Regeneration ecology of the bamboo climber *Flagellaria guineensis* in the Transkei Coastal Forests, Eastern Cape, South Africa

By

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Abstract

Economic benefits obtained from *Flagellaria guineensis*, a climbing bamboo, by local people received attention in previous studies but little is known about its regeneration ecology in three different forest stand conditions, i.e. forest edges, forest gaps and mature closed-canopy stands. In the Eastern Cape of South Africa the species grows in the Transkei Coastal Forests. The main aim of this study was to assess the regeneration ecology of *F. guineensis* in those forests. The specific objectives were to describe the phenological state that would influence the flowering, fruiting and growth of the species, and to compare the culm (stem) development from the rhizome between the different forest stand conditions. Phenological comparison was done in forest edge and forest interior conditions two forests. Rating scales were applied to determine the phenological states of the presence and amount of flower buds, open flowers, fruits, shoots and seedlings. Development of *F. guineensis* was assessed by sampling clusters in the three different forest stand conditions in three forests.

The observation made in two Transkei Coastal Forests indicate that *F. guineensis* regenerates by producing seed, new vegetative shoots from rootstocks and also shoots at the growing tips. The flowering and fruiting period occurred only in the rainy season in Mtambalala forest but both rainy and dry seasons in Bulolo forest. More flowers and fruits of *F. guineensis* were found in Bulolo forest and in the forest edge (where *F. guineensis* is able to form tangles on the canopy of its host tree) respectively. This climbing bamboo clings on any plant around it for support and forms tangles on the canopy of its host in forest edges with no direct damage caused to host trees. The production of seedlings, shoots from the rhizome and shoots at the growing tips was constant during the study period in both study sites. The growth pattern of *F. guineensis* was different when comparing the three Transkei Coastal Forests studied. Manubi forest was found to have clusters and culms with the highest diameters and length compared to Mtambalala and Mnenga forests. There was a significant difference in culm diameter and length of *F. guineensis* between all three forests, whereas cluster diameter and number of culms per cluster were not influenced by forest stand conditions. *F. guineensis* clusters were common in the forest edges or gaps, and formed tangles in the canopy of their host trees. The described pattern of growth of *F. guineensis* contributes to recovery of the forest edges or gaps by restricting easy movement in and out of the forests. Several recommendations were made for harvesting of culms for basket-making, such as: it should be done with care to reduce tangles in the forest and tree canopies; it must take place during the dry season, when the culms in a cluster are not flowering or fruiting; and studies are needed on the growth rate of seedlings and their growth into the forest canopy and how the bamboo can be cultivated outside the forest for better production of culms.

Keywords: Climbing bamboo, culm, regeneration, forest, host tree, cluster.

Declaration

I, Ndivhuwo Tshaduli declare that the thesis/dissertation, which I hereby submit for the degree MSc Forest Science at the University of Pretoria is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: ....

DATE: 13 March 2017

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CHAPTER ONE: A study of *Flagellaria guineensis*: Introduction and Objectives

1.1. Introduction

Flagellaria is a genus under the order Poales, family *Flagellariaceae*, consisting of four or more species which include *F. guineensis* and a closely related species *F. indica.* The climbing bamboo *Flagellaria guineensis* Shumach plays a significant role in local income of rural people around Port St Johns (Cawe & Ntloko, 1997) and its many uses in other parts of the continent have been outlined in Bosch (2010). The knowledge of this specie's growth pattern is vital for sustainable management of the plant in the forests. *Flagellaria guineensis* is the only African representative of the four or more species of this genus of climbing bamboos and occurs in the tropical and subtropical indigenous forests of Africa (Figure 1), including the east coast of Africa, as far south as the coastal districts of the Eastern Cape around Manubi (Baldwin & Speese, 1957).

Flagellaria guineensis occurs from sea-level up to 1100 m altitude, in coastal forest, swampy forest, along rivers, in forest edges, thickets and waste places (Bosch, 2010). Herbarium material examined at Kew in 1949 indicated that *F. guineensis* has a geographic range from the Ivory Coast through West Africa to the Belgian Congo (now Democratic Republic of Congo), across to Kenya, through East Africa to South Africa (Baldwin & Speese, 1957). In South Africa, *F. guineensis* is largely confined to the Tongaland-Pondoland Regional Centre of Endemism along the eastern seaboard (Cawe & Ntloko, 1997).

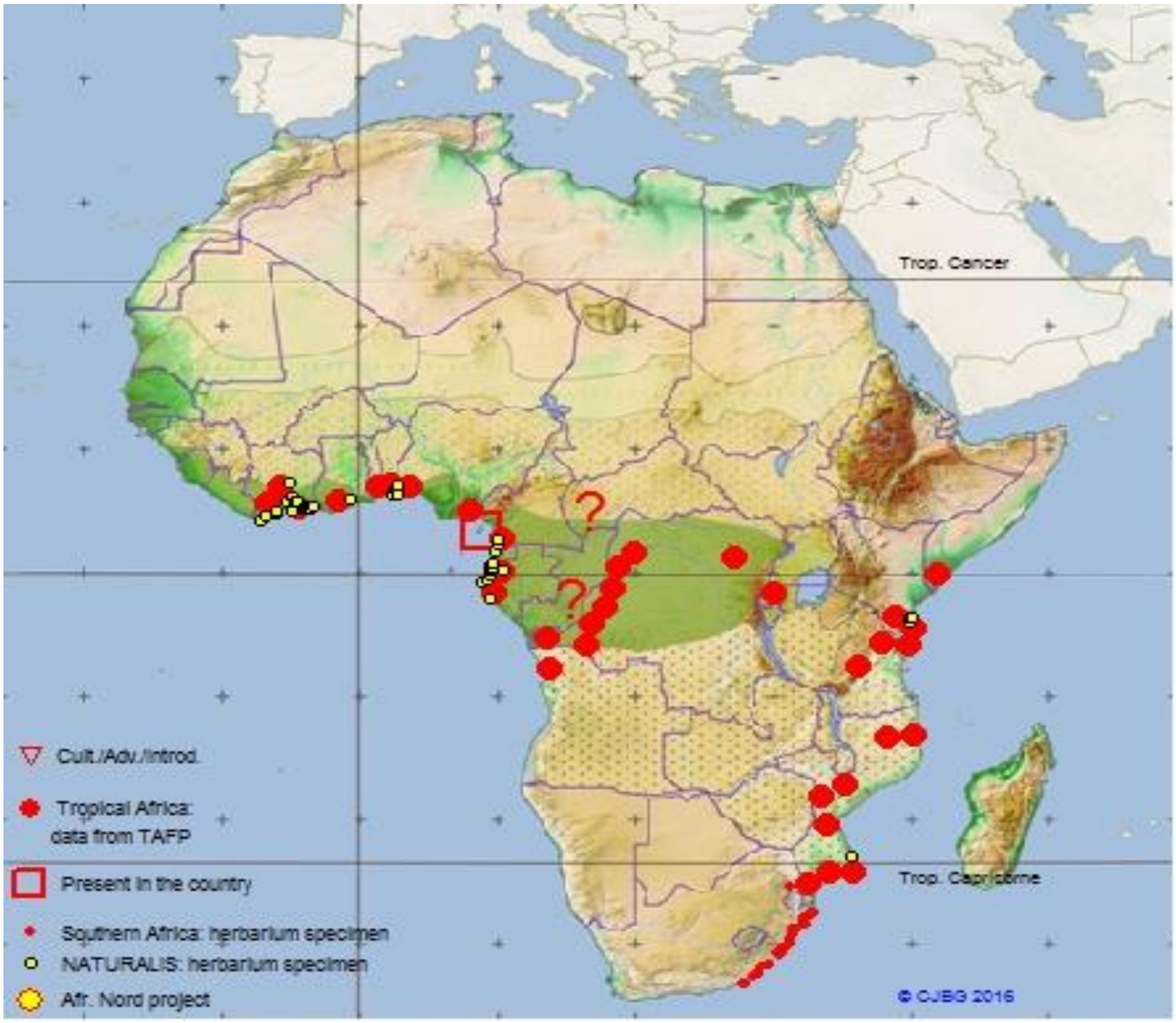


Figure 1: Distribution map of *Flagellaria guineensis* in Africa (Source: CJB & SANBI, 2012)

Flagellaria guineensis is a perennial climber with slender stems up to 2.5 cm in diameter and up to 10 m long with sympodial rhizomes (Bosch, 2010). Baldwin & Speese (1957) indicated that *F. guineensis* was observed in West Africa to be common on the edge of secondary forest and climbing to a height of 30 m. Climbers concentrate on the margins of forests and in tree fall-gaps because of their need for light and support, but their presence contributes towards maintaining the forest margin and microclimate (Balfour, 2004).

Tree hosts supporting climbers have suffered higher mortality rates and upon falling caused more other trees to fall than trees without climbers (Putz, 1984). Balfour (2004) outlined that tree mortality caused by climbers can take place by two possible mechanisms: firstly, through direct shading of an adult tree once the climber has gained a position in the forest's canopy; secondly, once in a canopy, a climber can 'canopy hop' between trees, thereby linking them, and pulling others down when one tree falls.

Certain plants are known to live vegetatively for many years, and then flower and die in mass (Seifriz, 1920). The climbing bamboo *Chusquea abietifola* has a purely vegetative growth of about thirty-one years and then has a single brief period not exceeding two years of synchronous flowering and seed dissemination and death, leading to a complete plant cycle of thirty-three years (Seifriz, 1920). Such simultaneous flowering and die-back had been observed in *Isoglossa woodii*, a common understory soft shrub in the South African Coastal Forests (Van Steenis, 1978). The question is therefore whether *F. guineensis* has a similar behavior.

Non-timber forest products (NTFPs) make up a diverse basket of products that ensure and enhance the quality of life of forest users (Sills *et al*., 2011). *Flagellaria guineensis* constitutes a NTFP of major cultural and economic importance, and its economic value has received attention in previous studies. Its stems are used for basket-making and other woven products (Figure 2) for generations, also as a source of income to rural people (Cawe & Ntloko, 1997; Cawe, 1999).

Figure 2: A small basket-market between Port St Johns and Lusikisiki in Eastern Cape Province.

Bosch (2010) indicated that *F. guineensis* will remain important for local use and is considered a good alternative for rattan. The local name for *F. guineensis* is “Ugonothi”; it is used extensively for weaving mainly baskets and is sold in bundles, locally called head loads in Port St Johns (Cawe & Geldenhuys, 2007). Bosch (2010) reported that the stems of *F. guineensis* are used for hut construction and to make necklaces in Gabon while in Tanzania they are used for making fish traps. In Côte d'Ivoire the leaf decoctions are drunk as a cure for gonorrhea and used as a mouth wash against dental caries; the fruits are sometimes eaten in Tanzania and Mozambique (Bosch, 2010).

Flowering, fruiting and growth patterns of climbing bamboos

Flowering, fruiting and growth patterns had been studied in various bamboo species. Flowers of *F. guineensis* are borne in terminal panicles of white flowers. The perianth is 6-parted, 2-whorled, subpetaloid, hypogynous and persistent. Stamens are 6, with free filaments and 2-celled introrse anthers. Ovary is superior and 3-celled, with single ovule in each cell. Style is 3-lobed. The fruit is a bright red, showy berry about 6mm in diameter (Baldwin & Speese, 1957).

Flagellaria indica is a pantropical species found from Australia to South America and also in Madagascar. It occurs mainly in coastal forest and moist lowland forest in Madagascar (Rabenantoandro *et al*., 2008). *Flagellaria indica* is a climbing bamboo (liana) which clings to surfaces using terminal leaves that have been transformed into tendrils. Young lianas cannot survive under full sun exposure and require shade in order to grow (Rabenantoandro *et al*., 2008). However, adult lianas are known to be strongly light-demanding (heliophytic), and most require trees and shrubs to cling to, in order to grow and receive light in the closed-canopy, forest gaps and edges (Rabenantoandro *et al*., 2008). It grows best on lateritic soils where it can reach diameters of 2 cm or more. It is estimated that the culms (stems) require about 10 years of growth to reach the minimum 1cm diameter (Rabenantoandro *et al*., 2008). This species produces flowers throughout the year, with fruit formation that peaks in December. The fruit is black in colour, and ripe fruits can be observed until April (Rabenantoandro *et al*., 2008).

Various species of *Chusquea* have been studied. Clark (in Widmer, 1999) stated that this genus is a clump (cluster)-forming bamboo which occur in South America, Central America, Mexico and The Andes. Widmer (1998b) indicated that when they grow among trees, *Chusquea* clumps have an erect habit and the culms show either pendulous tips (*C. talamancensis*) or climbing tips which ascend along the tree trunks foraging for light (*C. tomentosa*). In forests where the canopy is low more climbers enter the host-tree canopy vertically (Balfour & Bond, 1993). If high supports are lacking, *Chusquea abietifolia* succeeds very well in climbing over low shrubs (Seifriz, 1920).

Culm diameter and rhizome branch diameter of *Chusquea* species increase annually in the rainy season and under favourable growth conditions such as adequate light, nutrients and also with no-grazing; however development slows down as the clump approaches maturity (Widmer, 1998a). In the old-growth forest, as long as the canopy is closed, *Chusquea* growth is relatively slow because of the low light intensity (Widmer, 1998b).

