Phenology and Reproductive Behaviour of *Dentarium microcarpum* (Guill and Perr.) Grown in Humid Forest Research Station, Umuahia, Nigeria.

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Abstract
A phenological study of 43 years old of a single species of D. mircrocarpum was undertaken for three consecutive years (2014-2017) at Humid Forest Research station, Umuahia. The tree forked into five main boles. The biggest bole (251 cm girth) carried out its phenological process at periods different from the time other four boles (233, 190, 160 and 142 cm girth) carried out their phenological process. Bole with 251 cm girth was tagged as "A" while other four boles were collectively tagged as "B". Five accessible branches were selected from each bole and from each branch ten inflorescences were randomly selected for flowering and fruiting studies. In both "A" and "B" observation were made on the period of leafing, flowering, fruit formation and development. Observation was also made on the period of organs abscission. Fruit abscission occurred in "A" in the month of November and early December. But it occurred in "B" in the month of September and early October. It was observed that fruit production was low in all the boles and the period of phenological events were persistent to be different in both "A" and "B" within the period of the study.

Keywords: *Phenology, Dentarium microcarpum, timing, fruit production, organs abscission.*

Introduction

Detarium is a small tropical genus belongs to the family Fabaceae. It is represented in Nigeria by two tree species: *Detarium microcarpum* and *Detarium senegalense*. *D. microcarpum* occurs naturally in the drier regions of West Central Africa. This species is mainly found on shallow, stony and lateristic soil, often on hill as well as in regions with an annual rainfall of 600 - 1000 mm (Contu, 2012).There are no known conservation measure specifically for *D.microcarpum,* however the species is known to occur in many protected areas (Contu, 2012*). D. microcarpum* is highly appreciated by local people due to its verity of uses. It is said to be one of the most appreciated in the environments where it occurs naturally (Paulette, 2003) and is one of the legumes used mainly for emulsification of soup (Friday *et al.,* 2009).The task of plant phenology is to observe and record the periodically reoccurring growth stages such as leaf bud formation, flowering, fruiting etc and study the regularities and dependency of the yearly cycles of development on environmental condition. Plant reproductive biology has been undertaken from several perspectives including phenology, flora biology, mating system, pollination biology, seed dispersal, seed dormancy and seed germination. The final phase in this process is successful establishment of seedling and saplings in an environment where they can grow into reproductively mature trees. Reproductive biology has great role on design of successful in-situ conservation management plans for any plant population particularly endangered plant population. Any conservation approach has to be based on an in-depth study of plant reproductive phenology and reproductive biology (Fernando *et al*., 2015}. A general hypothesis establishing that tree size influence the reproductive output and the phenological patterns of the individuals (flowering intensity and timing) can be proposed with the prediction that proportional reproductive output will increase as does the size of the individuals. However many phonological strategies are present among plant species (Newstrom *et al*., 1994; Fernner

1998; Sakai, 2001) probably affecting their energetic requirement and allocation of resource, but also the way the productive output of the individuals of each species changes as they grow. In general, phonological behavior of the indigenous tree species in Nigeria is lacking in literature. Otegbeye and Oje (1995) had noted the need for a comprehensive study on phenology, flowering, and fruiting of local tree species throughout their natural range to facilitate the breeding of new cultivars of trees. In view of the dearth of information on phenology and reproductive behavior which is a useful apparatus in any conservation approach, a study was initiated in 2014 to investigate phenology and reproductive behavior of *D. microcarpum* in Umuahia, Nigeria.

Materials and methods

Study Area

The Forestry Research Institute of Nigeria Humid Research Station, Umuahia, Nigeria lies on latitude 5^0 32` N and longitude $7^0$ 29` along Umuahia/Ikot- ekpene road, Umuahia, at an altitude of over 122 m above sea level. The rainfall pattern is bimodal with peaks around June to July and September to October. Annual rainfall is 2238 mm. Minimum and maximum temperature **are** 23 ^{0}C and 3 ^{0}C respectively. Relative humidity is 86.4%. The vegetation has been described as high forest and soil type is sandy loam (Okeke *et al*.,1975).

