbres individuels. Les résultats montraient que la période moyenne et l'écart de floraison des espèces variaient. Ils étaient influencés également par les conditions pédoclimatiques des sites. Deux catégories d'espèces étaient distinguées: Les espèces qui fleurissaient tôt en octobre (*Alstonia boonei*) et celles qui fleurissaient en mi-février *(Ricinodendron heudelotii*). Selon l'écart de floraison *Alstonia boonei* était classé parmi les plantes avec la floraison brève alors que *Pycnanthus angolense* apartenait au groupe de floraison prolongée. Concernant la fréquence de floraison, les espèces avec la floraison régulière étaient identifiées Comme *Cordia plathyrsa, Pycnanthus angolense, Ricinodendron heudelotii, Milicia excelsa* et *Terminalia superba* alors que les espèces de floraison irrégulière comprenaient *Alstonia boonei, Ceiba pentandra. Ricinodendron heudelotii, Cordia plathyrsa et Milicia excelsa* étaient les espèces dioïques.

Introduction

Tropical moist forests are biologically the richest ecosystems in the world (Orians, Dirzo & Cushman, 1998). Their significance, characteristics and the origins of their extreme diversity are not yet well understood. Unfortunately, they are subjected to large-scale degradation and land conservation. Yet conserving biodiversity in the tropics has become an issue of increasing priority and urgency in recent years (Heywood & Watson, 1995). Land misuses could change structure and species composition of these forests. Specific pollinators, dispersal agents and important ecosystem functions might also be influenced. Forest regeneration, whether natural or not, depends first on the production of seeds. Knowledge of the flowering phenology of the humid lowlands of Cameroon tree species is very limited. In addition it is difficult to predict seed production in most agroforestry tree species, and, more so, in individual trees.

Initiation of flowering in trees is controlled by a complex interaction of genotype, past growth and environment which is poorly understood. The alternative and usual approach is to monitor flowering over extended periods and to examine correlation between these events and climatic variables. The common approach to the prediction of fruiting events is to search for correlations between environmental factors and flowering or fruiting events. Such correlations might not indicate causal relationships but, if sufficiently strong, could be useful predictors (Swaine *et al.*, 1997). Predicting a flowering event is the first step to predict fruiting, although this does not invariably follow. These kinds of fundamental data are potentially valuable for predicting timing and range of seed production to help in the management of natural forest and in the supply of seeds for nurseries.

Plant biology is controlled by a combination of various ecological processes including biotic and abiotic variables which are important on a spatial and temporal scale. Abiotic factors such as climate (precipitation, temperature, hygrometry) and soil are important in tropical forests as they influence the phenological mechanisms (Mapongmetsem *et al.*, 1998). However, data on the effect of climate on flowering patterns in the humid lowlands of Cameroon are still very scanty. The present study was, therefore, undertaken to investigate the influence of climate and site on the flowering patterns and the existing correlations.

Experimental

The study area

The study was conducted in two sites: Mfoundi in the centre Province, and Dja and Lobo in the South Province, both in the humid lowlands of Cameroon. The two sites are located between latitudes 2°56' N and 3°52' N; longitudes 11°32' E and 11°57' E at an altitude of 813 m above sea level. According to data collected during the study period (1989 - 1991), average precipitation for the two sites ranged from 1251 mm to 1329 mm (Table 1a), temperature ranged from 23.77 to 24.63 °C (Table 1b) with 78.25 per cent relative humidity (Table 1c). As in the rest of the forest zone of Cameroon, the soils developed from neutral to acid metarmophic rocks (migmatites to schists). These soils were highly weathered and intensively leached under the udic isohyperthermic regime. These low activity clay soils were grouped under ultisols and oxisols (Duguma, Tonye & Depommier, 1990). However, the population of Mfoundi Division was nearly twice that of Dja and Lobo with consequent high pressure on productive land. This led to the depletion of the forest and gradual transformation to grass savanna vegetation. The difference in population density between the two divisions, with associated effects on the vegetation, was the basis for deciding to monitor the flowering phenology in the two sites. Fallowing is the most commonly used technique for improving soil fertility on farm lands. The main crops are cassava, groundnut and maize. Poultry, pigs and small ruminants are the major domestic sources of animal protein in the region (Duguma, Tonye & Depommier, 1990).