The forest canopy has a clear effect on the morphological performance of mature *Chusquea* clumps of all species and also upon the spatial distribution of the populations. *Chusquea* clumps of all species tend to be few and large in gaps, and numerous and small under closed canopy (Widmer, 1998b). In large open sites the growth habit of the *Chusquea* bamboos is more arched and the culms of the different clumps are intermingled, forming an impenetrable thicket; passage is only possible by creeping below or climbing over the culm mat (Widmer, 1998b).

Widmer (1998a) observed that there is no seed production when isolated *Chusquea* bamboo plants flower. Observations of native bamboo species established in a natural community may facilitate the interpretation of the flowering and seeding process (Widmer,1998a). The flowering pattern of *C. talamancensis* followed the seasonal rainfall pattern (Widmer, 1998a).

1.2. Problem statement

Information on the ecology of *F. guineensis* is scarce; no detailed assessment of its regeneration patterns in the Transkei Coastal Forests in the Eastern Cape has previously been carried out. The bamboo climber was seen in Manubi forest (one of the study sites) directly shading the adult trees on the forest edge. The tree canopies appeared very green when observed from a distance, but when viewed from close-up, the green colour in the canopy is shown to be a dense tangle of *F. guineensis*. This bamboo climber is not utilized in Manubi forest, but in the Port St Johns and Lusikisiki areas of the Eastern Cape, it is being utilized for basket-making. Understanding of the development patterns of this species in the forest will help with a better management of the resource for basket-making. The observations in Manubi forest stimulated an interest to study this species in the Transkei Coastal Forests, particularly its ecological aspects in the forests of the Eastern Cape, i.e. to understand how *F. guineensis* function in different forest and their forest stand conditions. The hypothesis is that *F. guineensis* development will be significantly different between the forest edge, forest gaps and in mature forest with closed canopy. The knowledge gained from this study provides the ecological basis for sustainable use of the species from the forest, and for development of alternative resources for local industries based on woven products.

1.3. Study objectives and key questions

The main aim of the study was to assess the regeneration ecology of *F. guineensis* in the Transkei Coastal Forests. This main objective was pursued through two specific objectives.

Specific objective 1: To describe the phenological state that would influence the flowering, fruiting and growth of the species. In order to achieve the above objective, the following questions were formulated:

(i) What is the pattern of flowering, fruiting, shoot development and seedling production in the species?

(ii) Does the species regenerate from seeds or rootstocks or both?

(iii) How and under what conditions do the seedlings establish and grow?

Specific objective 2: Compare the development patterns of the culms (shoots) between different forest stand conditions and forests. In order to achieve the above objective, the following questions were formulated:

(i) How does the plant develop on forest edges (margins), in forest gaps and in mature closed-canopy forest?

(ii) How does it get into a tree if it continuously starts from the bottom?

1.4. Study area

1.4.1. Transkei Coastal Forests

The Transkei forms part of the Eastern Cape in South Africa (Figure 3), the coastal part is also known as the Wild Coast. This coastal part stretches for 300 km from the Great Kei River in the south to the Umtamvuna River in the north. Rainfall is usually greater than 700 mm per year and is more prevalent during summer. Mean temperature ranges from 17-20° C (Bredenkamp *et al*., 1996; Von Maltitz *et al*., 2003). The forests are mainly found on Sandstone outcrops, syenitic granites and rhyolites, and the soils are generally alkaline and medium to coarse-grained (Bredenkamp *et al*., 1996; Von Maltitz *et al*., 2003).

Transkei Coastal Forests occur as two spatially separated belts representing two subtypes; the Transkei Coastal Platform Forests which are found scattered along the Southern Transkei Coast between Mngazana (just South of Port St Johns) in the North and East London in the South. Transkei Lower Scarp Forests are situated in a belt more inland (up to 600-800m of altitude), in Scarp situations (Von Maltitz *et al*., 2003). The vegetation is characterized by medium to high forest (15-25 m) comprising three distinct strata: a tree stratum of canopy trees, with well-developed sub-canopy tree stratum with seedlings and saplings, and a poorly developed herb layer (Von Maltitz *et al*, 2003).

The forests are found on coastal slopes, below scarps and in deep incised valleys. Common tree species include *Buxus macowanii*, *B. natalensis*, *Drypetes gerrardii*, *Englerophytum natalense*, *Harpephyllum caffrum*, *Heywoodia lucens*, *Millettia grandis*, *Ptaeroxylon obliguum* and *Umtiza listeriana*. Herbaceous climbers include *Flagellaria guineensis*, *Thumbergia alata*. Common shrubs and scramblers include the Cat-thorn *Scutia myrtina*, *Grewia occidentalis* and *Eugenia natalitia* (Von Maltitz *et al*., 2003; Mucina & Geldenhuys, 2006).

1.4.2. Study forests

Four forests were selected for this study along the Transkei Coast (Figure 3; Table 1): Different forests were selected for the studies in chapters 2 and 3. It was logistically easier to do the phenological study with monthly visits in Bulolo and Mtambalala forests. The study of clusters

Figure 3: Location of the four Transkei Coastal forests in the Eastern Cape, South Africa, used in the two studies.

was a once-off study and it was considered best to select different widely-spaced forests along that coastal area representing different forest structures; that study was done in Manubi, Mnenga and Mtambalala forests.

Table 1: Biophysical characteristics of the four study forests in the Transkei Coastal Forests in the Eastern Cape Province.

Forest and specific studies[1]	Altitude (m)	Latitude and longitude	Geology and Soils (Source: King 1941; Cloete, 2004)	Climate	Topography
Manubi (b)	100 to 200	32˚26'34.83" S, 28˚35'42.02" E	Beaufort shales, Clayey and doleritic soils	Warm	Coastal platform with gentle slopes
Mnenga (b)	80 to 125	31˚36'27.94" S, 29˚34'33.96" E	Shales and sandstones, Sandy and clayey soils	Warm and humid	Coastal scarp with hills and steep slopes
Mtambalala (a, b)	50 to 125	31˚32'55.98" S, 29˚36'21.50" E	Shales, mudstone and sandstone, Sandy and clayey soils	Warm and humid	Coastal scarp and steep to gentle foot slopes
Bulolo (a)	6 to 100	31˚38'37.56" S, 29˚30'59.60" E	Shales and sandstones, Sandy and clayey soils	Warm and humid	Foot slopes below coastal scarp

[1] Studies: a = Phenology study, b = Shoot development study

1.5. Thesis layout

Chapter 1 (this chapter) includes a literature review in the introduction on relevant information for this study on the ecology and development stages of climbing bamboos. It states the identified problems associated with the ecology and management of the focus species in the forests and sets out the objectives and key questions for this study. It also provides a general description of the study area and studied forests.

Chapter Two involves the first stage of data collection and phenological observations in two Transkei Coastal Forests, to determine the flowering, fruiting and growth patterns of *F. guineensis* at the two forests.

Chapter Three involves the second stage of data collection and deals with the development of clusters and culms of *F. guineensis* plants in the forest edge, canopy gaps and closed mature forest in three Transkei Coastal Forests.

Chapter Four is the concluding chapter and includes guidelines for the sustainable management of the climbing bamboo *F. guineensis* in the forests.

CHAPTER TWO: Flowering, fruiting and growth phenology of *Flagellaria guineensis* in Transkei Coastal Forests

Abstract

Flagellaria guineensis is a climbing bamboo that occurs in the coastal forests of South Africa, its culms produce the flowers and fruits that would ensure perpetuation of the species after being harvested. This study compared the monthly phenological state of the presence and amount of flower buds, open flowers, fruits, shoots and seedlings in the Mtambalala and Bulolo Transkei Coastal Forests on the forest edge and the forest interior from April 2014 to April 2015. Both flowering and fruiting were seen only during the rainy season in Mtambalala forest whereas in Bulolo forest it was seen during the rainy and dry seasons, but in general relatively very few flowers and fruits were seen. Regeneration of the climbing bamboo in the forests through the production of seedlings and shoots was constant on the forest floor during the study period and also shoots at the growing tips in both study sites. Flowering and fruiting of *F. guineensis* differs between seasons and sites. The major result from this study is that there may be a two-phase cycle, with a vegetative phase of much leaf-shoot and rhizome shoot development, followed by a reproductive phase of much flowering and fruiting, with possibly some culm die-back following an intense reproductive phase.

Keywords: climbing bamboo, Flagellaria, forest, phenology, regeneration, cluster.

2.1. Introduction

Culms of the climbing bamboo *Flagellaria guineensis* in the South African coastal forests are harvested for basket-making, but they also produce the flowers and fruits that would ensure perpetuation of the species. Sustainable harvesting of the species from the forests therefore requires an understanding of the phenological stages of flower, fruit, shoots and seedling formation. Bamboo regrowth patterns are vital for sustainable management of the plant in the forests. The study of plant phenology involves the observation, recording and interpretation of the timing of their life history events (Fenner, 1998). Plant phenological stages provide knowledge about the plant growth and development patterns as well as the effects of the environment and selective pressures on flowering and fruiting behaviour (Zhang *et al*., 2006). The switch to flowering is the most important event in the life cycle of a plant, signaling its commitment to set seed ensuring survival of the species (Ramanayake, 2006).

Some plant species are known to live vegetatively for many years, then flower in mass and eventually die in mass, such as *Chusquea talamancensis* (Widmer, 1997). However, the life of the bamboo plant is sustained by the development of new shoots and culms. The shoot is the new growth from the dense root rhizome system (Muller and Rabello, 2010) that develops into a culm, *i.e.* the individual bamboo stem (Kigomo, 2007). In the case of the climbing bamboos, the developing culms in a cluster, *i.e*. culms growing together on the same rhizome, may climb by various means to the tree crowns. The reproductive success of a plant depends on its flowering time being adapted to the environment in which it grows (Ramanayake, 2006). In the climbing bamboos the culm grows from ground level under the forest canopy to the top of the host trees, and the changing light conditions may determine the successful flowering-fruiting behaviour of the species.

Patterns of bamboo regeneration through the production of new seedlings can be influenced by forest canopy conditions (Taylor *et al*., 2004). Forest canopy density has a strong influence on bamboo regeneration from seed. After a bamboo flowering event and when seedlings are seen on the ground, it takes many years for the seedlings to develop into mature plants (Taylor and Qin, 1993).

Widmer (1998a) pointed out that the culms of a bamboo clump do not always flower in synchrony; some plants have culms in two different phenological states. The pattern of flowering could be classified into three types as 1) only some culms in the clump flowering; 2) only some clumps flowering in the whole area, and 3) all clumps and culms flowering in the whole area (Marod *et al*., 2005). Kigomo (2007) outlined that there are two types of flowering in bamboos: gregarious flowering and sporadic flowering and further explained that gregarious flowering occurs when the clumps of an entire species flower, produce seed, and then die; sporadic flowering produce seeds but the clumps generally survive.

Flower formation in climbing bamboo lasts for about three months until the flower has developed the generative parts (Widmer, 1998a). Bamboos generate seeds when they flower; the fruit is the form in which most plants present their genetic off-spring to dispersal agents for dissemination (Geldenhuys 1996; Kigomo 2007).

In bamboo, the duration of the vegetative phase and switch to flowering varies according to the species (Ramanayake, 2006). The pattern of flowering of individual species varies widely (Fenner, 1998). Information about phenology of utilized non-timber forest products is important. Sustainable utilization of the bamboo is only possible if adequate information on the regeneration dynamics is available.

Flagellaria guineensis is a climbing bamboo which falls under the family Flagellariaceae, this species occurs in the tropical and subtropical indigenous forests of Africa. This climbing bamboo tends to shade the canopy of host trees in the forest edges. This species in the coastal forests is woody with sympodial rhizomes and is patchily distributed. The species is used by local people for making baskets and other woven products. Adequate management of this species is important as it provides local income for rural people and to avoid depletion of the resource in the state forests.

The main purpose of this specific component of a larger study was to i) determine the flowering, fruiting and growth phenology of *F. guineensis*, i.e. the periods of producing new shoots at the growing tips and at ground level, flower buds, flowers, fruits, seedlings, and ii) to determine the production patterns between the shady forest interior and the exposed (sunny) forest edge. The key questions asked are:

(1) What is the pattern in the seasonal variation in the production of flowers, fruits, leaf shoots, shoots and seedlings in the species, in particular the production of new shoots, inflorescences and ripe fruits?

(2) What are the flowering, fruiting and growth patterns of this species between the forest interior and forest edges?

2.2. Methodology

2.2.1. Study sites

The observations on the flowering, fruiting and growth phenology of *F. guineensis* were carried out in the Eastern Cape Province in Bulolo forest (31°38'36.25 S, 29°30'58.55; 6 m above sea level) and Mtambalala forest (31°32'57.22 S, 29°36'19.99 E; 7 m above sea level) around the Port St Johns area. The sites are state forests and are mainly covered by old-growth trees with *Millettia grandis, Trichilia dregeana* and *Englerophytum natalense* species dominating.

Total monthly rainfall during the study period was obtained from the Silaka Nature Reserve near Port St Johns, close to the Bulolo forest (Figure 4), showing two dry periods between May to August and January to February, and two rainy periods between March to April and September to December. Temperature information was not available for the study areas.

