



Phenological Studies of Some Indigenous Tree Species in the Takamanda National Park, South West Cameroon

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ABSTRACT

The vegetative and reproductive phenology of 17 overstorey and 10 understorey species were studied in the Takamanda National Park in Cameroon. Phenological observations; leaf initial, maturation, abscission, flush (vegetative), while flower initiation, maturation, dropping and fruit initiation, maturation, dropping and ripening (reproductive) were carried out monthly for two years (January 2012 - December 2013). Results indicated that phenological behaviour of most of the tree species was similar for the two years of monitoring. A prominent peak in leaf abscission, leaf initiation, flower initiation and fruit ripening of overstorey species occurred in December, February, July-August and February-March respectively. However, the peak periods of such phenological events in understorey species were different from that of the overstorey species. It was noted that fruit maturation and ripening of the overstorey species attained their major peak in December and a minor peak in February while the understorey tree species recorded their main peak in March and minor in February. Leaf flushing for both overstorey and understorey species occurred at the end of the dry season (January- February). Fruit dropping in many species coincided with early rains, thus

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ensuring available moisture for seed germination and establishment. Temperature was ($P < 0.01$) significantly positively correlated with fruit ripening for the overstorey and understorey species. Rainfall was significant ($P < 0.01$) but was negatively correlated with leaf initiation, leaf dropping, flower initiation and fruit ripening. The phenological information obtained in this study is mostly influenced by the seasons and would be useful for planning proper management strategies to sustain plant regeneration dynamics in the Takamanda National Park.

Keywords: Phenology; tree species; climate variability; leaf flush; flower maturation; fruit ripening; rainforest.

1. INTRODUCTION

Phenology is the study of the periodicity or timing of the reoccurring biological events, and these are important for biodiversity monitoring, conservation and management of the forest ecosystem [1,2,3,4]. Phenological studies have been widely studied in the temperate region where phenological patterns conform to normal climate or seasonality [5]. It is observed that in winter, low temperatures limit cambial activity causing dormancy in most plant species while flowering, fruiting and leaf dropping resume in spring, when temperatures and photoperiod rise again. In tropical rainforest as in temperate forests, phenological events are also triggered by temperature, precipitation, soil moisture and day length [5,6,7].

However, seasonality in the humid forest is hardly ever extreme and thus cannot be a strict limiting factor. During the dry season for example, temperatures are high while soil moisture and humidity are low enough to cause a phenophase. This situation allows for high plasticity and induces a high diversity of phenological patterns [8,9,10]. Thus, in the tropical rainforest it is obvious to observe different phenological stages simultaneously on different tree species but also on trees of the same species [11]. A tree of the same species can be on fruiting while the other is initiating flower and another on leaf flushing and a neighbour completely leafless [12].

Phenological events are useful in evolving a proper forest management strategy as well as better understanding of natural forest regeneration potential [13]. The lack of phenological information also limits the understanding of the ecology and evolution of tropical plant species and communities [9].

Phenological patterns in plants are influenced by a combination of biotic and abiotic factors that determines the occurrence and inhibition of

physiological events [14]. Over evolutionary time and through natural selection or survival of the fittest, these biotic and abiotic factors have structured plant events into suitable timing for leaf flushing, flowering, fruiting, ripening and fruit dropping for efficient growth, reproduction, distribution and regeneration of species [15].

These variability in seasons could be triggered by climatic or pressure of biotic factors. Many tropical trees are very sensitive to these environmental changes and these changes are usually preceded by phenological events [16] which are fundamental in biodiversity conservation and ecosystem maintenance [17]. According to Lobo et al. [18], phenological events in plants are affected by proximate or ultimate causes. Therefore, proximate causes mainly include short-term environmental events that may trigger phenological patterns, while ultimate causes involve evolutionary forces that are responsible for these patterns. Climatic variations such as temperature, rainfall and irradiance have been recorded as proximate causes that triggered phenological events in tropical plants [18,19,20].

Alternatively, biotic factors such as preferential differences of pollinators, animal seed dispersal, avoidance of seed predation and herbivory have been reported as ultimate factors that may influence phenological events in a forest ecosystem [18].

Pre-dispersal attack by pathogens that cause fruits or flowers to rot (e.g. fungi and bacteria) or consumers that destroy seeds prior to dispersal (insects and larvae) represent increase costs of dispersal due to waste of resources invested in the production of seeds and fruits. If the attack rates vary in a seasonally predictable way, it could also be suggested that pathogen trigger phenological events in rainforests [21]. Plant producing fruits of different sizes are likely to attract different kinds of seed dispersal [22].

The susceptibility of fruits and seeds to pathogens attack could reflect the degree to which they are chemically defended [23] and this would likely affect dispersal identity and the different benefits of phenological patterns [23]. Singh and Kushwaha [24] suggested that climate change has caused deviations in the length of the growing period, and competition among species may change the resource use patterns in different species.

Karmer [25] concludes that differences in tree species phenological responses to temperature changes can have long-term consequences on their geographic distribution. He further suggests that phenology and climate relationship can also reveal the potential impacts of future climatic changes. Pires et al. [26] also reported that the timing, duration, magnitude and synchronicity of plant life are fundamental aspects of community dynamics and ecosystem functioning.

The Takamanda National Park (TNP) is one of the largest tropical rainforests in southwestern Cameroon [27] and understanding the phenology of species is fundamental for biodiversity conservation and ecosystem maintenance. Climatic and biotic variability over a long time affects dynamic processes in the forest ecosystem, and affects reproductive success and regeneration of the forest [19].

Although scientific knowledge on the phenology of tropical forests has been accumulated globally during the past decades, there is no documented information on phenology in the TNP. Furthermore, biological factors that influence phenological events of tree species have not been studied in the TNP and there is also limited documented information on other forests in Cameroon. This information is vital for the understanding of the forest dynamics of this forest and reproductive successes of species to guide forest users, policy makers and conservators in the management of the forest.

2. MATERIALS AND METHODS

2.1 Description of Study Site

The Takamanda National Park which covers a surface area of 67,599 ha is located in the South West Region between 05° 59' to 06° 21' N and 09° to 09 30' E and this part of Cameroon has been described in details in [28]. The terrain is undulating in the lowland areas, but rises sharply to an altitude of 1,500 m in the northern part of this rainforest, where slopes are extremely steep.

In general, the region has two distinct seasons with most rainfall occurring from April to November, with peak period in July-August and September. The mean annual temperature is about 27°C. and, it is cooler in the rainy season than in the dry season. The estimated human population density of the area ranges from 6 and 12 individuals per km² [28].