Study species.

The *D. Microcarpum* was singly planted in the year 1973 as specimen tree in an open field. In the year 2007, Pine species (*Pinus caribaea* and *P .oocarpa*) were planted at the hedge of the road closer to the tree (*D. microcarpum*) as avenue trees. In the year 2011, other tree species such as *Psidium guajava, Citrus spp,* and *Terminalia mantaly* were scantly planted around the tree for recreational purposes. The tree *(D. microcarpum*) is one of the oldest and biggest trees in the station with 447 cm girth and with about 25 m high. Little centimeters above the ground, the tree is forked into five main boles, with different girths at the forked point. The girths were; 251, 233, 190, 160 and 143 cm (Fig.1) with some branches touching ground. The field where the tree grows is maintained frequently by manual cutting. The dominant plant under the study species is grass *(Paspalum conjugatum*). Before the year 2013, the tree as a biological entity showed the same phenological events in all the branches from the five main boles at the same time. In other words, each phenological event occurred in all the branches in the five main boles at the same month. In year 2013, it was observed that the phenological events in four boles with 233, 190, 160, and 143 cm in girth were no more timing with the fifth bole with 251 cm in girth. Bole with 251 cm girth which was biggest bole grows southward with other boles and it was tagged as "A". The other four boles were collectively tagged as "B" - because phenological events occur in them at the same time.

Phenological observation and data collection.

Observation were made weekly on "A "and "B" for the period of three years (January 2014-January 2017).The phenological events observed were as follows:

- **(a)** Period of leaf formation
- **(b)** Timing and duration of flowering.
- **(c)** Period of fruit formation and development.
- **(d)** Period of fruit fall/abscission and leaf abscission
- **(e)** Period of twig abscission.
- **(f)** Floral biology and their characteristics,

Method of data collection

Data were collected for three consecutive years on weekly basis. Accessible five stems from each bole were selected. Ten inflorescences were randomly selected from each stem and tagged. This was repeatedly done for three years. The number of flower buds and mature fruits were recorded from each inflorescence. Data were also collected on the number of days taken leaf bud to open completely into a leaf /leaves, the period of time taken new leaves to mature leaves (deep green), the number of days taken from fruit formation to the point of maturity and abscission. Data were transformed and subjected to statistical analysis for the comprehensive results.

Results

Leaf formation

From the observation made on "A" and "B" the period of leaf formation were not the same. Leaf formation started in "A" between the month of December and January. "B" on the other hand, leaf formation took place between the month of October and November. Leaf bud (Fig.2) changed to a complete leaf/leaves (Fig.3) between 5-8 days. From the leaf bud formation to a mature leaf (deep green) it took about 75 days in both "A" and "B". A leaf bud produced average 1-7 leaves at maturity. The leaf bud length ranged from 1-1.5 cm, the width ranged from 0.8-1.2 cm before bursting.

Timing and duration of flowering

From the new twigs produced from leaf buds, flower stalks emanated in "A" and "B" between four and six weeks after leaf bursting. The process of flowering started in "A" in first week of February and continued till second week of march. The process of flowering in "B" started in first week of November and continued till second week of December. From flower bud formation (Fig.4) to the anthesis (Fig.5) it took average 8-10 days followed with much abortion of flowers. Flower bud width and length were the same and ranged from 1.5-2.5 mm.

Period of fruiting formation and development

Fruit formation in "A" began in the month of March and continued till month of April. The process of fruit formation and development to the period of maturity took 7-8 months in "A" (March to October). In "B", fruit formation began in first week of December and continued till month of January. The process of fruit formation and development also took 7-8 months in "B" (February to August). (Fig.6 and Fig.7). The width of fruits produced by "A" and "B" ranged from 3-5 cm. Also the length ranged from 3-5. The width and the length of the fruits produced by *D. microcarpum* were the same.

Table 1: Showing period of phenological events.