TABLE 1a

Climate characteristics of the humid lowlands of Cameroon

	Precipitation (mm)					
	Mfoundi			*Dja and Lobo*		
	1989	*1990*	*1991*	*1989*	*1990*	*1991*
July	44.5	56.3	50.5	123.1	58.4	101.9
August	200.3	230.5	23.8	157.6	78.9	51.9
September	215.3	386.6	102.9	200.4	170	258.2
October	222.6	296.4	256.6	269.3	394	251.6
November	133.7	121.7	123.8	162	112.8	124.7
December	3.6	51.8	13.7	52.1	34.4	22.9
January	3.4	14.5	0	0.0	61.5	0.0
February	127.8	35.1	116	99.0	212.2	159.9
March	127.8	35.1	116	99.0	212.2	159.9
April	171.2	64.1	161.9	165.2	138.4	112.8
May	308.4	216.5	250.5	238.7	340.1	194.3
June	139.9	128.6	107	75.8	146	127.1
Total	1570.7	1612.9	1260.2	1544.3	1800.8	1439.8
Mean	130.89	134.41	105.02	128.69	150.08	119.98

Source: Mfoundi Meteorological Station (1992). Total: Mfoundi 4444 mm; Dja and Lobo 4785 mm. Mean: Mfoundi 125.10; Dja and Lobo 132.92 mm

Selection of species

Previous ethnobotanical survey carried out in the area showed that farmers had good knowledge on local agroforestry tree species (Duguma, Tonye & Depommier, 1990), which were used for soil fertility improvement and for edible fruits. In the light of this information, the species mentioned in more than 12 per cent of interviews were chosen. Top on the list were *Ceiba pentandra* (Linn.) Gearth. (mentioned by 70% of respondents), *Terminalia superba* Engl. & Diels (57%), *Triplochiton scleroxylon* K. Schum. (56%), *Cordia platythyrsa* K. Schum. (24%), *Milicia excelsa* (Welw) c.c.Berg (24%), *Pycnanthus angolense* (Welw) Warb (24%), *Alstonia boonei* De Wild (18 %) and *Ricinodendron heudelotii* (Baill.) Pierre ex Pax. (18%).

Methodology

To evaluate the flowering-fruiting patterns of the selected species in their natural habitat, three villages were chosen in each of the two divisions: Mfoundi (Akok Ndoe, Etatack and Nkolda) and Dja and Lobo (Nkwang, Mimbo and Gombo). For logistic reasons, there were situated along the road. The species were identified and labeled. The frequency of observation was twice a month. July was the starting point of the phenological year. Thus, July = month 1, August = month 2, up to December = month 6. The bimonthly investigation was carried out in a split-split-plot design (Gomez & Gomez, 1984) with three replications. The species were considered as main plot (Lowe, 1968). The years and sites represented sub-plot and sub-sub-plot, respectively (Bouillet, 1984). The villages were considered as replicates. The

Table 1b

Climate characteristics of the humid lowlands of Cameroon

	Temperature (°C)					
	Mfoundi			*Dja and Lobo*		
Month	*1989*	*1990*	*1991*	*1989*	*1990*	*1991*
July	22.9	22.9	23	22.7	22.6	23.8
August	22.9	22.9	22.8	22.5	22.7	23.8
September	23.5	23.1	23.3	23.5	23.5	24
October	23.4	23.9	22.8	23.8	23.6	23.8
November	23.9	24	23.5	24	23.9	24.3
December	23.7	24.2	23.4	23.7	23.4	23.8
January	23.6	24.6	24.1	23.1	24.8	24.8
February	25.5	25.8	26.1	24.7	25.6	25.5
March	25.1	26.6	25.4	24.9	25.5	25.1
April	24.8	26.1	24.5	24.3	24.9	24.9
May	23.8	24.4	24.2	23.8	24.6	24.3
June	23.7	24	24.1	23.9	23.6	24.2
Total	286.8	292.5	287.2	274.9	288.7	292.3
Mean	23.9	24.4	23.9	22.9	24.06	24.36

Source: Mfoundi Meteorological Station (1992). Total: Mfoundi 886 °C; Dja and Lobo 855.5 °C. Mean: Mfoundi 24.63 °C; Dja and Lobo 23.77.

experimental unit was made up of five trees for each species. A total of 240 individuals (15× 8 × 2) were observed.

For the eight species, the flowering-fruiting monitoring was made from July 1989 to June 1991. Data collected were number of trees in flowers and number of trees in fruits. Flowering and fruiting percentages were computed. Mean flowering time and duration of flowering were obtained from the positive observation. The mean flowering time referred to the period in which the majority of trees were in flowers whereas the range referred to the length of the blooming period. Three types of flowering times were distinguished: early (October-November), late (January-March) and medium (April-September). The statistical analysis performed was variance and correlation, using the Bstat microcomputer program.