2.2 Phenological Observation

Phenological observations were made on 27 tree species (135 individuals) in the Takamanda National Park. Out of these species, 17 were overstorey and 10 understorey tree species. Eight of the overstorey (OS) and understorey (US) tree species were deciduous (species has a marked leaf abscission and young leaf at particular periods of the year) in which only the species were observed for vegetative status; 19 were evergreen (species continually produce at least a small amount of new leaves throughout the year and do not show heavy leaf fall at any time of the year). The selection of tree species for phenological observation was based on their importance value index, economic importance and medicinal properties (Table 1).

Density, basal area, and importance value index (IVI) of plant species were calculated following Mishra [29] and Mueller-Dombois and Ellenberg [30]. The basal area of each individual tree species was calculated as follows

$$BA = (1/2 DBH)^2 \quad (1).$$

The importance value index (IVI) for trees was calculated by summing their relative frequency, relative density and relative dominance.

135 individuals of these 27 species of trees were marked with metal tags and were geo-referenced. Detailed observations were carried out monthly over a period of two years from January 2012 to December 2013. For each tagged tree, records were made on leaf abscission (LA), leaf initiation (LI), leaf maturation (LM), flower initiation (FI), flower maturation (FM), flower dropping (FD), young fruit production (YF), maturation of fruits (MF) and the ripening of fruits (RF). A species was considered to be in a particular phenophase when more than 50% of the individuals of that species were passing through that phase. However, in the case of species represented by only a few individuals, those present in nearby areas (*Milicia excelsa* and *Glyphaea brevis*) were observed to confirm the phenological status of

that species [31]. The observations on phenological events were expressed by the number of plant species in a particular phenophase. Behavioural patterns of plant species were described following Kikim and Yadav [13] and Sandarapandian et al. [6]. Brief and extended activity indicates the periodicity of leaf initiation, flowering and fruiting activity by

individuals of a species. Brief activity extends for 2 weeks or less while extended activity refers to periods of more than 2 weeks. When some individuals of a tree species are in flowering / fruiting simultaneously is referred to as synchronous activity (S). The species showing flower/fruit development during a distinct period is known as asynchronous (A).

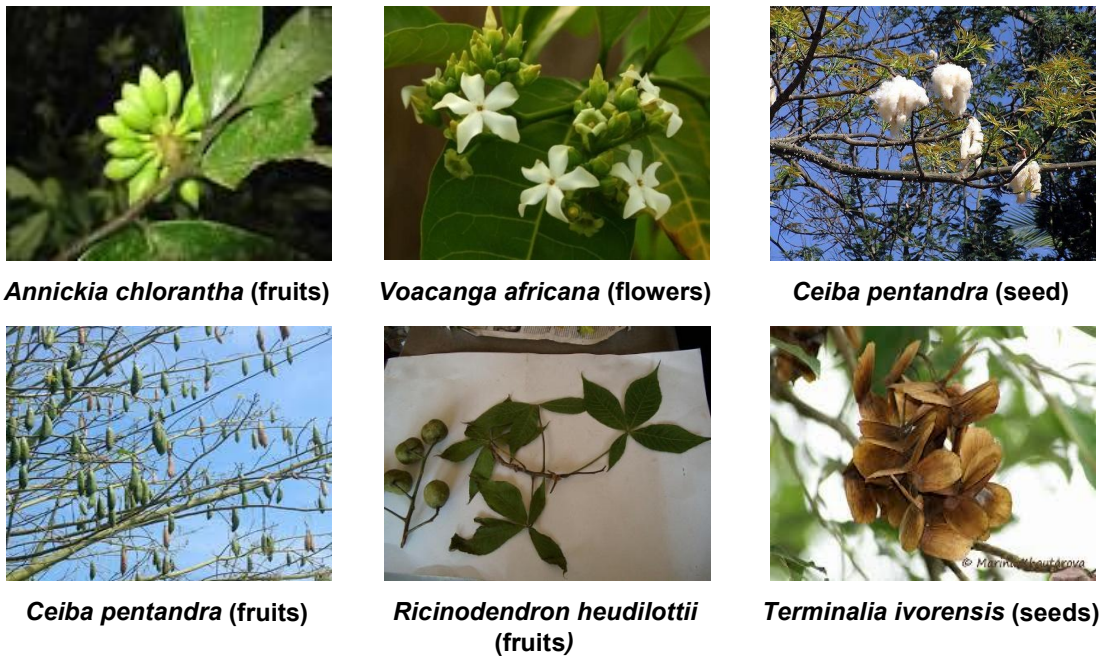


Fig. 1. Phenophases of some tree species in the Takamanda National Park
(Source: Field observations)



Fig. 1. Continues

On the basis of fruit maturation activity, individuals of a species population are grouped into two categories rapid (r) and lengthy (L). When the fruit maturation period is of 4 months or less, it is considered as “rapid” activity and when it is more than 4 months, it is “lengthy” activity Kikim and Yadav [13]. In classifying species into the different dispersal modes, first-hand observation was made on dispersal agents of many species as possible. Where direct observations were not possible, the mode of dispersal was inferred from fruit morphology Couralet et al. [32] for example, fleshy content were considered animal dispersed, even if we could not detect their seeds in animal's droppings. Those with winged seeds were considered as wind dispersed and those with suture lines on the fruits were considered as explosive-dispersed. Correlation analysis was carried out between climatic factors (temperature and rainfall) and the different phenological events. The significance of the different phenophases was determined at 5% probability level. Phenological phenophases were recorded and some photographed (Fig. 1).

3. RESULTS

The rainforest maintained its green nature throughout most of the year based on the interrupted rainfall within the region. Fig. 2 shows the variability in rainfall and temperature during the study period.

3.1 Leafing Phenology of Studied Species

The production of young leaves started in December-April for the different tree species (Fig. 3 a, b). The main peak of leaf flushing was observed in February for both overstorey and understorey tree species and these were 50% and above in that phenophase (Fig. 3 a, b). Eighty percent of the tree species (*Ficus exasperate*, *Terminalia ivorensis*, *Melicia excelsa*, *Albizia zygia* etc.) started leaf flushing in February with the early rains (Fig 3 a, b). Leaf initiations were significantly different ($P=0.05$) in February (Fig. 3 a, b). Leaf initiations did not show significant difference ($P=0.05$) from March 2012 to January 2013. Generally, seventy five percent of the tree species showed two peaks for leaf maturation. In March (25%) and May (50%) of tree species were observed in the vegetative phenological patterns (Fig. 3 a, b). Leaf maturation of tree species was significantly different ($P=0.05$) in March and May respectively.