Phenological events	Bole	Period of events	Peak of events
Leaf formation	A	Dec - Jan	Third week of December
	B	Oct – Nov	Third week of October
Flowering	A	Feb – March	Last week of February
	B	Nov – Dec	Third week of November
Fruit-fall	A	Nov – Dec	Fourth week of November
	B	Sep – Oct	Fourth week of September
Twig/Stem abscission	A	Oct – Nov	Third week of October
	B	Aug – Sep	Fourth week of August
Leaf abscission	A	Sep – Nov	Second week of November
	B	July – Sept	Second week of September
Fruit development	A	April – Oct	Seven months
	B	Dec – August	Eight months

Period of fruit fall/ abscission.

It was observed that fruit abscission in "A" began in first week of November throughout the studied years. The peak of fruit-fall was observed to be fourth week of November but the period of fruit-fall continued till second week of December.

The process of fruit-fall began in "B" in first week of September. The peak of fruit-fall took place at last week of September. The fruit-fall continued till second week of October (Table1)

Period of leaf-fall and twig abscission.

D. microcarpum is one of the tree species which abscise twigs. The process of leaf abscission starts before the twig abscission. Leaf-fall/abscission began in "A" in second week of October and continued till first week of December. The peak of leaf abscission was between third and fourth week of November. Shedding of twigs also occurred along with leaf abscission. Twigs abscission peak took place in the month of November (Table 1) the process of leaf defoliation started in "B" between July and August and continued till second week of October.

The period of high defoliation used to be month of September. Twig abscission commenced in the month of August and continued till first week of October (Fig.10 and Fig.11).

Floral biology and characteristics.

The flower of *D. microcarpum* are floret with white petals and tetramerous in nature. Sepals are not well developed. The number of flower produced by inflorescence was between 10 and above. Not more than one fruit was produced per inflorescence. *D. microcarpum* is monoecious, the flower is entemophilous with only one style situated at the center and surround by a number of stamen ranged from 6-10. Style is between 1-2.5 mm long. The inflorescence is compound cyme, flower is actinomorphic (regular), perfect (bisexual), complete, hypogynous and superior.

Table2: Showing flowering and fruiting pattern of *D. microcarpum* for three consecutive years.

Bole	Girth (cm)	Year	Number of flower bud	Fruits produced
A	251	1st	68.60±1.92	9±0.23
		2nd	46.02±2.09	15±2.01
		3rd	37.25±3.93	7±1.31
B1	233	1st	41.63±1.49	3±1.63
		2nd	32.81±3.58	6±3.44
		3rd	29.67±6.14	4±0.51
B2	190	1st	33.07±6.40	2±1.38
		2nd	23.49±5.51	3±0.31
		3rd	42.61±2.52	4±3.83
B3	160	1st	36.44±5.10	7±1.81
		2nd	46.38±3.34	3±3.58
		3rd	23.20±4.21	4±0.46
B4	143	1st	19.35±6.14	3±3.16
		2nd	43.73±1.97	5±0.25
		3rd	26.92±5.72	3±3.26
P(≤0.05)			3.71	0.79