Results and discussion

Timing of flowering

There was a very highly significant effect of species on mean flowering date ($P = 0.001$), indicating variation in flowering schedule for the different species. The species were classified into three groups: species which flowered later between January and March (*Ricinodendron heudelotii, Milicia excelsa, Cordia platythyrsa*), species which produced flowers earlier between October and November (*Alstonia boonei, Ceiba pentandra*) and especies which bore flowers between these extreme (the intermediary) (*Terminalia superba, Pycnanthus angolense*). The Duncan multiple range test (DMRT) revealed that *C. platythyrsa* and *R. heudelotii* were the most efficient species whereas *A. boonei* was the least, if later flowering was considered as a selection criterion (Table 2).

TABLE 1c

Climate characteristics of the humid lowlands of Cameroon

	Relative humidity (%)					
	Mfoundi			*Dja and Lobo*		
Months	*1989*	*1990*	*1991*	*1989*	*1990*	*1991*
July	80	82	82	82	83	77
August	79	82	82	84	83	82
September	80	82	80	82	83	83
October	81	80	81	84	85	84
November	80	81	81	85	83	82
December	79	79	75	83	84	85
January	66	75	71	75	80	76
February	63	67	72	70	77	76
March	70	67	76	76	79	78
April	76	72	79	80	81	80
May	79	77	81	83	83	82
June	80	81	81	82	84	81
Total	913	925	941	966	985	866
Mean	76.1	77.1	78.42	80.5	82.1	80.5

Source: Mfoundi Meteorological Station (1992). Total: Mfoundi 2779; Dja and Lobo 2817. Mean: Mfoundi 77.19%; Dja and Lobo 78.25%.

Species by site interaction was highly significant ($P = 0.01$). Differences in mean flowering time between sites is shown in Fig. 1. Flowering closely coincided at the two sites in October for *A. boonei,* in March for *C. platythyrsa* and *R. heudelotii,* and different for *P. angolense, T. superba* and *Triplochiton scleroxylon.* The species flowered earlier in Dja and Lobo around February and mid December, and later in Mfoundi by March and February (Fig. 1). Lack of synchronism in flowering between sites might be the result of the environmental cue for flowering occuring at different times at the two sites or different in the rate. *Pycnanthus angolense* bore fruits earlier at Mfoundi in November and later at Dja and Lobo in January whereas *T. scleroxylon* and *T. superba* flowered earlier at Dja and Lobo forest (September, December) in contrast to that of Mfoundi (November and January). This is in agreement with the findings in which Mapongmetsem (1994) noticed that the flowering pattern in the two sites might be related to the rainfall, which was lower in Mfoundi than in Dja and Lobo.

The effect of species by year interaction was also significant ($P = 0.001$) because the year 1990 was drier in Mfoundi (24.4 °C) as compared to 1989 and 1991. *Ceiba pentandra* and *C. platythyrsa* flowered in December and March, respectively, contrary to the previous flowering which took place in October 1989 and February 1991. This was probably due to climatic changes in 1989 and 1991.

Range of flowering

The effect of year on flowering range was significant ($P = 0.001$), indicating variation in the duration of flowering between the years (Table 3).

Therefore, the year 1991 was of extended flowering whereas 1989 was of mass flowering, and 1990, a year of intermediate flowering. The species by year interaction was significant ($P = 0.05$) because of the particular range of flowering occurring in 1989 and 1991. The length of the flowering period was longer in 1989 than in 1990 and 1991 for *C. pentandra* whereas that of 1991 was also longer than 1989 for *C. platythyrsa* and *P. angolense* (Fi.g. 2). The effect of species on the magnitude of flowering was significant ($P = 0.001$), indicating a considerable variation with respect to the number of trees bearing flowers per unit time. The length of the blooming period of the species ranges from 1.3 (*A. boonei*) to 5.5 month (*P. angolense*). In *P. angolense*, few individuals produced fewer flowers per month but bloomed for a long period (5.5 months) whereas in *A. boonei*, a large number of individuals, produced flowers per month but bloomed for a few months (1.3) (Table 4). The first type of flowering is referred to as extended blooming and the second as mass blooming. However, the DMRT classified the species into four groups. These models which represented only the end points of a spectrum that encompassed a broad range of variation could be compared to that of *Mutingia calabura*, which flowered continuously through out the year, and *Caseares praecax* among which all the plants of a population flowered synchronously for only one day (Bawa, 1983). Fruit development was low for *T. superba*, in constrast with other species, taking about 8 months, after which seed production persisted for several months (Mapongetsem, 1990).