3.2 Leaf Abscission of Studied Species

Leaf abscission was continuous for evergreen (*Annickia chlorantha*, *Musanga cecropioides*, *Eribroma oblongum*, *Irvingia* sp, *Mallotus oppositifolius*, *Baphia nitida* etc.) species and periodic for deciduous (*Ceiba pentandra*, *Terminalia ivorensis*, *Pterocarpus soyauxii*, *Ficus exasperata* etc) species (3b). Most deciduous tree species shed their leaves in the dry season of the year i.e. from October up to February and was lower in other months (Figure 3b). The peak of leaf abscission was observed in December (62.5%). Leaf abscission showed significant ($P=0.05$) differences from November-December for the deciduous tree species (over storey and under-storey). Leaf abscission showed changes with temperature and rainfall but did not show significant differences ($P=0.05$) from January-September (Fig. 3b).

3.3 Flowering Phenology of Studied Species

The seasonal pattern of flower initiation of the overstorey and understorey tree species started in January-December (Fig. 4). Three peaks were observed, the major peak was recorded in July-August (42.85%) and two minor peaks were recorded in February- March (21.42%) and September-November (30%). Flowers initiation in some of the species (*Ceiba pentandra* and *Staudtia stiapitata*) coincided with leaf shedding (Fig. 4). Flower initiation/production showed significant differences ($P=0.05$) for the periods between July-August, September-November and February- March for both overstorey and understorey species with rainfall and temperature (Fig. 4 a, b).

3.4 Flower Maturation of Studied Species

In respect to flower maturation, (Fig. 4 c, d). two main peaks were observed in overstorey (April and August) and understorey (September and December) respectively. Overstorey species observed in April (*Musanga cecropioides*, *Melicia excelsa* and *Pterocarpus soyauxii*) and August (*Azelia bipindensis*, *Piptadeniastrum africanum*, *Albizia zygia*, *Cylicodiscus gabunensis* and *Pycnanthus angolensis*) were observed in September (*Baphia nitida* and *Glyphaea brevis*) and December (*Voacanga africana*, *Rauvofia vomitoria* and *Garcinia kola*) (Fig. 4 c, d). Flower maturation showed significant differences ($P=0.05$) in the months of April-August and

September-December for both overstorey and understorey species respectively (Fig. 4 c, d).

3.5 Flower Dropping and Fruit Initiation of Studied Species

Flower dropping showed two main peaks in November (21.42%) and January (30%) for both overstorey and understorey species (Fig. 5 a, b). Dropping of flowers was significantly different ($P=0.05$) in the months of November and January for both overstorey and understorey species when compared with temperature and rainfall (Fig. 5 a, b). Fruit initiation had two peaks, the first peak was recorded in February (*Ficus exaspinata*, *Barteria fistulosa*, *Glyphaea brevis* and *Rauvofia vomitoria*) and the second peak was observed in August for overstorey tree species (*Pterocarpus soyauxii*, *Pycnanthus angolensis* and *Ricinodendron heudelotti*). Fruit initiation was significantly different ($P=0.05$) in February and August with temperature and rainfall, while other months did not show significant differences ($P=0.05$) (5 c, d).

3.6 Fruiting Phenology of Studied Species

In the present study maturation and ripening of fruits were observed to vary in both overstorey and understorey tree species (6 a, b). The overstorey species attained their major peak in December and a minor peak in February whereas the understorey tree species recorded their main peak in March and minor in February (Fig. 6 a, b). However, it was noticed that fruit maturation occurred almost throughout the year for the different species (Fig. 6 a, b). Fruit maturation was significantly different ($P=0.05$) in the months of December and March for overstorey and understorey species respectively when compared with respect to temperature and rainfall (Fig. 6 a, b). Fruit ripening showed two conspicuous peaks for both overstorey and understorey tree species. Ripening of fruits for both tree types were synchronised with leaf shedding for the deciduous tree species with the onset of rains and warm temperatures (Fig. 6 c, d). The major peak for overstorey fruit ripening was observed in February and in March for understorey and these were significantly different ($P=0.05$) from other months.

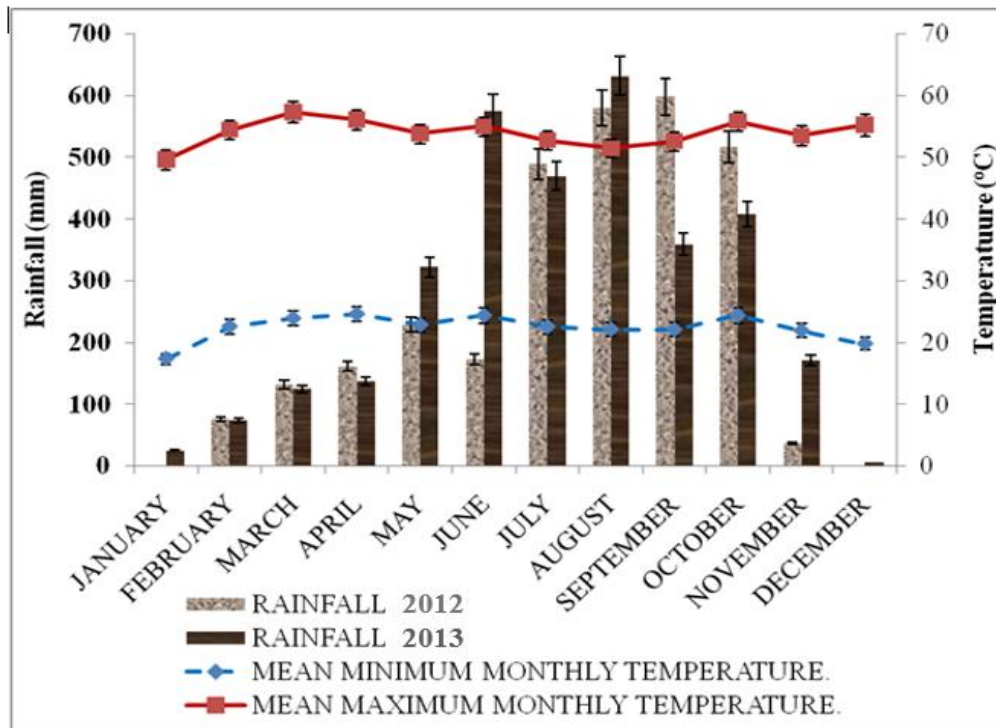


Fig. 2. Mean monthly rainfall and temperature (means for 2 years) pattern of the TNP from January 2012- December 2013