2.2.2. Data collection

Selection of sites and plants for observation

At each study area (forest), 30 observation spots (one bamboo cluster) 10 m distant from each other were selected in the forest with 10 spots in each of three forest stand conditions: Forest edge (E), Forest edge (W) and Forest interior (I). There were not many clusters at a spot;

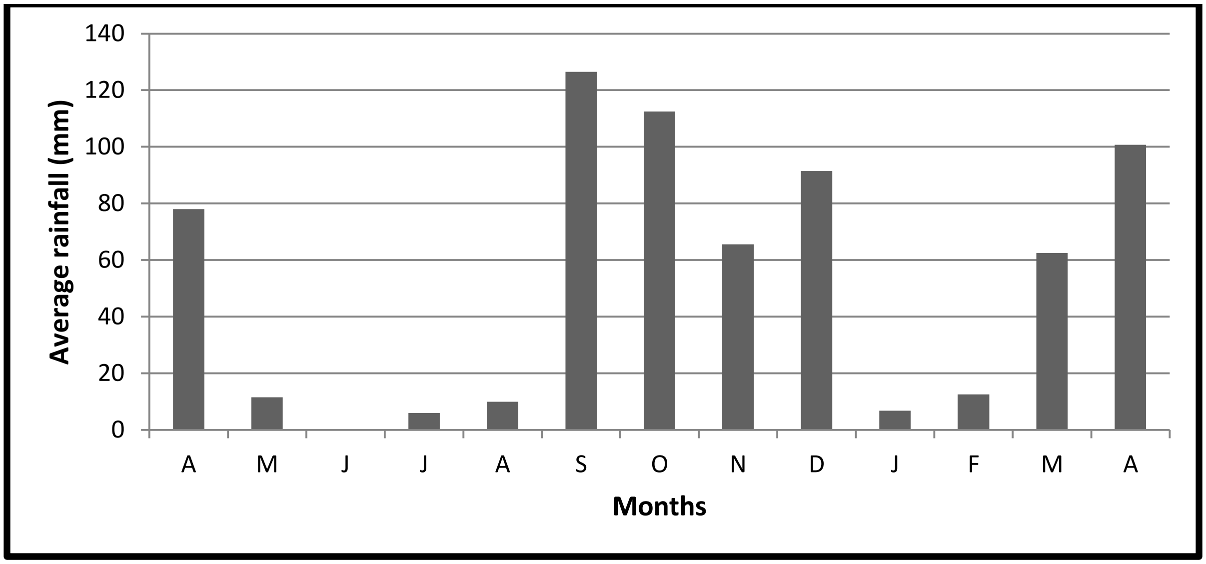


Figure 4: Rainfall diagram for the study period from April 2014 to April 2015 (data from Silaka Nature Reserve near Port St Johns).

therefore, an available cluster closest to a random point was selected. Forest edge (E) was exposed to the east or south (exposed to the sun during the morning with cooler conditions); Forest edge (W) was exposed to the west or north (exposed to the sun during the afternoon with warmer conditions); and Forest interior (I) was inside the forest below the forest canopy. In total, 60 clusters were observed in the two areas.

Marking of plants for observation

Each observation spot was marked with a number (1 to 30) in each area, on the nearest tree stem, and the geographic coordinates were recorded with a GPS.

Frequency of observation

Quantitative data on the phenological state of *F. guineensis* were gained from a survey made from April 2014 to April 2015. The study period was limited to 13 months because it was a once-off study. Observations were done once every month, and always during the last week of the month. Data collection on shoot production from rhizomes was started in June 2014 until April 2015, when it was realised that shoot development from rhizomes may be important.

Observation and recording of phenological stages

A separate form was used for each observation spot (60 forms in total for the two study areas). Each form provided for different sets of information to be recorded: (a) site information, including forest stand conditions, altitude and coordinates of the observation spots; (b) phenological state of the observed cluster, recorded by the presence and abundance of the following stages: flowering buds, flowers, fruits, leaf shoots, shoots regenerating from the rhizomes, and seedlings (regeneration from seeds). Distances of than <2 m from the parent cluster. A plant can present different phenological states at the same time, such as flowering and fruiting. In order to record the intensity of each observed state, a rating system from 0-3 was devised to record the level of each particular phenological state as follows:

0 = none;

1 = few;

2 = intermediate; and

3 = abundant.

2.2.3. Data analysis

Microsoft excel and descriptive statistics in SPSS were used to analyze the data in order to answer the study research questions. The phenological observations of *F. guineensis* in the two forests and their forest stand conditions were compared. The monthly mean intensity of occurrence of a specific phenological state (flower buds, flowers, fruits, leaf shoots, shoots from rhizomes and seedlings) was determined and summarized per forest and per stand condition. (1) To compare the mean phenological state per month for each forest the following formula was used (see example for flowering intensity in Appendix 2.1):

Mean intensity per month = (No of clusters with few flowering * 1) + (No of clusters with intermediate flowering * 2) + (No of clusters with abundant flowering * 3) ÷ 30

(2) To compare the mean plant information per stand conditions for each forest the following formula was used:

Mean intensity per month = (No of clusters with few flowering * 1) + (No of clusters with intermediate flowering * 2) + (No of clusters with abundant flowering * 3) ÷ 10

The above formulas were used to calculate the monthly mean intensity of occurrence (abundance of plants in state x level of state on a plant) of a specific phenological state (flower buds, flowers, fruits, leaf shoots, shoots from rhizome and seedlings) in two forests (Bulolo and Mtambalala) and relevant forest stand conditions (Forest edge E, Forest edge W and Forest Interior I).

2.3. Results

Field observations showed that in *F. guineensis* the leaf shoots at the end-tip of a culm and inflorescences (with green flower buds in a cluster) do not form at the same time. The inflorescences develop at the end-tip of the culm, which then change to open white flowers. After flowering the fruits are formed on that inflorescence cluster. When they ripen, they either fall off to the forest floor, or get dispersed. Leaf shoots then develops at the tip end of the culm after the dead inflorescence has dropped. Seedlings often germinate next to the parent plant (cluster) but also sometimes some distance away from the cluster (Cawe & Geldenhuys, 2007), and with shoots from the rhizome sometimes present outside of the cluster.

2.3.1. Flower bud phenology of *Flagellaria guineensis*

Phenological patterns of flower buds (closed flowers; Figure 5A) of *F. guineensis* for the 30 plant clusters varied widely between the two forests and their microsites (Table 2). In Bulolo forest, a few flower buds were present during April 2014 with the main period of presence from September 2014 until March 2015, in both rainy and dry seasons (Table 2). In Mtambalala forest the flower buds were seen from April to October 2014, in some of the clusters and then again during February 2015 (both rainy and dry seasons).

In Bulolo forest, a peak in flower bud presence was during the months December to February, and more on both exposures of forest edges, with relatively low presence in the forest interior. Few clusters showed some presence of flower buds. In Mtambalala forest the flower bud production was generally low.

Figure 5: *Flagellaria guineensis* flower buds (A) observed inside the indigenous forest at Bulolo forest during the study period, and open flowers (B, Source: John E Burrows).

2.3.2. Flowering phenology of *Flagellaria guineensis*

Flowers of this climbing bamboo are white or light creamy in colour (Figure 5B). Flowering patterns (open flowers) for the 30 plant clusters in each study area varied widely (Table 3). The clusters with open flowers started to be seen in the late-dry season in Bulolo forest. The clusters

Table 2: Flower buds of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of flower bud presence in each category													
All	0,03					0,13	0,13	0,10	0,67	0,67	0,70	0,27	
Edge E	0,10					0,30	0,30	0,20	0,90	0,90	1,40	0,20	
Edge W						0,10	0,10		1,00	1,00	0,60	0,30	
Interior I								0,10	0,10	0,10	0,10	0,30	
Mtambalala forest													
Mean intensity of flower bud presence in each category													
All	0,07	0,10	0,13	0,07	0,07	0,03	0,03				0,03		
Edge E		0,30	0,10			0,10					0,10		
Edge W	0,20		0,20	0,10	0,10								
Interior I			0,10	0,10	0,10		0,10						

Table 3: Flowers of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of flowers presence in each category													
All					0,03	0,10		0,07				0,80	0,07
Edge E					0,10	0,20						1,30	0,20
Edge W						0,10						1,00	
Interior I								0,20				0,10	
Mtambalala forest													
Mean intensity of flower presence in each category													
All												0,10	
Edge E												0,30	
Edge W													
Interior I													

were seen with open flowers in August, September and November 2014, followed by March and April 2015. In contrast, in Mtambalala forest, the flowers were only seen during March 2015 (rainy season), and only in edge (E).

In Bulolo forest a peak in flower presence was during March 2015 (rainy season), with more than half of the clusters (53%) showing presence of flowers with low intensity. Forest edges had more flowers presence while forest interior showed low presence. In Mtambalala forest the flower production was generally low, and only occurred in March.

2.3.3. Fruiting phenology of *Flagellaria guineensis*

Fruiting of *F. guineensis* occur at the top-end of the culm (Figure 6). Fruiting patterns for the 30 plant clusters in each study area and their forest stand conditions varied widely (Table 4). In Bulolo forest, clusters were bearing fruits during February to April (rainy season) in forest edge E, W and interior, with the occasional few fruits on a few clusters during May, July, October, November and January (Table 4).

Figure 6: Fruits of the climbing bamboo *Flagellaria guineensis* observed inside the indigenous forest at Bulolo forest during the study period.

Table 4: Fruits of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	A	M	J	J	A	S	O	N	D	J	F	M	A
Bulolo forest													
Mean intensity of fruits presence in each category													
All	0,47	0,03		0,03			0,03	0,03		0,03	0,67	0,73	0,60
Edge E	0,20			0,10			0,10	0,10			1,00	1,10	1,00
Edge W	1,00	0,10									0,90	0,90	0,70
Interior I	0,20									0,10	0,10	0,20	0,10
Mtambalala forest													
Mean intensity of fruits presence in each category													
All	0,17										0,47	0,43	0,10
Edge E	0,30										0,90	0,70	
Edge W	0,20										0,50	0,60	0,20
Interior I													0,10

In Mtambalala forest the fruits were only seen from February to April (rainy season). In Bulolo forest, a peak in fruiting was during March with 50% of the clusters bearing fruit at one time and more on both exposures of forest edges, with relatively low presence in the forest interior. In Mtambalala forest, the fruit production was low.

2.3.4. Leaf shoot phenology of *Flagellaria guineensis*

Leaf shoots of *F. guineensis* occur at the tip of the culm and it indicates an absence of flowers or fruits on that particular culm in a cluster (Figure 7). Leaf shoots were seen throughout the study period in almost all clusters, in both Bulolo and Mtambalala forests, and in all stand conditions (Table 5). The survey made in both Bulolo and Mtambalala forests showed that *F. guineensis* clusters were having more leaf shoots during April to August 2014 and then December 2014 to January 2015 (Table 5), with abundant leaf shoots on many clusters.

Figure 7: Leaf shoots of the climbing bamboo *Flagellaria guineensis.*

Table 5: Leaf shoots of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	A	M	J	J	A	S	O	N	D	J	F	M	A
Bulolo forest													
Mean intensity of leaf shoots presence in each category													
All	2,40	2,40	2,40	2,40	2,03	1,63	1,50	1,70	2,23	2,40	1,43	1,70	1,77
Edge E	2,70	2,80	2,80	2,80	2,40	2,00	1,90	2,30	2,10	2,30	1,70	2,10	2,30
Edge W	2,40	2,30	2,30	2,30	2,00	1,40	1,30	1,70	2,60	2,80	1,20	1,90	1,80
Interior I	2,10	2,10	2,10	2,10	1,70	1,50	1,30	1,10	2,00	2,10	1,40	1,10	1,20
Mtambalala forest													
Mean intensity of leaf shoots presence in each category													
All	2,57	2,57	2,57	2,43	2,30	1,87	1,50	1,63	2,60	2,63	1,63	1,33	1,63
Edge E	2,70	2,60	2,60	2,50	2,30	1,80	1,60	1,90	2,60	2,60	2,10	1,20	1,90
Edge W	2,50	2,60	2,60	2,40	2,40	1,90	1,60	1,70	2,40	2,50	1,50	1,50	1,60
Interior I	2,50	2,50	2,50	2,40	2,20	1,90	1,30	1,30	2,80	2,80	1,30	1,30	1,40

2.3.5. Shoot phenology of *Flagellaria guineensis*

Observations on shoot production from rhizomes (Figure 8A) started from June 2014 to April 2015 at both study sites (Table 6). The shoots were seen throughout the study period in both forests and in all stand conditions. Many clusters developed only a few shoots.

Figure 8: Shoot (A) and Seedlings (B) of the climbing bamboo *Flagellaria guineensis* observed inside the indigenous forest at Bulolo forest during the study period.