TABLE 2

Flowering time of the species

Species	*Flowering time (months)*
Ricinodendron heudelotti	8.6a
Cordia platythyrsa	8.6a
Milicia excelsa	7.9ab
Terminalia superba	6.7bc
Pycnanthus angolense	5.5cd
Ceiba pentandra	5.0de
Alstonia boonei	4.3e
Mean	6.67
LSD 0.05	1.3
C.V%	26.50

LSD = Least significant difference, CV= Coefficient of variation. Treatments followed by the same letters are significantly identical.

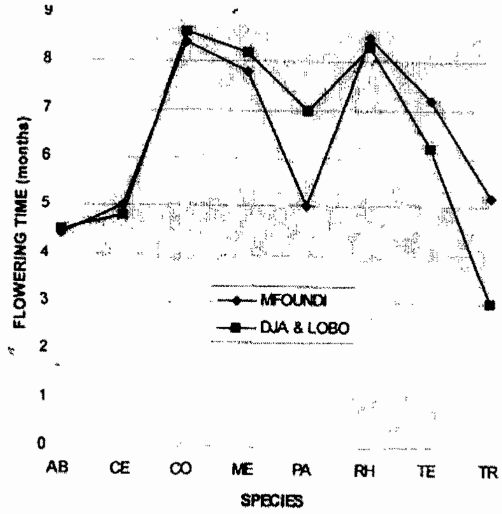

Fig. 1. Effect of the site on the flowering time of *A. boonei, C. pentandra, C. platythyrsa, M. excelsa, P. angolense, R. heudelotti, T. superba* and *T. scleroxylon.*

TABLE 3

Flowering time of the species

Years	*Range of flowering (months)*
1989	1.33
1990	2.69
1991	3.23
Mean	2.42
LSD 0.05	0.44
C.V%	47.30

As for the timing, the duration of flowering could vary from year to year according to the pedoclimatic changes of the study site. Mean flowering date and range of flowering were not

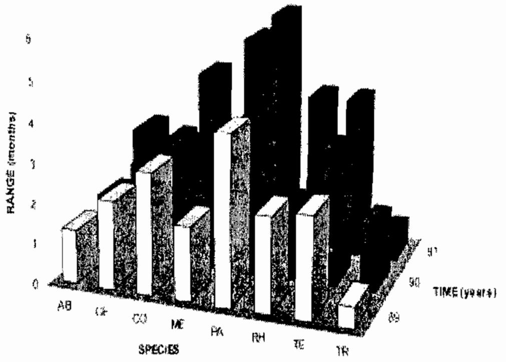

Fig. 2. Effect of year on the range of flowering of the spicies

dependent variables. As the climate of a site follows the same seasonal pattern each year, it might also be expect to see inter-annual synchronism with the species flowering at the same time each year. This implied that the environment of individual trees and their physiological status had an important influence on seed production, as well as the general environment of the site. In general, the longer the blooming period, the fewer the flowers per unit of time.

TABLE 4

Range of flowering of the species

Species	*Flowering time (months)*
Pycnanthus angolense	5.5a
Cordia platythyrsa	3.4b
Terminalia superba	3.3b
Ricinodendron heudelotti	2.7bc
Ceiba pentandra	2.7de
Milicia excelsa	2.1cd
Alstonia boonei	1.3d
Mean	3.0
LSD 0.05	0.8
C.V%	43.65

Treatments followed by the same superscripts are significantly equal

Frequency of flowering

As far as the frequency of flowering was concerned, two patterns were distinguished: regular and irregular flowering. The regular flowering species were *C. platythyrsa, M. excelsa, P. angolense, R. heudelotii* and *T. superba*. However, it was noticed that among the typical species which had flowering activities every year, some species like *C. platythyrsa* and *T. superba* in the Dja and Lobo forests blossomed twice a year (Mapongmetsem, 1990). A similar pattern was found in *Ficus mucuso* which flowered three to five times during the year. In contrast to species bearing flowers every year, there were species which did not flower every year. In this category, the typical species were *A. boonei, C. pentandra* and *T. scleroxylon*. Observations by Lowe (1968) on "periodicity of tropical forest trees (*Triplochiton scleroxylon* K. Schum.)" confirmed analogous factors. Nevertheless, it was noticed that some *T. scleroxylon* individuals flowered successively during years in Mfoundi. This result disagreed with that of Lowe (1968) and Kinnaird (1992).