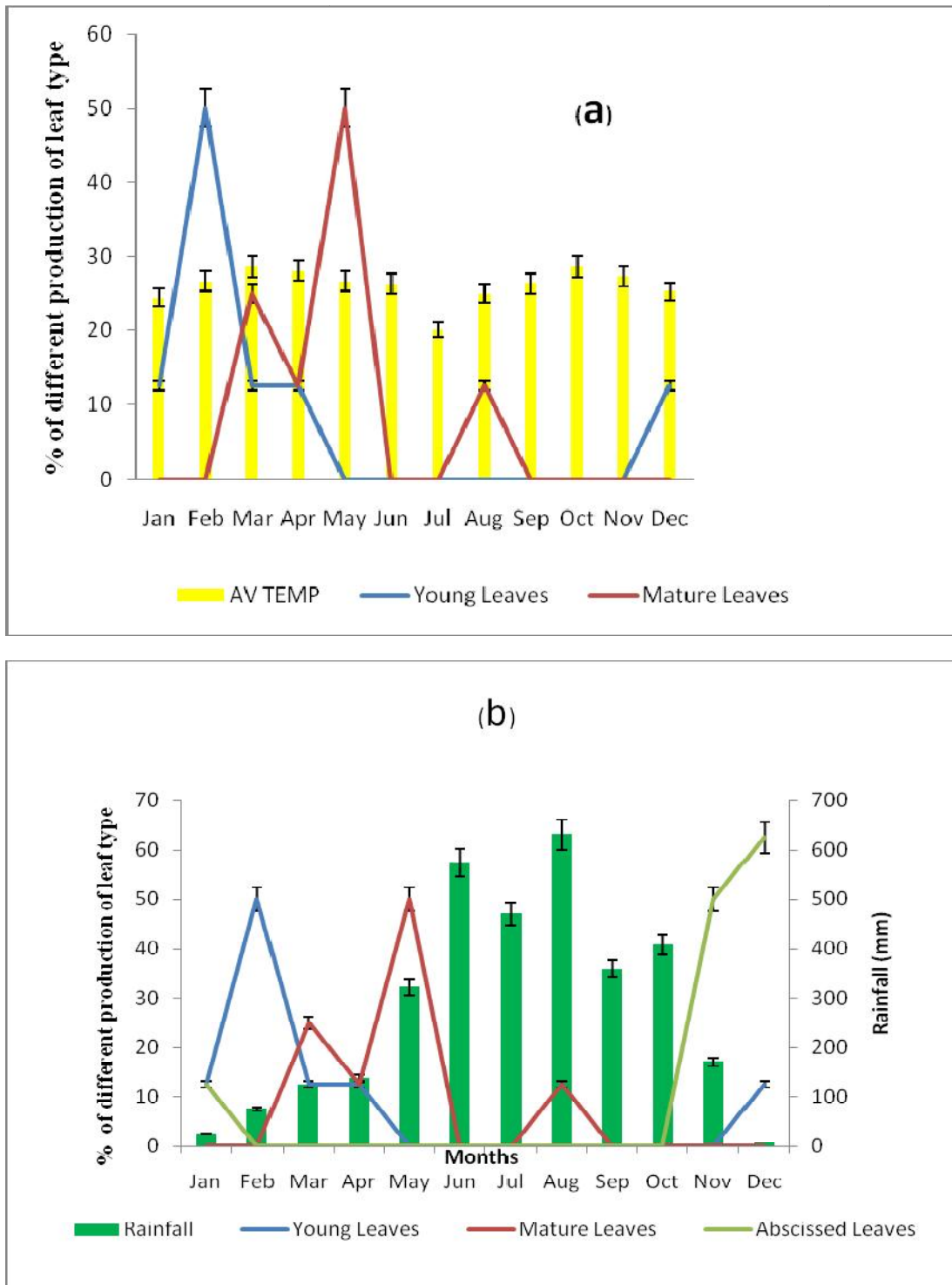


Fig. 3. Influence of monthly temperature (a) and rainfall (b) on vegetative phenological patterns (young leaves, mature leaves, and abscised leaves) of overstorey and understorey tree species in the TNP (I = standard error bar)

Table 1. Some phytosociological values of important tree species in the over and under- storey of the Takamanda National Park (TNP)

Family	Species	Storey	Density/ha	Basal area /ha	IVI	Other uses
Annonaceae	<i>Annickia chlorantha</i> (A), Ev	OS	8.09	1.81	3.16	medicinal
Apocyanaceae	<i>Voacanga africana</i> (A), Ev	US	0.74	0.02	0.30	medicinal
Apocynaceae	<i>Rauvolfia vomitoria</i> (A),Ev	US	0.74	0.02	0.30	medicinal
Bombacaceae	<i>Ceiba pentandra</i> (E,W), D	OS	0.74	0.41	0.35	timber
Burseraceae	<i>Dacryodes edulis</i> (A),Ev	OS	4.69	0.20	2.70	fruits
Cecropiaceae	<i>Musanga cecropioides</i> (A),E	OS	10.94	5.61	6.08	medicinal
Clusiaceae	<i>Garcinia kola</i> (A),Ev	US	0.74	0.31	0.30	Medicinal/stimulant
Combretaceae	<i>Terminalia ivorensis</i> (W),D	OS	2.21	1.68	1.11	timber
Euphorbiaceae	<i>Ricinodendron heudeloti</i> (A), D	OS	0.74	0.31	0.34	condiment/medicinal
Euphorbiaceae	<i>Mallotus oppositifolius</i> (A),Ev	US	0.04	0.01	25.19	medicinal
Fabaceae	<i>Azelia bipindensis</i> (E,W),D	OS	0.74	0.05	0.31	timber
Fabaceae	<i>Albizia zygia</i> (E,W),D	OS	43.75	316.91	69.10	timber
Fabaceae	<i>Cylicodiscus gabunensis</i> (E,W),D	OS	0.74	0.05	0.31	timber/medicinal
Fabaceae	<i>Pterocarpus soyauxii</i> (W),D	OS	12.50	39.47	9.72	timber/dye
Irvingiaceae	<i>Irvingia gabonensis</i> (A),Ev	OS	3.68	0.26	1.54	condiment/medicinal
Irvingiaceae	<i>Irvingia wombulu</i> (A),Ev	OS	3.46	0.25	1.45	condiment/medicinal
Leguminosae	<i>Piptadeniastrum africanum</i> (A),D	OS	18.38	8.53	10.33	timber
Moraceae	<i>Ficus exasperata</i> (A),D	US	17.19	8.38	9.55	medicinal
Moraceae	<i>Milicia excelsa</i> (A), D	OS	1.56	1.08	1.07	timber/medicinal
Myristicaceae	<i>Pycnanthus angolensis</i> (A),D	OS	16.91	20.83	7.39	timber
Myristicaceae	<i>Staudtia stipitata</i> (A),D	OS	41.18	56.67	17.35	timber
Pandaceae	<i>Microdesmis puberula</i> (A)Ev	US	0.02	0.01	7.29	medicinal
Papilionaceae	<i>Angylocalyx pyneartii</i> (A)Ev	US	0.08	0.02	59.02	medicinal
Papilionaceae	<i>Baphia nitida</i> (A) Ev	US	32.81	13.16	13.29	medicinal
Passifloraceae	<i>Barteria fistulosa</i> (A),Ev	US	0.01	0.01	4.21	medicinal
Steculiaceae	<i>Eribroma oblongum</i> (A),D	OS	2.94	0.87	1.31	timber
Tiliaceae	<i>Glyphaea brevis</i> (A),Ev	US	0.01	0.01	1.04	medicinal