When comparing forest stand condition in both forests, many shoots were seen in the forest interior in Bulolo forest while in Mtambalala forest the production of shoots was not much different between forest stand conditions

Table 6: Shoots from rhizome of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	J	J	A	S	O	N	D	J	F	M	A
Bulolo forest											
Mean intensity of shoots presence in each category											
All	0,77	1,03	1,03	0,80	1,00	0,87	0,97	0,90	0,87	1,07	1,20
Edge E	0,50	0,50	0,70	0,50	0,50	0,90	0,90	0,60	0,40	0,80	0,60
Edge W	0,50	0,60	0,90	0,80	1,00	0,60	0,70	0,70	1,10	1,00	1,10
Interior I	1,30	2,00	1,50	1,10	1,50	1,10	1,30	1,40	1,10	1,40	1,90
Mtambalala forest											
Mean intensity of shoots presence in each category											
All	0,70	0,80	1,03	0,93	1,07	0,83	1,23	1,23	1,07	1,30	0,93
Edge E	0,60	0,70	0,80	0,90	0,90	1,00	1,20	1,20	1,20	1,50	0,90
Edge W	0,80	0,70	1,20	1,10	1,20	0,80	1,00	1,00	0,90	1,20	0,80
Interior I	0,70	1,00	1,10	0,80	1,10	0,70	1,50	1,50	1,10	1,20	1,10

2.3.6. Seedling phenology of *Flagellaria guineensis*

Seedlings of *F. guineensis* have smooth, long, narrow dark green leaves and their new culms are protected by sheaths that are attached to each node (Figure 8B). As they mature, the sheaths covering the culms dry-out leaving the nodes of the culms exposed; with the leaves only at the top of the culms. The seedlings next to the clusters were also seen throughout the study period in both study sites (Table 7).

Few seedlings were found next to many clusters at both study sites, as more than half of the clusters in each month were having seedlings next to them. When comparing seedling production in forest stand conditions, many seedlings were seen in forest interior in both study sites, followed by forest edge W.

Table 7: Seedlings of 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Month	A	M	J	J	A	S	O	N	D	J	F	M	A
Bulolo forest													
Mean intensity of seedlings presence in each category													
All	0,60	0,80	0,77	0,73	0,73	0,63	0,77	0,83	0,97	0,97	1,03	1,30	1,33
Edge E	0,50	0,50	0,40	0,20	0,40	0,40	0,80	0,30	0,30	0,30	0,20	0,80	0,80
Edge W	0,40	0,70	0,70	0,80	0,80	0,70	0,60	1,10	0,90	1,00	1,00	1,40	1,20
Interior I	0,90	1,20	1,20	1,20	1,00	0,80	0,90	1,10	1,70	1,60	1,90	1,70	2,00
Mtambalala forest													
Mean intensity of seedlings presence in each category													
All	1,07	1,17	0,90	0,93	0,97	0,93	0,77	1,23	1,33	1,33	0,93	1,60	1,70
Edge E	0,60	0,80	0,60	0,60	0,90	0,90	0,60	1,10	1,30	1,40	0,70	1,50	1,70
Edge W	0,70	1,00	1,10	1,20	1,10	1,00	0,80	0,80	0,90	1,00	0,70	1,40	1,30
Interior I	1,90	1,70	1,00	1,00	0,90	0,90	0,90	1,80	1,80	1,60	1,40	1,90	2,10

2.4. Discussion

Results on the phenological stages of *F. guineensis* are summarised for Bulolo forest (Table 8) and Mtambalala forest (Table 9). The overriding result is that the reproductive states (flower buds, flowers and fruits) generally showed low levels of the states and only on a few plants, except for quite a number of seedlings. By contrast, the vegetative states (leaf shoots and rhizome shoots) showed relatively high levels of the two states in most clusters. The study was done only for one year. It is possible that during this time period *F. guineensis* in these forests went through an intense vegetative period with a low intensity of flowering and fruiting.

Although it was a short-term study, there were definite patterns emerging from the study. The reproductive phenological stages were very variable between forests, stand conditions and clusters, and some plants showed no sign of flowering or fruiting. Relatively more flowering in Bulolo forest occurred in March with more clusters showed open flowers in forest edge E and W

Table 8: Phenological table with the sequence in production of flowering, fruiting, shoots and seedlings of *Flagellaria guineensis* in Bulolo Forest from April 2014 to April 2015.

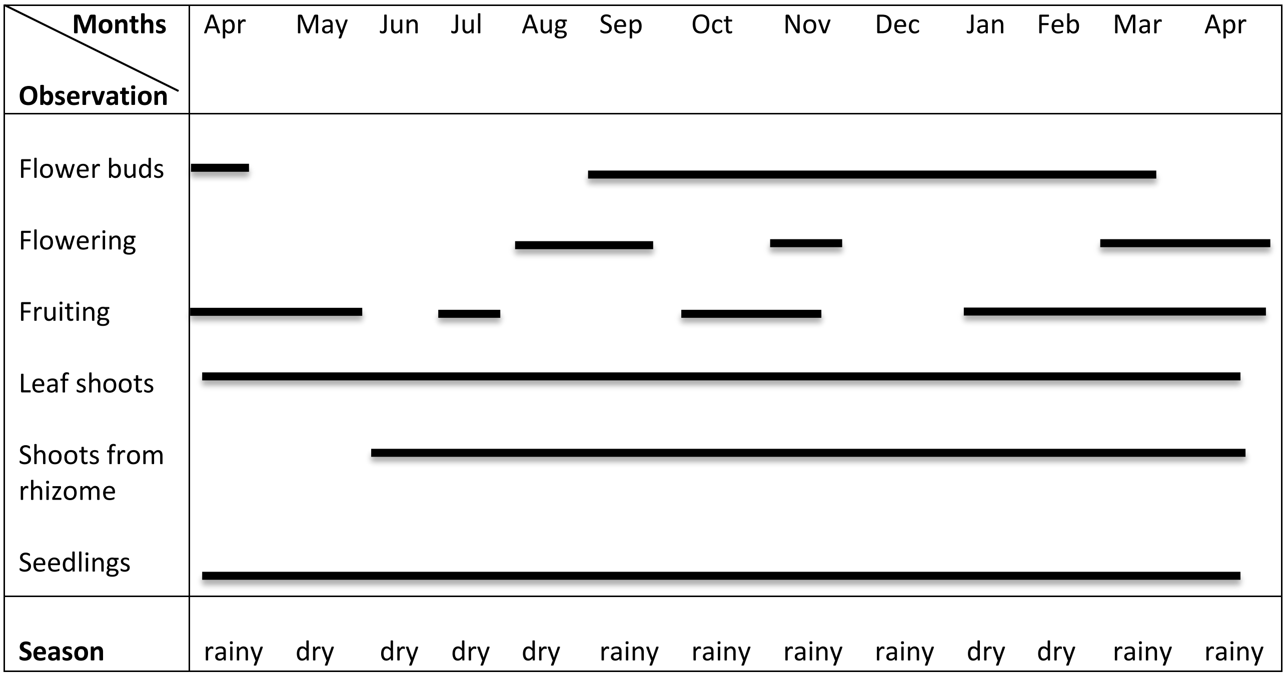
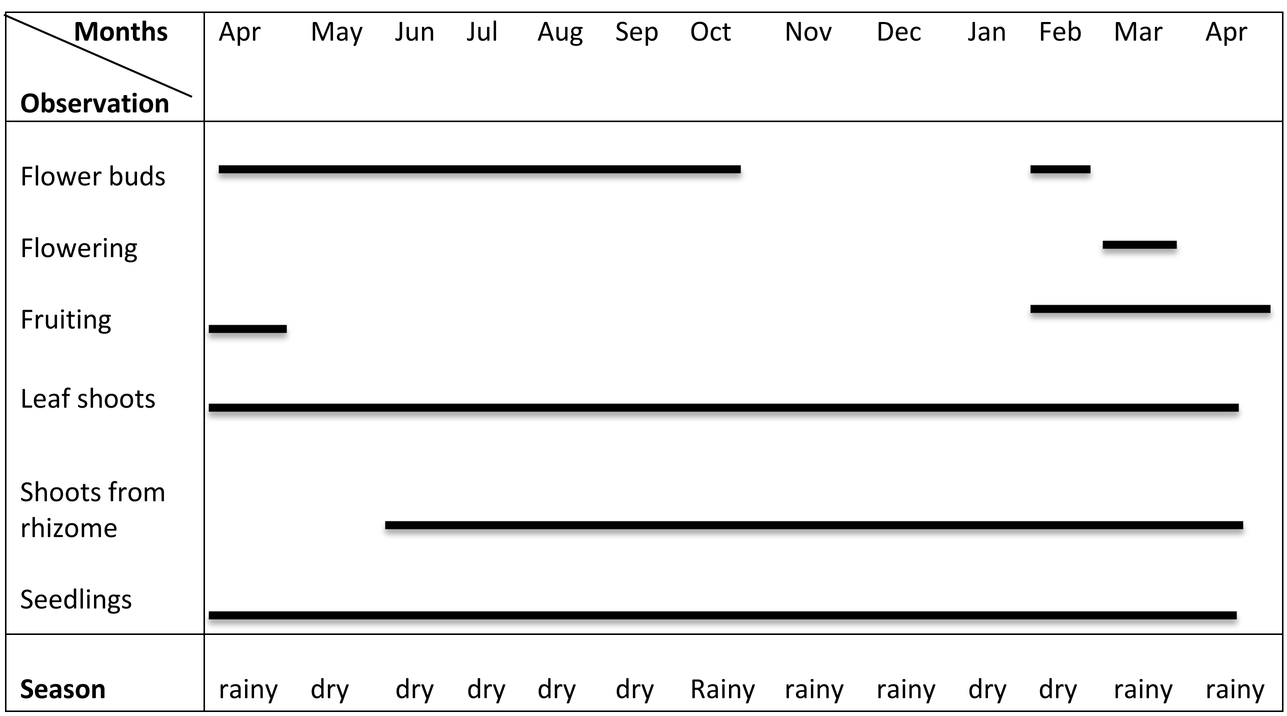


Table 9: Phenological table with the sequence in production of flowering, fruiting, shoots and seedlings production sequence of *Flagellaria guineensis* in Mtambalala Forest from April 2014 to April 2015.



and interior. In Mtambalala forest, relatively few flowers were present only in March and also only in the forest edge E. Ripe fruits were found from February to April in both Bulolo and Mtambalala forests. However, in Bulolo forest the fruits were seen in both rainy and dry seasons whereas in Mtambalala forest fruits were seen only in rainy season. A comparison between the two forests and their forest stand conditions showed that Bulolo forest produced relatively more flowers and fruits in both the interior and forest edge conditions. The Bulolo forest canopy is more open, with shorter host trees in forest edges than in Mtambalala forest. In Mtambalala forest, the forest edge is more developed and the trees are tall with a fully developed canopy compared to Bulolo forest. Flowering and fruiting was mostly seen in short host trees where *F. guineensis* is able to form a dense mat on the canopy of the host tree, i.e. better exposure to the sun.

New buds and flowers did not always end up in fruit production, and sometimes fruit production was recorded with no prior observation of flowering. However, each flower bud was not marked for this current study and this could be the reason for the disjunctive patterns. It may be useful in future studies to mark the specific inflorescences and to do observations maybe once every two weeks or shorter intervals, at least for a few clusters, to have better control over the flowering and fruiting periods within individual inflorescences.

During the study period, not all culms of clusters were flowering at the same time; some culms in a cluster remained in a vegetative state while others were flowering. The observation in the forest showed that the culms of *F. guineensis* that were seen to be broken or dry in some clusters were regenerating. Die-back of culms was seen in the forest but it was few culms in a cluster that were showing this signs (partial die-back of the culms in a cluster).

As indicated earlier, leaf shoots and rhizome shoots were present in most clusters at a relatively high level, even though observations on the rhizome state only started during June 2014. Similarly, seedlings were relatively abundant too throughout this study period in both forests. It is possible that *F. guineensis* in these forests go through a two-year cycle. In year 1, during the vegetative phase, the clusters produce abundant new leaf shoots that would store reserves in the rhizomes, which then result in more shoots developing from the rhizomes. During year 2 the plant goes through the reproductive phase, i.e. beyond the period of this study. It is further possible that the many observed seedlings are from such an earlier intense reproductive period. It is further possible that there may be a die-back of culms that were previously in such a possible intense reproductive phase. A longer time study, of a minimum of three years, may be needed to verify such a vegetative-reproductive cycle.

Flagellaria guineensis regenerates in two ways, i.e. it produces seedlings from seeds and shoots from the rhizomes. Some clusters did not produce flowers and fruits for many months and this could possibly be related to the two-phase cycle mentioned earlier. Seedlings after an intense reproductive period could then develop into clusters over time. In the forest edge, shoots and seedlings of *F. guineensis* where found to occur in large amounts in the forest edge W (west), which is the side where the plants are exposed to sunlight during the afternoon with warmer conditions, compared to forest edge E (east) where the plants are exposed to sunlight during morning with cooler conditions.

The position of the plants in relation to sunlight in the forest edge does influence the production of new shoots and seedlings. However, *F. guineensis* rhizome shoots and seedlings grow in abundance in the forest interior compared to the forest edge. This suggests that the climbing bamboo requires shade or some shade to regenerate, which means shade increases the number of shoots and seedlings on the forest floor. This agrees with the results from Rabenantoandro et al. (2008) who suggested that young climbers require shade to grow. The seedlings seen in the forests may have come from a previous season of flowering and fruiting and the assessed seedlings may not reflect the current flowering and fruiting patterns.