Fig 1: Five main boles of *D.microcarprum*

Fig 2: Leaf bud of *D.microcarprum*

Fig 3: Leaf bursting of *D.microcarprum*

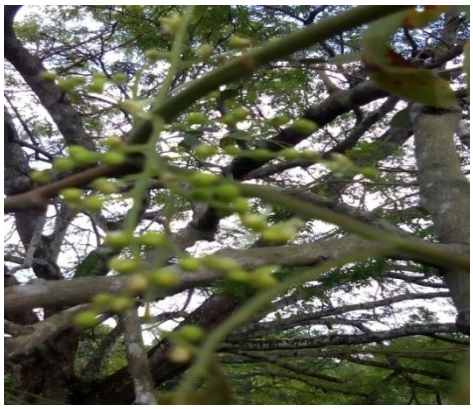

Fig 4: Flower bud of *D.microcarprum*

Fig 5: Opening of flower buds

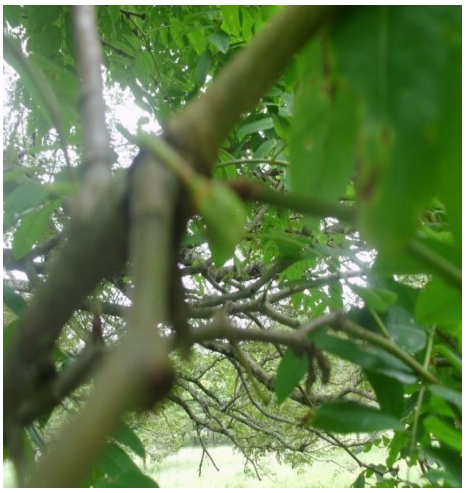

Fig 6: Early fruit stage of *D.microcarprum*

Fig 7: Developmental fruit stage of *D.microcarprum*

Fig 8: Mature fruit of *D.microcarprum*

Fig 9: Abscissed fruit of *D.microcarprum*

Fig 10: Leaf defoliation in *D.microcarprum*

Fig 11: Abscisseion twig point in *D.microcarprum*

Fig 12: Defoliation in "A" and leafing in "B" in the same month.

Discussion

Detailed information on phenological studies helps in the conservation as well as framing effective measures for successful conservation of a species (Delanoe *et al*., 1996; Wafai *et al*., 1996).Phenological information with respect to flowering, fruiting, leafing and leafless periods is scarce about deciduous tree in Nigeria (Otegeye and Oje, 1995). Advanced in phenological events in all the "B" branches of the studied tree species could be as a result of climatic factors coupled with physiological alteration. Several studies have shown significant variation (advanced or delayed) in date of flowering (Fitter and Fitter, 2002) and fruiting responses (Chapman *et al*., 2005) in tree species as a result of climatic change. The advanced in phenological events observed in "B" branches could also be as a result of physiological factors such as variation in period of auxin production. Because auxin plays important role in leaf formation, fruit formation and development (Sarojini, 2010). It could be that the auxin which helps in leaf formation produced earlier in all the "B" branches than "A" which led to early leaf formation and fruiting in "B". Newstrom *et al*. (1994) reported that many phenological strategies are present among plant species which affecting their energetic requirement and allocation of resources. Profuse twigs and small branches abscission is one of the phenological events displayed by *D.microcarpum* which is not so common among tropical trees. The tree abscised twigs and small branches in both "A" and "B" at different periods of time. The abscission process of twigs and small branches brought about by a fall in auxin level and an accompanying rise in abscic acid level. Although a specific study was not conducted to determine auxin level in this study. Immediately after twigs and branch abscission, a layer of cork cells forms just below the abscission layer and protects the exposed part of the stem from attack by micro-organism (Sarojini, 2010).

Production of more fruit was observed in "A" (Table 2) although the fruits produced by "A" were small in size and the weight ranged from 75 to 85 g. The fruits produced by "B" were bigger and their fresh weight ranged from 95-102 g. Tropical trees respond variously to changes in rainfall and temperature because they differ widely with respect to adaptations to seasonal drought and cues for bud break of vegetative and flower buds (Singh and Kushwala, 2005). Within the period of the study (2014-2017) the fruit production was very low in both "A" and "B". Although in the second year of the study, "A" produced 15±2.01 fruits which was still very low compared to the number of flower buds produced (46.02±2.09) by those branches. Recent studies showed that effects of pollen quantity and quality on reproductive success have become an important issue in plant conservation (Dudash and Fenster, 2000). In

this study, specific studies were not carried out to test for pollen viability. The failure of high rate of transformation from flower bud to fruit observed could be indicative of reduced pollen viability. Other probable reasons for reduced fruit set include low pollen loads on stigma, the absence of pollen tubes, at the base of the style, small population size, genetic loads and climatic change (Dorken and Ecker, 2001). Also the relative age (43 years) may account for low flower production. Xie *et al*. (1991) observed that variation in genetic composition and age structure affects flowering of population of plant. This could also applicable to the single species of *D. microcarpum* studied. The phenological study of 43 years old *D. microcarpum* reveals that a single isolated tree species can have phenological events not timing in all its branches with low fruit production at that age. For the fact that this study was carried out on isolated tree, any further research on phenology and reproductive biology of *D. microcarpum* should be studied on the population of the species in any other part of eastern Nigeria.

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