(OS= Over storey; US =Under-storey). Letters in parenthesis indicate modes of fruit dispersal (A, Animal; W, Wind; E; Explosive D, Deeciduous, Ev, Evergreen).

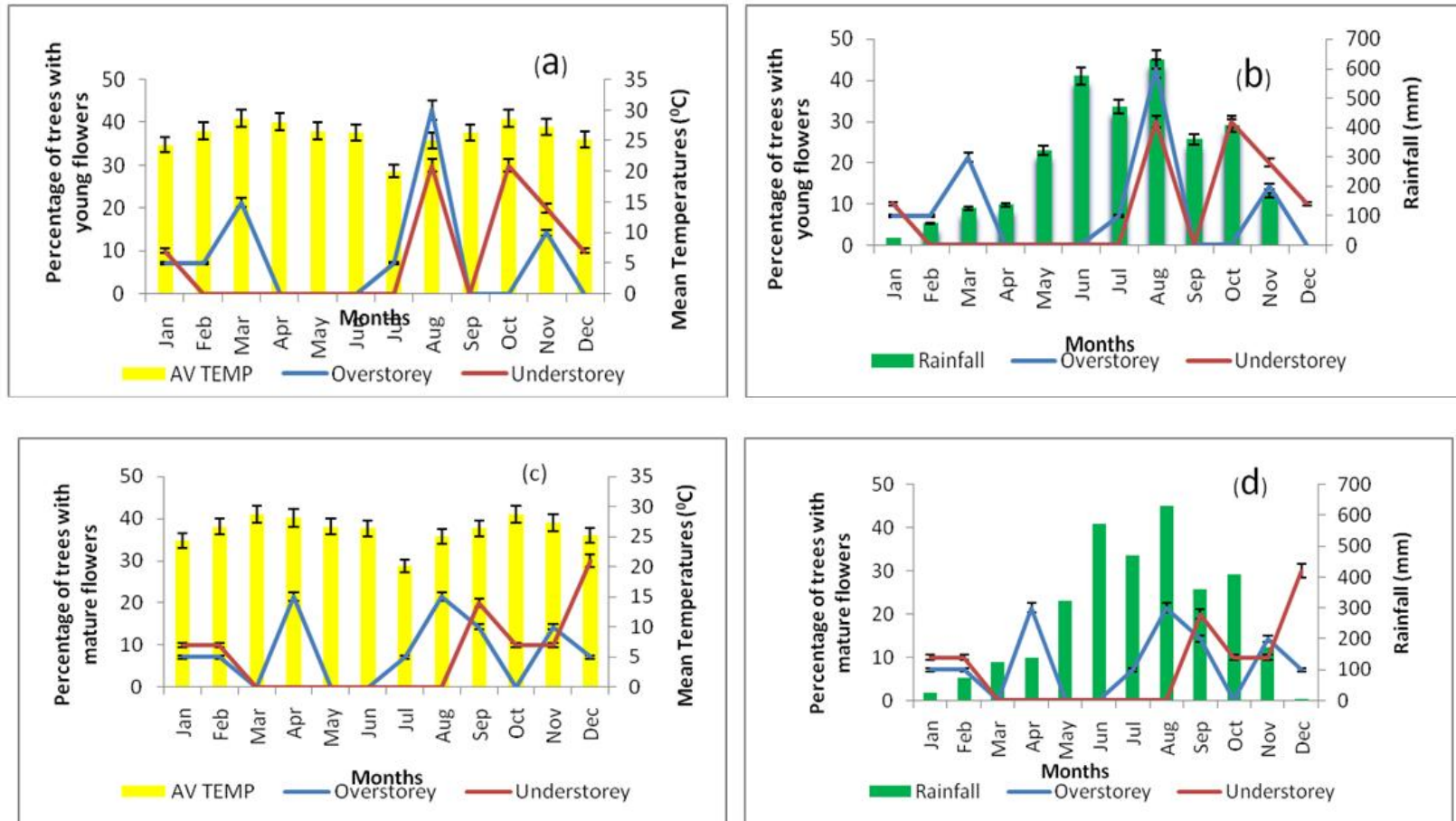


Fig. 4. Influence of monthly temperature (a, b) and rainfall (c, d) on reproductive phenological pattern (flower initiation and flower maturation) of overstorey and understorey tree species in the TNP (I = standard error bar)