2.5. Conclusion

The study did achieve the stated objective of determining the flowering, fruiting and growth phenology of *F. guineensis*, and differences in the production patterns between the shady forest interior and the exposed (sunny) forest edges in the two Transkei Coastal Forests. The major result from this study showed a high intensity in the vegetative growth of clusters of this climbing bamboo, and a relatively very low intensity of reproductive production during this one-year study period. It is suggested that such a study be done over a longer period of preferable longer than two years. This study did not show that *F. guineensis* may go through a major synchrony in massive flowering-fruiting followed by a massive die-back of culms, as has been recorded in other bamboo species (Seifriz, 1920). However, there is some indication that there may be a two-phase cycle, with a vegetative cycle of much leaf-shoot and rhizome shoot development, followed by a reproductive cycle of much flowering and fruiting, with possibly some culm die-back following an intense reproductive phase. Further studies over a longer period are needed to follow-up on this two-phase cycle.

Results from this study can be used to indicate when *F. guineensis* is likely to produce more flowers and fruits. It is recommended that in the forests *F. guineensis* should be harvested around May-August (dry season) when there are no flowers and fruits on the clusters. However, if there is such a two-phase cycle between the vegetative and reproductive phases, then harvesting practices definitely would need some adjustment to ensure that culm harvesting would not cause a reduction in production of rhizome shoots or that such shoots are not damaged during harvesting.

CHAPTER THREE: Development of *Flagellaria guineensis* in the forest interior, gaps and edges in the Transkei Coastal Forest

Abstract

The development pattern of plants of the climbing bamboo *Flagellaria guineensis* in different forest stand conditions such as forest edge, forest gaps and closed-canopy, was studied along the Eastern Cape coast. There was a significant difference ($P \leq 0.05$) in cluster diameter, culm (stem) diameter and culm length between the three studied forests, however the number of culms per cluster showed no significant difference ($P > 0.05$). Clusters and culms with the highest mean diameters were found in Manubi forest (185.5 cm and 1.0 cm) and in Mtambalala forest (67.3 cm and 0.9 cm) respectively, while the longest culms where found in Manubi forest (11.1 m). Culm diameter and length showed significant differences ($P \leq 0.05$) between the forest stand conditions. However, cluster diameter and number of culms were not significantly influenced ($P > 0.05$) by forest stand conditions. Culm development is influenced by forest stand conditions and differs between forests. There was no significant relationship between cluster diameter and number of culms, nor between culm diameter and culm length. *F. guineensis* clings on various tree species and trees of different size for support to grow to the forest canopy.

Keywords: Flagellaria, culm, climbing bamboo, forest, host tree, cluster.

3.1. Introduction

Flagellaria guineensis is a climbing bamboo that occurs in the Eastern Cape coastal forests in South Africa. It forms tangles on the canopy of its host tree in forest edges or gaps. Tangles help with the recovery of the edge or gap of the forest by preventing easy movement of browsers in and out the forest gaps and edges. A seedling of *F. guineensis* develops into a rootstock with a cluster usually more than five climbing culms (an individual bamboo stem), which develops from the same rhizome and which reaches for the surrounding host trees for vertical support and later for the tree canopy for better light. Also the clumps of the climbing bamboo *Chusquea tomentosa* was reported to have an erect habit when growing among trees and the culms show climbing tips which ascend along the tree trunks foraging for light (Widmer, 1998b).

Climbing bamboo species can tolerate semi-shade in a forest understory but are rare or absent beneath the densest tree canopies (Veblen *et al*., 2007). Climbing bamboo culms are slender, solid and composed of nodes, a factor that makes them different from other climbers and differs from other bamboos because of their need for support from host trees. A climber needs a support structure, such as other plants and specifically trees, to reach the canopy (Balfour & Bond, 1993).

Many of the trees in tropical and subtropical forests are colonized by lianas (Campanello *et al*., 2012). Once a woody climber, or a liana, forms a tangle, it continues to expand, thereby blocking and delaying conventional gap-phase regeneration of trees by preventing light penetration and imposing mechanical interference (Schnitzer *et al*., 2000).

Bamboos are evergreen, monocotyledonous (yet woody) plants which produce primary shoots without any later secondary growth (i.e. branches). They occupy a dominant position in the understory in temperate and subtropical forests around the world (Kleinhenz & Midmore, 2001; Giordano *et al*., 2009). Bamboos grow in open to shaded environments (Soderstrom & Calderon, 1979). They are potentially keystone understory species due to their abundance and potential effects on the rate, timing, and composition of tree regeneration in treefall gaps (González *et al*., 2002).

Many woody bamboos are typical examples of invasive plants, having many attributes of successful invaders (Lima *et al*., 2012). Lowe & Walker (1977) indicated that lianas often increase in density when the forest canopy is disturbed. Dense tangles of lianas are often found on forest margins (Williams-Linera, 1990) and lianas are particularly abundant in forest gaps and disturbed sites (Campanello *et al*., 2012).

Forest trees in the Transkei Coastal Forests are colonized by the climbing bamboo *F. guineensis*. This climbing bamboo requires support from host trees to grow vertically and to reach the canopy. The current study was motivated by the concerns that foresters have about the appearance of *F. guineensis* on the canopy of its host trees in forest edges and gaps. *Flagellaria guineensis* appeared to be shading the canopy of adult trees on the forest edge. Information from this research would contribute towards a better understanding of the growth patterns of the climbing bamboo in the forest and its role in the recovery of forest edges and gaps and in resource-use.

The purpose of this study was to assess the development pattern of *F. guineensis* in different forest stand conditions such as forest edge, forest gaps and closed-canopy. Key questions that were addressed were as follows: (1) How do the *F. guineensis* culms grow from the rhizome to the tree canopy? (2) Does the development of *F. guineensis* differ when growing on forest margins, in forest gaps and in mature forest with closed canopy? (3) How does *F. guineensis* interact with the plants around it (from small plants to canopy trees)?

3.2. Methodology

3.2.1. Study site

The study was conducted in three forests along the Eastern Cape coast: Mnenga forest and Mtambalala forest north of Port St Johns and Manubi forest north of East London (Figure 9). The study areas have been selected for two reasons: Firstly, *F. guineensis* must be present in the area; secondly, there should be resource use activities taking place in the area, such as harvesting of *F. guineensis* for basket-making.

The forests form part of the Transkei Coastal Forests (Von Maltitz *et al*., 2003), occurring fragmented on seaward slopes below ridges and in valleys. Mature forests in these areas have a low to high canopy (20-30 m) with a smooth to uneven surface, but relatively closed, restricting light penetration onto the forest floor. The tree and climber species vary in importance in different forests in this coastal zone.

Figure 9: The location of the Mtambalala, Mnenga and Manubi forests along the Eastern Cape Coast north of Port St Johns and of East London.

The dominating tree species are *Millettia grandis* on the forest margin, the canopy tree species *Apodytes dimidiata*, *Calodendrum capense*, *Cassipourea gummiflua*, *Celtis africana*, *Chaetachme aristata*, *Chionanthus peglerae*, *Combretum kraussii*, *Croton sylvaticus*, *Cussonia sphaerocephala*, *Ekebergia capensis*, *Harpephyllum caffrum*, *Heywoodia lucens*, *Nuxia floribunda*, *Olinia radiata*, *Philenoptera sutherlandii*, *Podocarpus falcatus*, *Podocarpus latifolius*, *Ptaeroxylon obliquum*, *Rhus chirindensis*, *Trichilia dregeana*, *Vepris lanceolata*, *Zanthoxylum davyi*, and the sub-canopy to understory tree species *Buxus macowanii*, *Buxus* *natalensis*, *Drypetes gerrardii*, *Duvernoia adhatodoides*, *Englerophytum natalense*, *Hypericanthus amoenus*, *Memecylon natalense*, *Ochna arbórea*, *Oricia bachmannii*, *Rinorea angustifolia*, *Rothmannia globosa*, *Strychnos henningsii*, *Teclea natalensis*, *Tricalysia capensis* and *Tricalysia lanceolata*. The dominant woody climbers are *Dalbergia* species, *Monanthotaxis caffra* and *Scutia myrtina* (Von Maltitz *et al*., 2003; Cawe & Geldenhuys, 2007; Geldenhuys 2007; Geldenhuys *et al*., 2013). The climbing bamboo *F. guineensis* in these coastal forests is patchily distributed.

3.2.2. Data collection

Flagellaria guineensis clusters were sampled in Mnenga, Mtambalala and Manubi forests along the Eastern Cape coast known as the Wild Coast. In each forest, six *F. guineensis* clusters (consisting of two or more culms) were randomly chosen from each of the three stand conditions: forest edge, forest gaps (natural or anthropogenic) and closed mature forest, giving a total of 18 clusters per forest, and a total of 54 clusters overall (Figure 10). The clusters were sampled in sites with a flat to gentle slope.

Forest edge is the outer boundary of the natural forest onto grassland or a road. Forest gap is a canopy opening found inside a forest, caused by humans (e.g. harvesting of trees for firewood or other purposes) or natural reasons such as tree falls caused by wind, lightning or age (senescence), and can vary in size (gap diameter). Gap size was defined as an area of 25 m^2 or more, with maximum size of at least 1-2 times the height of the forest canopy. Gap shape ranged from irregular circles to squares.

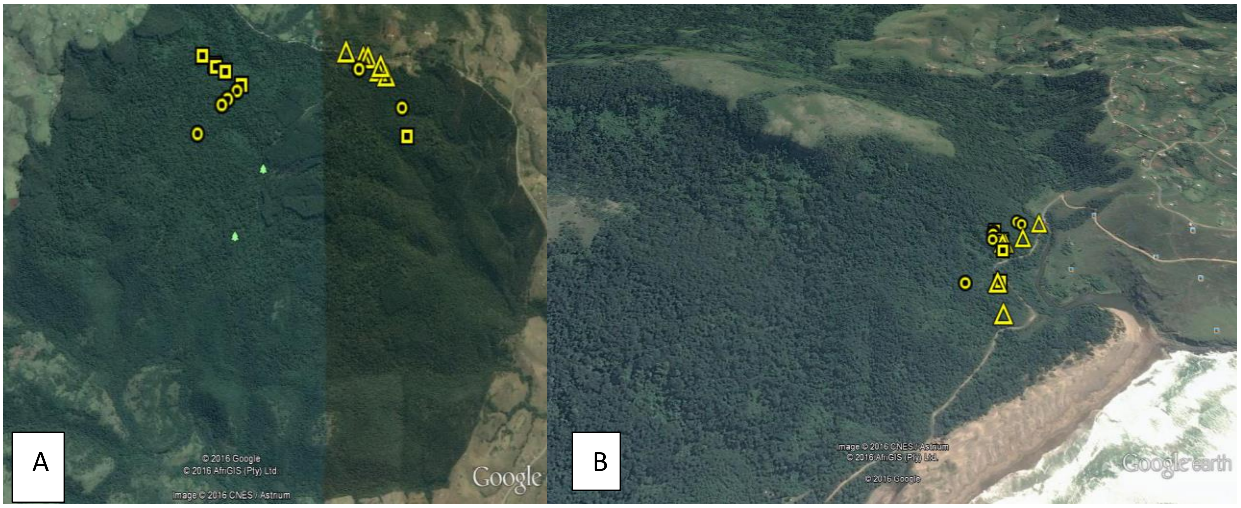


Figure 10: Example of the map of Manubi (A) and Mnenga (B) forests showing location of clusters in different forest stand conditions (triangle shape = **edge**, circle shape = **closed canopy**, square shape = **gap**).

For each cluster (Figure 11A), the following parameters were recorded: forest stand condition (closed canopy, gap or edge), location coordinates next to each cluster using GPS, and species,

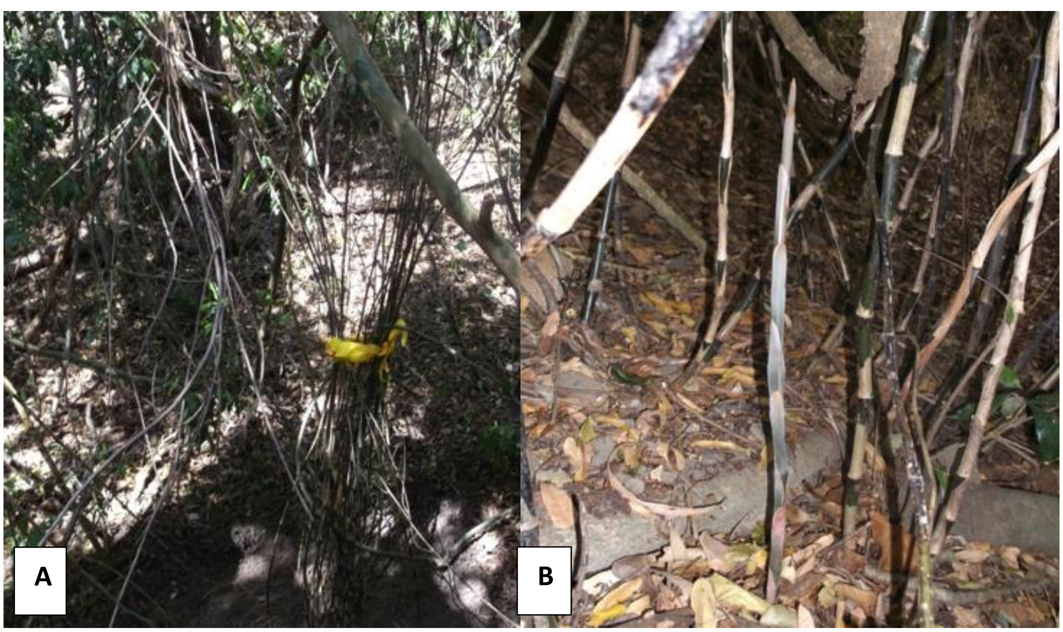


Figure 11: A cluster of culms of *Flagellaria guineensis* in the forest (A) and individual culms in a large cluster (B).

height and stem diameter at breast height (dbh) of all host trees. Each cluster was measured and recorded as follows: the diameter of each cluster at ground level (distance between stems on the edge of the cluster in two perpendicular directions, recorded as the mean of the two distances), height at which the culms start to climb the host trees, number of culms in each cluster (Figure 11B), the diameter and length of each culm in a cluster (each culm was pulled down to ground level for measuring length and basal diameter).