It was observed that flowering periodicity of the above-mentioned species varied from 3 to 10 years. Jones (1972) quoted the frequency and regularity of flowering of the species in Cameroon. It was identified that some individual species of *A. boonei* and *C. pentandra* flowered every year, then every 2 years successively, but not in the 3rd year; others blossomed once in 2 or 3 years, and, finally, others did not flower at all. In others, it flowered and fruited twice a year. *Ceiba pentandra* was the prototype. It dispersed seeds twice a year, from September to December and January to April, with the first period yielding greater number of seeds. Concerning the reproductive biology, there were monoecious and dioecious species. Monoecious species were *A. boonei, C. pentandra, T. superba* and *T. scleroxylon*, whereas *C. platythyrsa, M. excelsa* and *R. heudelotii* were dioecious.

The quality and quantity of seeds from the flowering could not be predicted because of inner genetic factors (Mapongmetsem, Duguma & Nkongmeneck, 1997; Mapongmetsem *et al.*, 1998). For instance *C. pentandra* gave abundant flowers, but few fruits were formed. When examining fruiting records of this kind, it is tempting to recognize repeating annual patterns. Flowering and seed production appeared to be less regular, therefore, less predictable in *A. boonei* and *C. pentandra*. In *T. superba*, seed fall occurred in each of the 3 years (1989-1991) between November and December. However, some seeds fell between February and April, casting doubt on a regular annual pattern of seed production.

The shortage of fruits or seeds could affect the schedule of the farmer. To avoid this, the farmer should select several mother specimens for germplasm among trees of irregular flowering to be sure that the selected trees would supply him with enough seeds. Regular flowering suggested that the flowering hormones were renewable automatically after each flowering, whereas for the irregular species there were some endogenous factors which controlled its production. The alternate flowering could be due to dormancy of buds (quantity of flowering hormone decreases after each blossom). The effect of site was significant ($P = 0.05$) due to the fact that no *T. scleroxylon* individual flowered in 1991 in Dja and Lobo while 75 per cent gave flowers in Mfoundi.

The flowering of *C. platythyrsa* and *R. heudelotii* were negatively correlated to the precipitation and hygrometry ($r = -0.72$; $P < 0.05$) and positively to the temperature. This suggested that 72 per cent of the trees blossomed during the dry season and only 28 per cent in the wet period. These results were in agreement with the observations of Kinnaird (1992), who indicated that many trees gave flowers during the dry season.

Relationships between flowering and other phenophases

Concerning shading off against flowering, the species with regular flowering (*C. platythyrsa, M. excelsa, R. heudelotti* and *T. superba*), and all the defoliated trees bore flowers automatically. There was a partial correlation for *A. boonei, C. pentandra* and *T. scleroxylon*. *A. boonei* defoliated when fructification was ended contrary to other species. For *A. boonei, C. pentandra* and *T. scleroxylon*, flowers occurred on naked branches indicating the absence of correlation between reproductive function and vegetative one. As far as *C. platythyrsa, M. excelsa, R. heudelotti* and *T. superba* were concerned, the flowers were formed either at the same time with new leaves or after new leaves were formed. This suggested a close correlation between the two functions. The high correlation was found in *C. platythyrsa* ($r = 0.93$; $P < 0.01$), *M. excelsa* ($r = 0.98$; $P < 0.01$), *R. heudelotii* ($r = 0.89$; $P = 0.01$) and *T. superba* ($r = 0.94$; $P < 0.01$). This result indicated that about 90 per cent of individual trees bore flowers at the same time with the new buds. Similar facts had been quoted in the Congo on *T. superba*, and it was suggested that the stimulating role of auxins synthesised during the flushing on the flowering was responsible (Alexandre, 1980; Bouillet, 1984). It seems that the new shoots produced the chemical substances which enabled and stimulated the flowering activities of the buds. Contrary to the above species, the abundance of flowers in *C. pentandra* and *T. scleroxylon* kept the trees deciduous for a long period till the end of the flowering event.

Conclusion

Regular flowering led to regular fruiting of monoecious trees whereas irregular flowering resulted to irregular fruiting. Plants displayed a wide variety of flowering patterns. Individuals of a population might flower for periods as brief as 1 month or as long as 6 months, several times a year or once every year, one or many times in their lifetime. During the models spreading, plants could bear flowers every year (regular flowering) or periodically (irregular flowering). These parameters varied according to the pedoclimatic conditions of the study site. The time taken for fruits to mature varied between species. To a very large extent, this pattern reflected different ways of resolving the constraints imposed by the environment. It could also represent the compromise among different selective forces (endogenous and exogenous factors). There were many flowering models among which extended and mass flowering were the extremes.

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