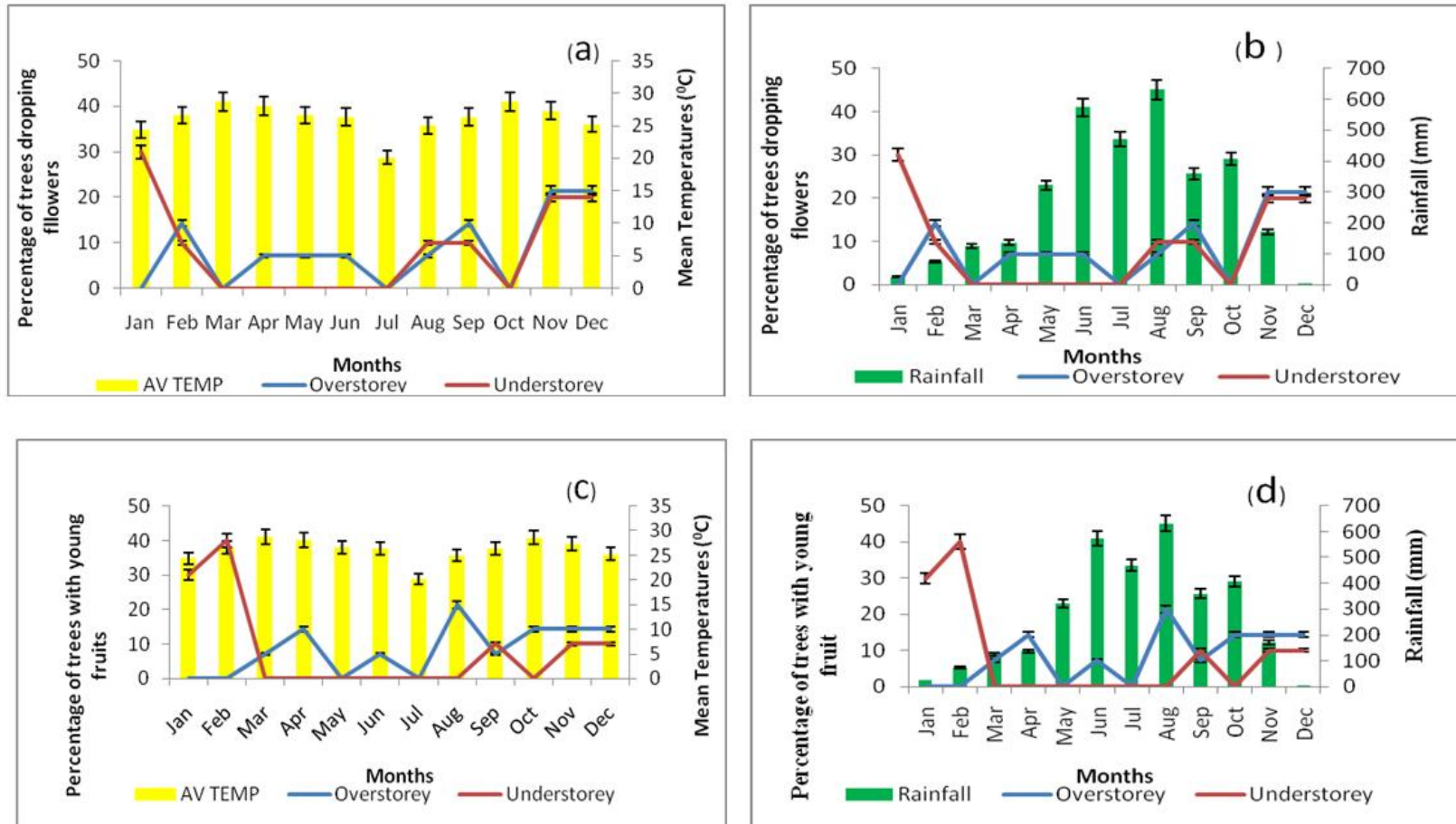


Fig. 5. Influence of monthly temperature (a, b) and rainfall (c, d) on reproductive phenological pattern (dropping of flowers and fruits initiation) of the TNP (I = standard error bar)

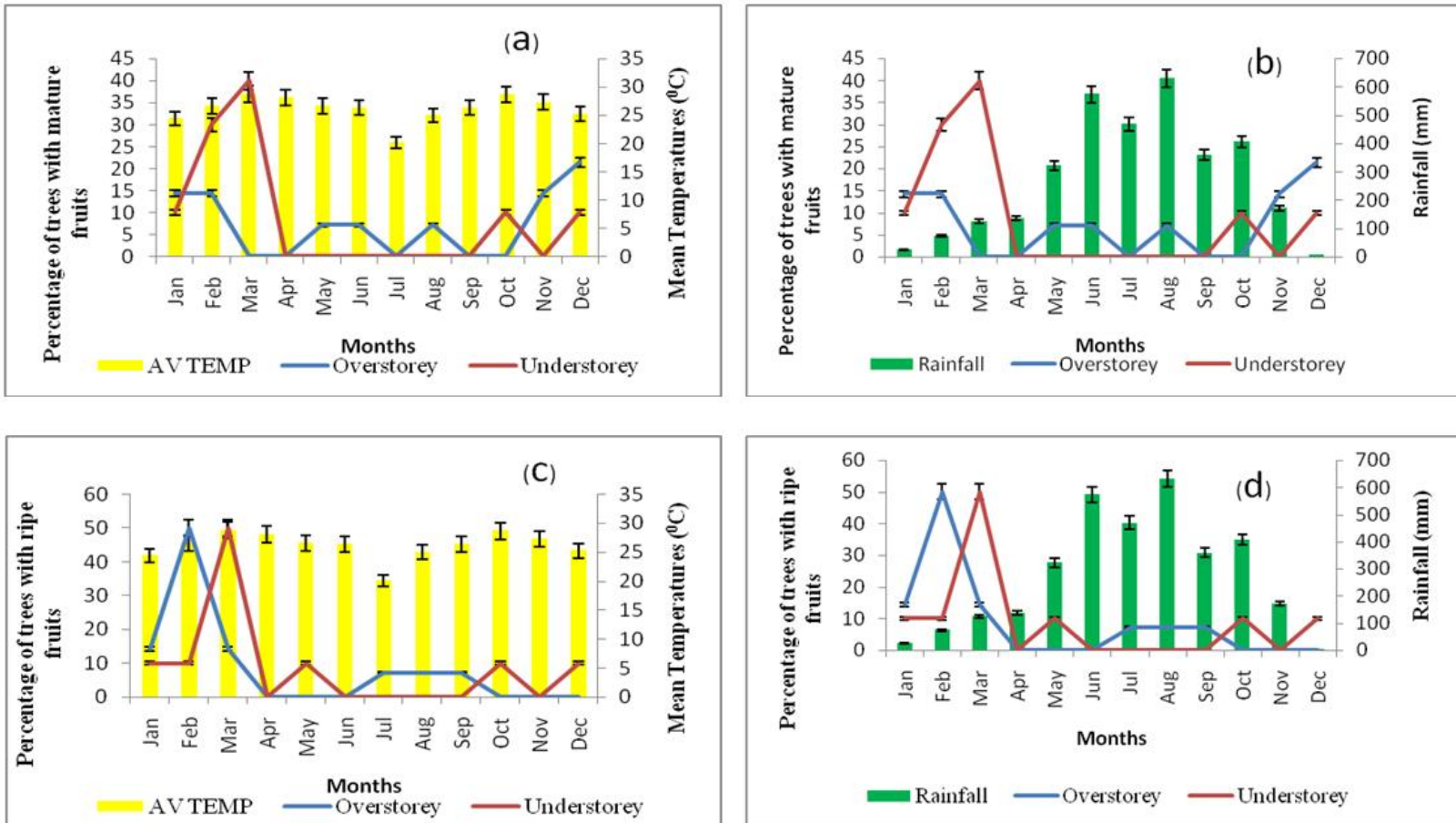


Fig. 6. Monthly temperature (a, b) and rainfall (c, d) on reproductive phenological pattern (maturation and ripening of fruit) of overstorey and understorey tree species in the TNP (I = standard error bar)