3.2.3. Data analysis

Data were analysed for variance in GenStat Ver 12.1. One-way ANOVA was used to test for the statistical significance difference between mean values of cluster diameter, number of culms per cluster, culm diameter and culm length in different forest stand conditions and forests. If the ANOVA value was found to be significant, the parameter mean values were considered significant at $P<0.05$. Log transformation was used for the response variable ‘‘number of culms per cluster,’’ which was in the form of count data. Regression analysis was carried out to determine the relationship between cluster diameter and number of culms, and between culm length and culm diameter that could help in the monitoring of the species.

3.3. Results

Cluster diameter, number of culms per cluster, culm diameter and culm length of *F. guineensis* varied between the three sampled forests and the forest stand conditions (sections 3.3.1 to 3.3.4).

3.3.1. Cluster diameter in forest stand conditions

The largest mean cluster diameter for all forest stand conditions per forest was found in Manubi forest and was significantly larger than in Mtambalala and Mnenga forests (Table 10). In Manubi forest cluster diameter was largest in closed forest and smallest on forest edge (Table 10). Mnenga and Mtambalala forests showed the opposite trend, *i.e.* it was highest in forest edge and smallest under the closed canopy. However, the differences were not significant (p>0.05).

Table 10: Summary of (A) mean cluster diameter of *Flagellaria guineensis* over forests and stand conditions, and (B) results of the ANOVA to assess the significance of the differences between forests, stand conditions, and their interactions.

A. Variable	**Forests**	**Forest edge**	**Forest gaps**	**Closed canopy**	**Total mean**
Cluster diameter(cm)	Manubi	163,9	185,4	207,2	185,5
	Mnenga	72,2	71,3	48,6	64,1
	Mtambalala	85,8	51,0	65,0	67,3
B.	**S.E**	**d.f**	**MS**	**P-value**	
Forests	15,83	2	86199	<.001*	
Stand Conditions	15,83	2	125	0,946^{ns}	
Forests×Stand C	27,41	4	2801	0,307^{ns}	

*= Significant (P < 0.05), ns= non-significant (P ≥ 0.05)

3.3.2. Number of culms per cluster in forest stand conditions

The number of culms per cluster was very variable with no significant differences between the forests (p>0.05) or between the different stand conditions (p>0.05). It was highest on the forest edge in Mnenga forest and lowest in the forest gaps at Mtambalala (Table 11). The trend over forest stand conditions varied between the sampled forests.

Table 11: Summary of (A) mean number of culms per cluster of *Flagellaria guineensis* over forests and stand conditions, and (B) results of the ANOVA to assess the significance of the differences between forests, stand conditions, and their interactions.

A. Variables	**Forests**	**Forest edge**	**Forest gaps**	**Closed canopy**	**Total mean**
Number of culms	Manubi	11,8	11,0	16,2	13.0
	Mnenga	18,8	13,0	9,7	13,8
	Mtambalala	13,5	7,8	12,3	11,2
B.	**S.E**	**d.f**	**M.S**	**P-value**	
Forests	2,003	2	0,2903	$0{,}292^{ns}$	
Stand Conditions	2,003	2	0,3256	$0{,}252^{ns}$	
Forests×Stand C	3,47	4	0,4396	$0{,}124^{ns}$	

*= Significant (P < 0.05), ns= non-significant (P ≥ 0.05)

3.3.3. Culm diameter in forest stand conditions

The culm diameter was higher in Manubi forest, followed by Mtambalala forest and Mnenga forest and there was significant differences between all three forests (p<0.05). In forest stand conditions, Manubi forest had the highest mean value in forest edges (Table 12), but the mean value was very similar in the other forests and their forest stand conditions, including forest gaps at Manubi forest.

Table 12: Summary of (A) mean culm diameter of *Flagellaria guineensis* over forest and stand conditions, and (B) results of the ANOVA to assess the significance of the differences between forests, forest stand conditions, and their interactions.

A. Variables	**Forests**	**Forest edge**	**Forest gaps**	**Closed canopy**	**Total mean**
Culm diameter(cm)	Manubi	1,2	0,8	1,0	1.0
	Mnenga	0,8	0,9	0,8	0.8
	Mtambalala	0,8	0,9	0,8	0.9
B.	**S.E**	**d.f**	**M.S**	**P-value**	
Forests	0,0668	2	0,17526	0,020*	
Stand Conditions	0,0668	2	0,0172	0,654^{ns}	
Forests×Stand C	0,1157	4	0,13784	0,016*	

*= Significant ($P < 0.05$), ns= non-significant ($P \geq 0.05$)

3.3.4. Culm length in forest stand conditions

The highest mean culm length per forest was found in Manubi forest, followed by Mnenga forest and the lowest was Mtambalala forest, and the difference in culm length between these three forests was significant (p<0.05). Mean culm length was significantly different (P<0.05)) between the different forests, mainly because of the much higher culm length under closed canopy in Manubi forest (Table 13). Culm length was relatively similar in the other forest stand conditions and across forests.

Table 13: Summary of (A) mean culm length of *Flagellaria guineensis* over forests and stand conditions, and (B) results of the ANOVA to assess the significance of the differences between forests, stand conditions and their interactions.

A. Variables	Forests	Forest edge	Forest gaps	Closed canopy	Total mean
Culm length (m)	Manubi	9,9	9,2	14,1	11.1
	Mnenga	9,2	9,6	8,6	9.1
	Mtambalala	9,1	8,9	9,1	9.0
B.	**S.E**	**d.f**	**M.S**	**P-value**	
Forests	0,787	2	24,101	0,019*	
Stand Conditions	0,787	2	9,887	0,182^{ns}	
Forests×Stand C	1,364	4	16,569	0,029*	

*= Significant ($P < 0.05$), ns= non-significant ($P \geq 0.05$)

3.3.5. Allometric relationship between cluster diameter and culm variables

In general, contrary to expectations there were no significant allometric relationship between cluster diameter and number of culms, and also between culm diameter and culm length (Table 14). Significant relationships were only found for some forests and in specific stand conditions., The number of culms increased with increasing cluster diameter in closed canopy forest in Mnenga (Figure 12; R^2 = 0.8342) . This indicates that 83% of the variation in cluster diameter could be explained by the logarithm relationship with the number of culms in Mnenga forest under closed-canopy. Relatively weak relationship between culm diameter and culm length of *F. guineensis* was found in Mtambalala forest (Figure 13) where only 24% of the variation in culm length could be explained by the logarithm relationship with culm diameter.

Table 14: Correlation analysis between (A) culm length and culm diameter and (B) cluster diameter and number of culms of *Flagellaria guineensis*, during the study period.

A. Culm length and culm diameter		
Forest	Relationship	*r*
Manubi	y = 5,64ln(x) + 12,269	0,0757
Mnenga	y = -2,124ln(x) + 8,6276	0,0535
Mtambalala	y = 5,8136ln(x) + 9,985	0,2411
B. Cluster diameter and number of culms		
Forest	Relationship	*r*
Manubi	y = -3,635ln(x) + 31,689	0,0811
Mnenga	y = 6,5545ln(x) - 12,693	0,2810
Mtambalala	y = 4,9087ln(x) - 8,9287	0,1164

Through the analysis, the highest correlations between culm length and culm diameter were found in Mtambalala forest, followed by Manubi and Mnenga respectively (Table 14). On the other hand, the highest correlations between cluster diameter and number of culms were found in Mnenga, followed by Mtambalala and Manubi. Correlation between culm diameter and culm length of *F. guineensis* under different forest stand conditions is shown in Table 15. Moderate correlations between culm diameter and culm length were found in Mtambalala and Manubi forest under closed-canopy whereas the weakest correlations between culm diameter and culm length of *F. guineensis* were found in Mnenga gap and Manubi edge.

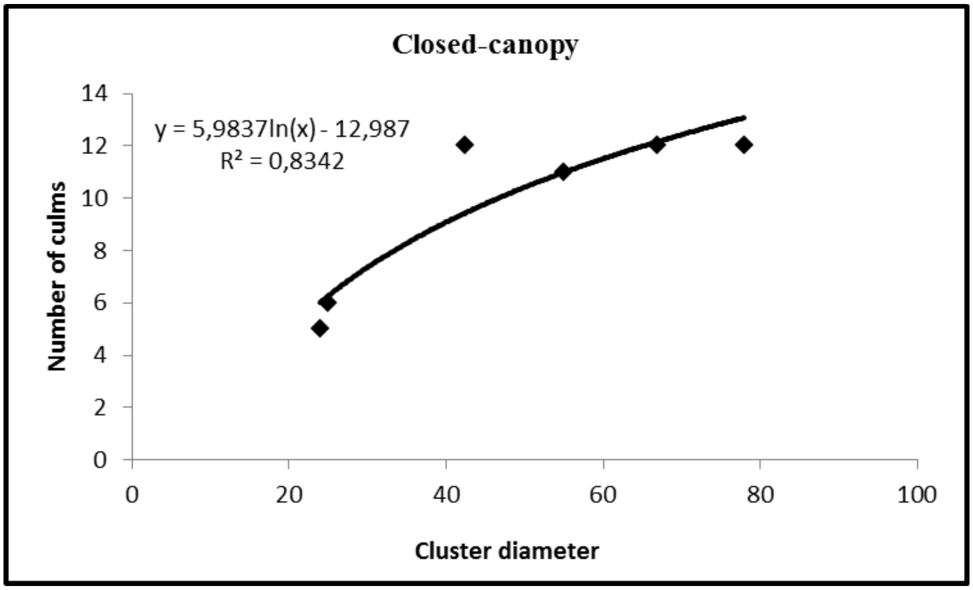


Figure 12: Relationship between cluster diameter and number of culms of *Flagellaria guineensis* under closed canopy, Mnenga forest.

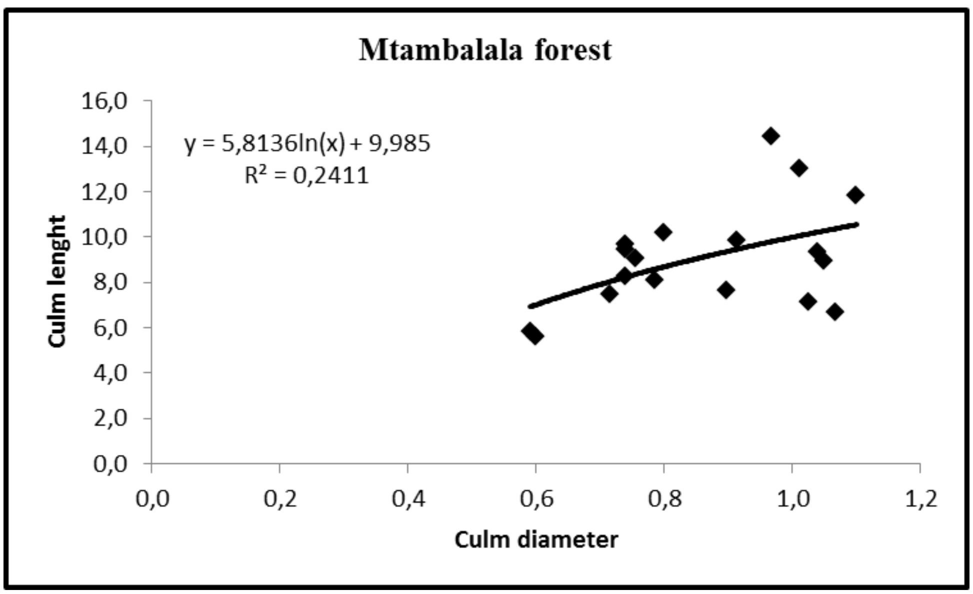


Figure 13: Relationship between culm diameter and culm length of *Flagellaria guineensis* in Mtambalala forest (all the forest stand conditions), Eastern Cape, South Africa.

Moderate correlations were found in cluster diameter and number of culms of *F. guineensis* under different forest stand conditions (Table 16). For instance, the correlation coefficient in Mnenga forest under the closed stand conditions was found to be 0.8342 followed by Manubi closed forest (0.4411). The weakest correlations between cluster diameter and number of culms of *F. guineensis* were found in Manubi edge and gap.

Table 15: Correlation analysis between culm length and culm diameter of *Flagellaria guineensis* in forest stand conditions, during the study period.