3.7 Behavioural Patterns of Studied Species

Phenological patterns of tree species in the TNP vary for overstorey and understorey tree species (Tables 2 and 3). However, similar patterns were also observed in both understorey and overstorey tree species. Among the 17 overstorey species observed, 76.47% recorded extended leaf flushing activity and 23.33% recorded brief leaf-flushing activity whereas the 10 understorey species exhibited 100% of extended leaf-flushing activity (Table 2 and 3). Leaf dropping initiation varied from periodic deciduous, periodic evergreen and continuously evergreen for both overstorey and understorey species (Tables 2 and 3) respectively.

Out of the 17 overstorey species, 47.05% showed, extended flowering activity and synchronous activity for flowering and fruiting (*Afzelia bipindensis*, *Dacroyodes edulis*, *Irvingia* spp, *Pterocarpus soyauxii*, *Pycnanthus angolensis*, *Ricinodendron heudeloti* and *Staudtia stipitata*). About 29.41% of the species showed extended flowering activity (but with asynchronous activity for flowering and fruiting (*Albizia zygia*, *Ceiba pentandra*, *Cylicodiscus gabunensis*, *Musanga cecropioides*) (Table 2). Three species (*Annickia chlorantha*, *Melicia*

excelsa and *Terminalia ivorensis*) recorded no flowering for overstorey tree species during the studied period (Table 2). *Mallotus oppositifolius*, *Glyphaea brevis* and *Rauvofia vomitria*) recorded flowering and fruiting activities throughout the year for the understorey tree species (Table 3). Out of the 17 overstorey species observed, 52.94% showed lengthy fruit maturation, 23.52% had rapid fruit maturation in overstorey trees and 23.54% of the over storey species did not fruit for the studied period (Table 2). However, all the understorey tree species showed rapid fruit maturation activity (Table 3).

3.8 Pearson's Correlation analyses for Temperature, Rainfall and Tree Phenological Parameters of Studied Species in the TNP

The correlation analysis of temperature, rainfall and phenological parameters revealed both positive and negative correlations (Table 4). Temperature showed positive correlation with leaf initiation (LI), fruit initiation overstorey (FRIO) and fruit ripening (RFU) but were not significantly ($P= 0.05$) different. However, temperature showed negative correlation with leaf dropping (LD), flower initiation overstorey (FIO), fruit initiation understorey (FRIU) and fruit ripening

Table 2. Phenological patterns of overstorey tree species in the TNP

Species	Behavioural Patterns			
	Leaf abscission	Leaf initiation	Flowering	Fruiting
<i>Afzelia bipindensis</i>	PD	Pe	PeS	PeL
<i>Albizia zygia</i>	PD	Pb	PeA	PeL
<i>Annickia chlorantha</i>	CE	Ce	None	None
<i>Ceiba pentandra</i>	PD	Pe	PeA	Per
<i>Cylicodiscus gabunensis</i>	PD	Pe	PeA	Per
<i>Dacroyodes edulis</i>	PE	Pe	PeS	PeL
<i>Eribroma oblongum</i>	PE	Pe	None	None
<i>Irvingia gabonensis</i>	PE	Pe	PeS	PeL
<i>Irvingia wombulu</i>	PE	Pe	PeS	PeL
<i>Milicia excelsa</i>	PD	Pe	None	None
<i>Musanga cecropioides</i>	CE	Ce	PeA	Per
<i>Piptadeniastrum africanum</i>	PD	Pb	PeS	PeL
<i>Pterocarpus soyauxii</i>	PD	Pe	PeA	PeL
<i>Pycnanthus angolensis</i>	PE	Ce	PeS	Per
<i>Ricinodendron heudeloti</i>	PD	Pb	PeS	PeL
<i>Staudtia stipitate</i>	CE	Ce	PeS	PeL
<i>Terminalia ivorensis</i>	PD	Pb	None	None

(P=Periodic, b=Brief periods, less than 2 weeks per episode, e=Extended periods, equal or more than 2 weeks per episode, S=Synchronous, A=asynchronous, D=Deciduous, C = Continual production of green leaves, E=Evergreen, r=Rapid fruit maturation, less than 4 months, L= Lengthy fruit maturation, equal to or more than 4 months).

Table 3. Phenological patterns of understory tree species in the TNP

Species	Behavioural Patterns			
	Leaf abscission	Leaf initiation	Flowering	Fruiting
<i>Mallotus oppositifolius</i>	CE	Pe	CbS	Cr
<i>Microdesmis puberula</i>	PE	Pe	PbS	Pb
<i>Angylocalyx pynaertii</i>	PE	Pe	PbA	Per
<i>Ficus exasperate</i>	PD	Pe	PeA	Per
<i>Baphia nitida</i>	CE	Pe	PeA	Per
<i>Barteria fistula</i>	PE	Pe	PeA	Per
<i>Voacanga africana</i>	PE	Pe	PeA	Per
<i>Glyphaea brevis</i>	PE	Pe	CbS	Cr
<i>Rauvofia vomitria</i>	PE	Pe	CbS	Cr
<i>Garcinia kola</i>	PE	Pe	PeA	Per

(P=Periodic, b=Brief periods, less than 2 weeks per episode, e=Extended periods, equal or more than 2 weeks per episode, S=Synchronous, A=asynchronous, D=Deciduous, E=Evergreen, r=Rapid fruit maturation, less than 4 months, L= Lengthy fruit maturation, equal to or more than 4 months), C = Continual production of young flowers and fruits.

Table 4. Correlation of tree phenological parameters with temperature and rainfall in the TNP

Parameters	Temperature		Rainfall	
	r	P	r	P
Leaf initiation (LI)	0.13	NS	-0.59	P= 0.01
Leaf dropping (LD)	-0.13	NS	-0.50	P=0.05
Flower initiation overstorey (FIO)	-0.08	NS	0.29	NS
Flower initiation understorey (FIU)	0.24	NS	0.26	NS
Fruit initiation overstorey (FRIO)	0.35	NS	0.22	NS
Fruit initiation understorey (FRIU)	0.26	NS	-0.58	P=0.01
Ripening of fruit over storey (RFO)	0.52	P=0.05	-0.33	NS
Ripening of fruit understorey (RFU)	0.56	P=0.05	-0.50	P=0.05

*values in the table are Pearson's correlation coefficients (significant levels * P=.05, **P<0.01).