Forest	Stand conditions	Relationship	*r*
Manubi	Edge	y = -0,893ln(x) + 9,6913	0,0178
Mnenga	Edge	y = -7,235ln(x) + 7,1478	0,2815
Mtambalala	Edge	y = 6,7687ln(x) + 10,471	0,4355
Manubi	Gap	y = -8,144ln(x) + 7,4114	0,0681
Mnenga	Gap	y = 0,2211ln(x) + 9,599	0,0006
Mtambalala	Gap	y = 4,7145ln(x) + 9,2738	0,1121
Manubi	Closed	y = 21,887ln(x) + 17,836	0,7100
Mnenga	Closed	y = -4,277ln(x) + 7,5828	0,3905
Mtambalala	Closed	y = 8,422ln(x) + 10,855	0,5419

Table 16: Correlation analysis between cluster diameter and number of culms of *Flagellaria guineensis* in forest stand conditions, during the study period.

Forest	Stand conditions	Relationship	*r*
Manubi	Edge	y = -1,83ln(x) + 20,851	0,0508
Mnenga	Edge	y = 4,4471ln(x) + 0,1944	0,1089
Mtambalala	Edge	y = 7,1843ln(x) - 17,717	0,1358
Manubi	Gap	y = -4,773ln(x) + 35,984	0,0416
Mnenga	Gap	y = 3,8917ln(x) - 3,2048	0,1414
Mtambalala	Gap	y = 2,751ln(x) - 2,7347	0,3880
Manubi	Closed	y = -12,12ln(x) + 79,954	0,4411
Mnenga	Closed	y = 5,9837ln(x) - 12,987	0,8342
Mtambalala	Closed	y = -5,183ln(x) + 33,732	0,0964

3.3.6. Cluster development and their host trees

Flagellaria guineensis was observed climbing its host trees for vertical support in the forests (Figure 14). Trees of various species and of different size (height and stem diameter) have been observed to provide such support for climbing culms (Appendix 7) but there was no apparent preference for specific tree species. The bamboo clings on tree trunks and grows towards the canopy of host trees. However, some culms (shoots) in a cluster reached for the canopy directly.

Culms of *F. guineensis* in a cluster in forest edges and gaps tend to form dense mats on the canopy of its host tree while in mature forest with closed canopy the culms of a cluster tend to climb on different host trees (trees a far distance from each other). Seedlings of both host trees and *F. guineensis* were seen on the forest floor. The bamboo seedlings develop into young culms that would climb small trees and then reach for canopy trees whereas, shoots that grow from rhizomes can reach up to 4 m without climbing a tree (erect position without bending).

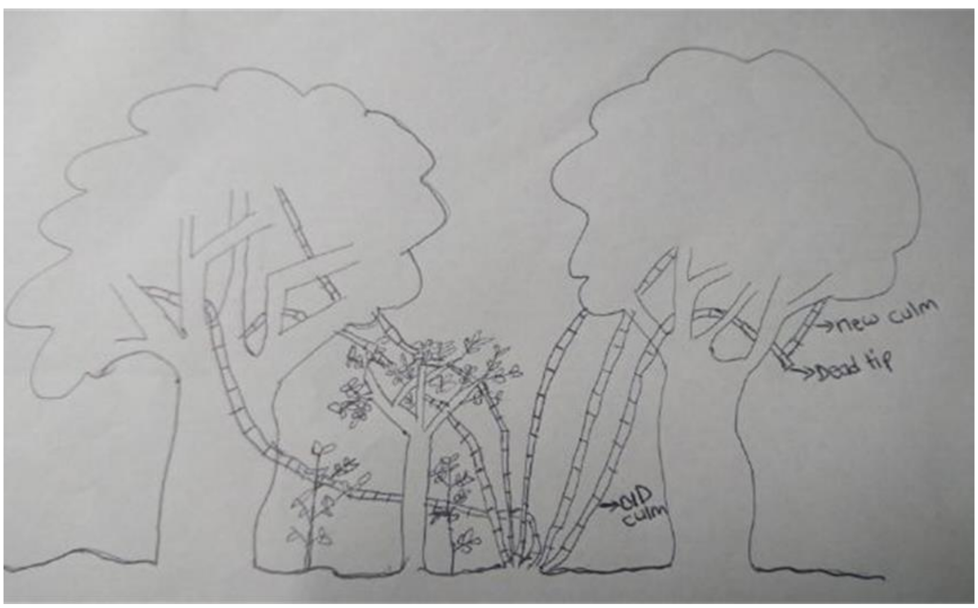


Figure 14: A schematic diagram showing the interaction between cluster development of the climbing bamboo *Flagellaria guineensis* and its host trees in the forest.

3.4. Discussion

In general, few studies have been done on the growth patterns of the bamboo. *Flagellaria guineensis* is a cluster-forming climbing bamboo that occurs in the Transkei Coastal Forests of the Eastern Cape. Seedlings of this climbing bamboo have more than one culm that grows from a sympodial rhizome. As the plants mature the number of culms also increases, as new shoots grow from the rhizome. Some of the observed *F. guineensis* clusters consisted of more than 20 culms in different forest stand types. The culms developing from a cluster can reach up to 20 m in length and 2.5 cm in diameter.

Cluster diameter increases with rhizome or rootstock expansion, and was greatest in Manubi forest (see 3.3.1). *Flagellaria guineensis* clusters and culm diameter was highest in open habitats (forest edge and gaps), while culm length was found to be longest in closed habitats in forest stand types. Cluster and culm diameter growth of this species seem to favour light or sun and length increases in closed habitats with particularly tall host trees as the culm reaches the canopy to receive light.

In mature forest with closed canopy the culms in a cluster grow until they are on top of the host canopy, and this is a sign of climbers competing with trees for light. The climbing bamboo clings to the host trees with its leaves and if there is no host trees around to climb, this climber bends to climb the small trees around and then reaching for big trees. The relationship between cluster diameter and number of culms, and between culm length and culm diameter indicates a lot of variation between forest areas. This pattern may be because of the resource use in some of these forests and also light may be a factor, since as mentioned above culm length increased in closed habitats and culm diameter increased in open habitats.

Flagellaria guineensis appearance on the canopy of its host trees is different in different forest stand conditions (closed-canopy, gap or edge). In the forest edge, the climbing bamboo forms dense tangles on the canopy of its host tree conforming to other studies about climbers (Williams-Linera, 1990) that dense tangles of climbers are often found on forest margins. The use of culms for basket-making may reduce the overload of tangles on the canopy of host trees.

The current study revealed that the dense tangles on the canopy of host trees is caused by culms in a cluster that climbs usually on one tree without reaching for other trees. When comparing among the three forests, Manubi forest is a big forest with many tall canopy trees (25-30) and the forest floor is less open than Mnenga and Mtambalala forest floors. This could be the reason why *F. guineensis* in Manubi forest has the big culm diameters in forest edge and highest culm length in closed canopy compared to the other two forests. Generally, host trees in forest edges and gaps tend to be shorter than in closed-canopy mature stands. *F. guineensis* culm length could be influenced by the height of the host trees in the forest.

3.5. Conclusion

Flagellaria guineensis is one of the four species of the genus *Flagellaria* and this species is only found in Africa. There are few publications and reports about the climbing bamboo *F. guineensis.* The current study compared the development patterns of *F. guineensis* in different forest stand conditions (closed canopy, gap or edge). The results revealed that *F. guineensis* development patterns regarding number of culms, cluster and culm diameter was not significantly different in different forest stand conditions such as forest edge, forest gaps and in mature forest with closed canopy. However, there was a significant difference in culm length of *F. guineensis* in different stand conditions.

Host tree observations conducted revealed that the climbing bamboo *F. guineensis* clings on both small plants and canopy trees in the forests. Small plants provide vertical support to this climbing bamboo to reach for canopy trees. Host trees with different diameters were observed in Manubi, Mnenga and Mtambalala forest and this indicates that *F. guineensis* can interact with any plant around for support. The findings from the study indicated that there is no significant allometric relationship between culm length and culm diameter, and also between cluster diameter and number of culms in both forests. Though *F. guineensis* forms tangles on the canopy of its host in forest edges, the observations in the forests revealed that there is no direct damage caused to host trees.

CHAPTER FOUR: Climbing bamboo *Flagellaria guineensis* in Transkei Coastal Forests - A Synthesis

4.1. Introduction

Do the dense tangles (intermingled stems) of *Flagellaria guineensis* (Ugonothi or Rotan grass) in forest gaps and edges along the Eastern Cape coast threaten the recovery of forest gaps and forest edges? Do the use of the stems for weaving baskets and other household uses contribute to these dense tangles? These questions related to observations in the Manubi forest stimulated an interest in this species and this study.

F. guineensis is a climbing bamboo that is used in various ways as a non-timber forest product by communities from the coastal forests in the Eastern Cape Province of South Africa. The culms (stems) are used for hut construction, and as a source of income in the Transkei area through weaving and basketry (Cawe & Ntloko, 1997). The woody stem is used as fuel. Leaf decoctions are drunk as cure for gonorrhea and used as a mouth wash against dental caries (Bosch, 2010).

The species habitat ranges from sea level up to 1100 m altitude, in coastal forest, swampy forest, along rivers, in forest edges, thickets and waste places, in many parts of Africa (Bosch, 2010). Along the Eastern Cape coast, the culms of the different clusters of this species form dense tangles in forest gaps and edges. However, in the canopy of closed forest the tangles formed by the culms are not dense.

After cutting, the bottom unharvested nodes of the culms of *F. guineensis* regrow by producing young shoots that quickly turn into seedlings (Bosch, 2010), increasing the number of culms in a cluster and making this species maintainable in the forests. Observations from this current study revealed that even though some flowers and fruits of *F. guineensis* are visible during the dry season, this species produces many creamy-white flowers and round red fruits during the rainy season (start of the year) in the forests.

The current study addressed the following two objectives: (i) to describe and assess the seasonal variation in the phenological state of flowering, fruiting and growth of the species in different forest stand conditions; and (2) to compare the development patterns of the species between different forest stand conditions such as forest edges (margins), forest gaps and mature forest stands. This chapter is a summary of key findings on seasonal changes in flowering, fruiting and growth (Chapter 2), and culm development patterns (Chapter 3) of *F. guineensis* in the Transkei Coastal Forests, and present recommendations for managing sustainable resource use of the species from the natural forests.

4.2. Phenological sequence of flowering, fruiting and growth

The following questions were addressed in this section:

(1) What is the seasonal pattern in the production of flower, fruit, leaf shoots, stem shoots and seedlings in the species?

(2) How do this flowering, fruiting and growth patterns of this species vary between the forest interior and forest edges?

Observations on the flowering, fruiting and growth phenology of *F.guineensis* were carried out in the Bulolo and Mtambalala coastal forests in the Eastern Cape Province. At each study area, 30 observation spots (clusters) 10 m distant from each other were selected in the forest with 10 spots in each of three forest stand conditions: Forest edge with eastern exposure (E) representing cooler conditions, Forest edge with western exposure (W) representing warmer conditions, and Forest interior (I) representing shaded conditions. In total, 60 clusters were observed in the two areas. Each observation spot was numbered (1 to 30) in each area on a tree stem, and the geographic coordinates were recorded with a GPS. Observations were done once every month, and always during the last week of the month, for a period of 13 months.

During the observation the following parameters were recorded: (a) site information, including forest stand conditions, altitude and coordinates of the observation spots; (b) phenological state of the observed plant, recorded by the presence and abundance of the following stages: flowering buds, flowers, fruits, leaf shoots, shoots regenerating from rhizome, partial cluster dieback, total cluster dieback and seedlings (regeneration from seeds).

4.2.1. Seasonal patterns

Seasonality was observed in the process of flowering and fruiting of *F. guineensis* in the Transkei Coastal forests. Flowering presence and intensity of *F. guineensis* in Bulolo and Mtambalala forest, *i.e.* green flower buds and creamy-white flowers, varied during the study period. Flowering and fruiting during the 1-year study period was low. Flower buds in the two forests were seen in both rainy and dry seasons but in Bulolo forest most occurred in the rainy seasons (September 2014 until March 2015), whereas in Mtambalala forest most occurred in the dry season (June to August 2014), during the study period.

Flowers occurred in both rainy and dry seasons in Bulolo forest and only in the rainy season in Mtambalala forest but peak flowering period was concentrated around the rainy season (March) in both areas; *i.e.* as expected the peak flowering time matched within the two forests. The flowering production showed considerable variation between the two forests, with a higher production in Bulolo forest than in Mtambalala forest. Generally, flowering (flower buds and open flowers) of *F. guineensis* occurred throughout the year. A close relative *F. indica*, growing in Madagascar mainly in coastal forest and moist lowland forest was also reported to produce flowers throughout the year (Rabenantoandro *et al*., 2008). The flowering state of single clusters of *F. guineensis* differed from other clusters in the forest, *i.e.* some clusters were showing flower buds, some were having open flowers, and others were in a vegetative state (no flowering) whereas some clusters were presenting both stages at the same time. Peaks of mass flowering and fruiting were not recorded during this short-time study period. It is recommended that a longer-time observation of *F. guineensis* flowering cycles in the forests is needed to assess whether the climbing bamboo clusters do produce flowers or fruits all at the same time (mast-flowering or fruiting) in the forests.