Where r = correlation values and P= probability levels.

overstorey (FRO). Rainfall was significantly (P=0.05) negatively correlated with leaf initiation (LI), leaf dropping (LD), fruit ripening understorey and overstorey (RFO and RFU). Furthermore, rainfall was positively correlated with flower initiation for overstorey and understorey and fruit initiation for overstorey tree species (Table 4) and these were not significantly different (P=0.05).

4. DISCUSSION

The Takamanda National Park is characterised by an immense diversity of tree species of varying forms (deciduous and evergreen) and structure (overstorey and understorey). Climatic variability has strongly influenced leaf flushing, leaf dropping, flowering and fruiting. These

phenophases are highly influenced by both biotic and abiotic factors that trigger species responses to particular stimuli in species [32,33].

Leaf flushing peak was noticed in February in both overstorey and understorey species. This could be attributed to the returns of favourable environmental conditions in the area (humidity, moderate temperature and soil moisture) triggering leaf flushing. Leaf initiation towards the end of dry season and before the rains (November – February) in the tropics have been reported by other authors [24]. According to Coley and Barone [34], Anderson et al. [35], leaf flushing starts at the end of the dry season and when water stress is still high, before the seasonal increase in insect biomass. This is an adaptation strategy exhibited by most plant

species to minimise herbivory on the young vulnerable leaves. Herbivorous insect biomass is greatest in the wet months (due to susceptibility to desiccation in dry months), and predictably, leaf damage by insects has been shown to be greatest in the wet months [36,37].

Leaf abscission was more in the dry season from October to early February. The high leaf dropping of many species could perhaps be influenced directly by decline in soil moisture content and increasing water stress conditions over a considerable period. The high abscission of leaves of tree species could as well be as a result of high evapo-transpiration rate which causes excessive loss of water from plants. Anderson et al. [35] reported that most plants are sensitive to water stress and have developed an adaptive strategy to avoid desiccation. However, Borchert and Rivera [38] and Borchert et al. [10], suggested that leaf shedding by several species is probably caused by a combination of increasing leaf age and a decline in photoperiod rather than increasing drought.

Flowering patterns varied among overstorey and understorey tree species in the TNP. Nevertheless, it was observed that some species of overstorey and understorey species had flowers throughout the year. Couralet et al. [32] and [35] noticed similar observations in the Luki Reserve of Congo and Tai National Park in Cote d'Ivoire. Probably, the variation in flowering could be attributed to avoidance of competition from pollinators. Synchronisation of flowering and leaf abscission was observed in some species. This synchrony in phenophases could be an adaptation to favour wind pollination and flower display to attract pollinators. Similar results were reported by Sing and Kushwaha [24] working on selected woody species in the tropics. The low production of flowers during the highly wet periods could be attributed to the poor weather conditions such as low temperatures, heavy rainfall and high winds.

Fruit ripening activity was generally continuous for the overstorey and understorey species in the area. However, fruiting peaks in the overstorey (February) and understorey (March) species were slightly dissimilar. Probably, this is due to the differences in the maturation time of the species. Fruit ripening coincided with leaf shedding. This might be an adaptation of wind dispersed species (*Ceiba pentandra*, *Terminalia ivorensis*, *Pterocarpus soyauxii*) for seeds to be dispersed from mother plants to avoid

competition. Similar findings were reported by Yadav and Yadav [15] for the tropical forest species. Tesfaye et al. [31] also reported related findings with seven indigenous species in Southern Ethiopia. Fruit dehiscence species (*Azalia bipindensis*, *Albizia zygia*, *Cylicodiscus gabunensis* etc.) release their seeds, which coincided with the onset of the rains to allow optimal germination. This finding corroborates with Couralet et al. [32] in the Luki forest Reserve in the Congo.

Overstorey and understorey species foliage were recorded as extended or brief leaf behavioural patterns in the rainforest. The high percentage for the extended leaf fall pattern could be attributed to the sporadic rainfall which sometimes occurred during the dry period and disrupted many physiological processes in plants resulting in extended activity such as continuous foliage production. Similar findings have been reported by Nanda et al. [39] on interruption of climatic factors on physiological processes of plants. The brief activity of the leaf fall of some overstorey and understorey tree species could result from the sensitivity to drought stress by some of these species that show rapid shedding of leaves as an adaptive mechanism to soil moisture stress. This finding also corroborates that of Pires et al. [26] who studied tree community phenodynamics in a lowland tropical rain forest in Brazil. Lengthy and rapid fruit maturation was equally observed in both overstorey and understorey tree species in the Takamanda National Park. The rapid fruit maturation of most of the understorey species as compared to overstorey species might be due to their small size and therefore needs low carbon to carry out their reproductive processes. The timing of fruit maturation in the overstorey and understorey species varies throughout the year. Consequently, both groups of overstorey and understorey species are essential in providing a continuous supply of food for frugivorous species in the forest. Related findings were reported by Anderson et al. [35]; on the abundance of frugivorous vertebrates in Tai National Park in Cote d'Ivoire while Chapman et al. [40] made similar observations in other tropical forest. Synchronous and asynchronous behavioural patterns were noticed for both overstorey and understorey tree species as adaptive mechanisms. Asynchronous activity of species may be attributed to avoidance of nectar to species that are interested for nectar and competition with pollinators.

5. CONCLUSION

The results of this study showed that seasonality plays a major role in the vegetative and reproductive phenological patterns of tree species in the Takamanda National Park. Increasing temperature and reduction in soil moisture content between October- January was observed to cause a major peak in leaf abscission in both overstorey and understorey tree species. Leaf flushing exhibited one main peak in February and a minor one in December, during the end of the dry season and the start of the rainy season in both overstorey and understorey species. Fruit ripening with main peaks in February (overstorey) and March (understorey) were observed during the end of the dry season and the start of the rains. Synchronised and asynchronised activities were recorded as adaptation mechanisms for wind pollinated species which shed their leaves, flushing flowers and thereby attracting pollinators. The seasonal variations played a paramount role in the movement of pollinators, dispersal agents, phenophases and inter-phenophase in the structuring and function of the forest ecosystem. The biotic and abiotic variability function in synergy to determined phenological patterns of tree species in the forest ecosystem. These factors play major roles in the phenological mechanism in the Takamanda National Park.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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