To enhance its regeneration status, *F. guineensis* regenerates by both vegetative sprouting from rootstocks (shoot production) and by seedlings germinating from seeds produced from fruiting clusters. Clusters of *F. guineensis* were bearing round, red fruits in both rainy and dry seasons in Bulolo forest, but only during the rainy season in Mtambalala forest. Fruit ripening peaked during the rainy season (February until April). This seasonal fruit ripening pattern is similar to the patterns observed in *F. indica* (Rabenantoandro *et al*., 2008), but literature is extremely scarce to compare the flowering and fruiting events of *F. guineensis* with other bamboo species. This study revealed that the climbing bamboo favours more the rainy season for production of flowers and fruits than the dry season.

Shoot growth from the rhizome, leaf shoots from the end-tip of the culm and also seedlings from seeds are the important regeneration components that keep the species thriving in the forest. Leaf shoots, shoots from the rhizome and seedlings were all present in all the months (in both rainy and dry seasons) during the study period in both study sites, but many clusters had only few of these components associated with them. This study about the flowering, fruiting and growth phenology of the climbing bamboo *F. guineensis* has provided information on the seasonal variation in the presence and intensity of these stages, and also advised on the suitable time for harvesting culms in the forests.

4.2.2. Variation on phenological state between forest Interior and edges

The study findings in sections 2.3.2 and 2.3.3 indicated that flowering and fruiting were regular and abundant in forest edges, which shows that the ideal site for collection of gene bank seeds is the edge. Both flowering and fruiting was more abundant in forest edges than in the forest interior. Leaf shoot production of *F.guineensis* is high in both forest edges and forest interior. Many shoots from the rhizome were seen in the forest interior in Bulolo forest, while in Mtambalala forest the production of shoots was similar between forest edges and forest interior. Young climbers cannot survive under full sun exposure (Rabenantoandro *et al*., 2008), and this may be the reason why many seedlings of *F.guineensis* were only seen in the forest interior in both study sites.

4.3. Plant development patterns between forest stand conditions

Keys questions addressed in this section were as follows: (1) How do the *F. guineensis* culms grow from the rhizome to the tree canopy? (2) Does the development of *F. guineensis* differ when growing on forest margins, in forest gaps and in mature forest with closed canopy? (3) How does *F. guineensis* interact with the plants around it (from small plants to canopy trees)?

Clusters were sampled in three Eastern Cape Coastal Forests (Manubi, Mnenga and Mtambalala). In each forest, six *F. guineensis* clusters were randomly chosen from each of three stand conditions: forest edge, canopy gaps and closed mature forest, giving a total of 18 clusters per forest, and a total of 54 clusters overall. For each cluster, the following parameters were recorded: forest stand condition (closed canopy, gap or edge), location coordinates next to each cluster using GPS, and species, height and stem diameter at breast height (dbh) of all host trees. Each bamboo cluster was measured and recorded as follows: cluster diameter at ground level, number of culms in each cluster, the diameter and length of each culm in a cluster (each culm was pulled down to ground level for measuring length and basal diameter)), and the height at which the culms start to climb the host trees.

4.3.1. Forest stand conditions (closed canopy, gap and edge)

The current study presented the influence of forest stand conditions on the development patterns of the climbing bamboo *F. guineensis*. The seedling of *F. guineensis* matures into a cluster and the cluster can have more than 20 climbing culms, when the shoots grow from the rhizome of that cluster they add highly to the number of culms. The culms climb the trees that are around the cluster. If there is only one tree next to the cluster, the culms would form a dense mat on the canopy of the host tree, but if there is more than one tree around the cluster then the culms climb more than one tree, with less culms on each host tree canopy. The growth habits of clusters that occur at the edge of the forest differ from the clusters inside the forest under closed canopy. Clusters at the forest edge are shrubby and culms form dense tangles, whereas clusters growing inside the forest under a closed canopy have culms with an erect growth habit and each culm can be easily traced up to the canopy of their host trees.

The relationship between cluster diameter and number of culms were not significantly different under differing forest stand conditions. However, the growth patterns of *F. guineensis* between forests and their stand conditions varied. Mean cluster diameter was highest in Manubi forest compared with the other two forests. Here the forest edge had the largest cluster diameter. The number of culms per cluster was highest in Mnenga forest, followed closely by Manubi forest. The highest number of culms per cluster in Manubi and Mtambalala forests occurred under closed canopy; in Mnenga forest the highest number occurred in the forest edge situation. The number of culms per cluster seems not to be affected by the light regime.

The culms of this climbing bamboo are slender and hard, with the diameter of up to 2.5 cm and length of up to 20 m. Culm diameter was found to be higher in Manubi forest, and was highest in open environments such as forest edge in Manubi forest, and in forest gaps in both Mtambalala and Mnenga forests. Under closed canopy this climbing bamboo had the highest culm length in Manubi forest. Observations in this study showed that *F. guineensis* culms would grow to the canopy of the forest, and that when the host trees were tall in the forest, then the culms would be long. In Manubi forest most of host trees were taller than in the other two forests. That would explain why the culms were longer in Manubi forest. Under closed forest canopy culm growth is relatively fast because they require light.

The culms are the plant parts of the climbing bamboo *F. guineensis* utilized in the Transkei for basket-making. In Manubi forest the species is not utilized, while in the other forests the climbing bamboo is used for basket-making. It is recommended that culms that are already in the canopy of their host trees should be harvested for basket-making. This will help in reducing tangles on the canopy of the host trees.

4.4. Discussion and Conclusion

This study has contributed to an understanding that a seedling of *F. guineesis* develops into a cluster with many culms of different diameter and length, and the culms climb into the tree crowns in closed canopy, gaps and edges to maintain a situation of good light conditions. The study observation revealed that the tangles in forest edges are a natural growth habit of this climbing bamboo in open sites. *Flagellaria guineesis* needs shade to reproduce effectively by seed since abundant seedlings of this species were found in the forest interior.

This study has shown that *F. guineensis* regenerates vegetatively by producing shoots from rhizomes and also by seedlings from seeds. In the current study, low production of flowers and fruits were recorded in the forests, with few clusters flowering and fruiting in different forest stand conditions. Flower and fruit production of this species peaks in the rainy season (February until April) in the forests, therefore harvesting of culms need to be done during the dry season to avoid reduction of flowering or fruiting culms. The seedlings of *F. guineensis* develop into mature clusters which have more than five culms, with a diameter and length of less than 2.5 cm and 30 m respectively. The culms in a cluster increase as the shoots grow from the rhizome. *Flagellaria guineensis* is capable of growing and producing viable seed in both open and shady conditions.

Observations during this study showed that *F. guineensis* was common in the forest edges of the forests, supporting a report by Baldwin & Speese (1957). Clusters at the forest edges or gaps formed tangles in the canopy of their host trees in all three forests. This pattern of growth of *F. guineensis* contributes in maintaining the forest edges or gaps. Because the trees in edges and gaps tend to be short, tangles restrict easy movement in and out of the forests and recovery of disturbed edges and gaps is possible. It is interesting that such ecological adaptability may be a necessary trait of a non-timber forest species with a vigorous regeneration pattern in a natural forest.

Flower and fruit production of *F. guineensis* is high in the rainy season. However, shoots from the rhizome and seedlings production of this climbing bamboo are the same throughout the year. In forest stand conditions, shoots and seedlings are abundant in the forest interior. Mature culms of *F. guineensis* require light and support to grow. In forest edges and gaps these culms forms tangles but in closed canopy culms are taller with no tangles on host trees.

This climbing bamboo appears as an easy manageable species in forest stands if planted. There have been studies exploring planting of non-timber forest products such as a fern *Rumohra adiantiformis* for flower market (Geldenhuys, 1994.) and medicinal plants (Diederich, 2006), found inside the natural forests in South Africa and used as local income by communities. The same approach can be used with *F. guineensis*, by planting this species in low altitude areas and under forest tree stands for support. Rabenantoandro *et al* (2008) indicated that planting of seeds is an appropriate way to propagate the related species *Flagellaria indica ex situ* and *in situ*. Planting of *F. guineensis* outside of state forests for the benefits of communities around the forests is recommended. This will also prevent future depletion of the species in state forests thereby sustaining local income generation through basket-making.

4.5. Recommendation for sustainable management of *Flagellaria guineensis* in the forests

The information captured in this study can assist with the management of the climbing bamboo in the state forests. *Flagellaria guineensis* is an important non-timber product for basket-making in the Eastern Cape Coastal forests, and its management in the forests is vital to such local industries and the well-being of the forest. Culms are the only part of the plant that the local people use. Demand for culms for basket-making can increase as it provides the local communities with income. Since *F. guineensis* tangles were seen as a negative impact on the canopy trees at the forest edge, harvesting for basket-making is recommended as a way of reducing tangles on the host canopy. In the forests, *F. guineensis* is known for its potential to regenerate after cutting (Bosch, 2010). Research to investigate the regeneration rate of *F. guineensis* culms after harvesting is also recommended in order to provide the base information for plant production of the species for basket-making. There is literature (Cawe & Ntloko, 1997) about economic benefits of *F. guineensis*, and together with the information from this study could guide the better use of the culms.

Climbing bamboo *F. guineensis* seedlings develop into mature clusters which are found in the edge and interior of the forest, but there seems to be no information on the growth rates of the culms and how long (months to years) seedlings of this species may take to reach maturity. Future research needs to consider monitoring the growth rate of young *F. guineensis* seedlings until they become big clusters, as this will be vital when planting the climbing bamboo for basket-making. Ripe fruits are found during the rainy season in the forests; a study of plant production of *F. guineensis* by collecting and planting of seeds outside the state forests for basket-making is recommended. The growth of *F. guineensis* clusters and their culms between forest stand conditions is not different. Harvesting of the culms in any stand condition (edge, gap or closed-canopy) is recommended since the development of *F. guineensis* does not significantly differ inside the forest.

The following guidelines could be used for harvesting culms for basket-making to ensure sustainable supply of material for basket-making:

1) Harvesting of culms must take place during the dry season, when the culms in a cluster are not flowering or fruiting.

2) Culms must be harvested without damaging the seedlings around the cluster and shoots resprouting from the rhizome of the cluster.

3) Culms must be harvested at least at a knee height to allow the nodes of the culm left on the forest floor a chance to regenerate.

4) When harvesting, the culms chosen must be of larger diameter, i.e. 0.8 cm to 2.5 cm diameter. Smaller shoots from rhizome of the cluster or plant must not be harvested.

5) Harvesting of culms can be done in all forest stand conditions, but harvesting in closed canopy is recommended because of taller culms.

REFERENCES

Baldwin, J.T. & Speese, B.M., 1957. *Flagellaria guineensis* Schumach. *Bulletin of the Torrey botanical Club*, 84, 90-93.

Balfour, D., 2004. Ecology of climbing plants in Southern African Forests. In Indigenous forest and woodlands in South Africa: Policy, People and Practice. Edited by M.J. Lawes, H.A.C. Eeley, C.M. Shackleton & B.G.S. Geach. Scottsville: University of KwaZulu-Natal Press, pp. 56-58.

Balfour, D.A. & Bond, W.J., 1993. Factors limiting climber distribution and abundance in a Southern African Forest. *Journal of Ecology*, 81, 93-100.

Bosch, C.H., 2010. *Flagellaria guineensis* Schumach. Records from protabase. In PROTA (Plant Resources of Tropical Africa/Resources Vegetales de l' Afrique Tropicale). Edited by M. Brink, E.G. Achigan-Dako. Wageningen, Netherlands. http://database.Prota.org/search.htm [Accessed 2 November 2012].

Bredenkamp, G., Granger, J.E. & Van Rooyen, N., 1996. Moist sandy Highveld grassland. In *Vegetation of South Africa, Lesotho and Swaziland*. Edited by A.B. Low & A.G. Robelo. Pretoria: Department of Environmental Affairs and Tourism.

Campanello, P.I., Villagra, M., Garibaldi, J.F., Luis, J., Ritter, L.J., Araujo, J.J. & Goldstein, G., 2012. Liana abundance, tree crown infestation, and tree regeneration ten years after liana cutting in a subtropical forest. *Forest Ecology and Management*, 284, 213-221.

Cawe, S.G., 1999. Spatial and temporal utilization patterns of *Flagellaria guineensis* Shumach in demarcated forests of the Lusikisiki district of Transkei, South Africa. *South African Journal of Botany*, 65, 69-74.

Cawe, S.G. & Geldenhuys, C.J., 2007. Resource status and population dynamics of target species in natural forests of the Port St Johns Forest Estate: A basis for sustainable resource use. Report for Project 2006-397. Directorate: Forestry Technical Services. Pretoria: Department of Water Affairs and Forestry.

Cawe, S.G. & Ntloko, S.S.T., 1997. Distribution, uses and exploitation patterns of *Flagellaria guineensis* Schumach, with particular reference to Port St Johns, South Africa. *South African Journal of Botany*, 63, 233-238.

Cloete, E.C., 2004. A floristic study of a portion of the Pondoland centre of endemism, Port St Johns, South Africa. MSc thesis. Rhodes University.

Conservatoire et Jardin botaniques. & South African National Biodiversity Institute., 2012. *Flagellaria guineensis* Schumach. African Plant Database. Accessed on 11 August 2016.

Commercialising medicinal plants: A Southern African guide. Edited by N. Diederich. 2006. Stellenbosch: SUN Press.

Fenner, M., 1998. The phenology of growth and reproduction in plants. *Perspectives in Plant Ecology, Evolution and Systematics*, 1, 78-91.

Geldenhuys, C.J., 1994. Review of studies of the fern *Rumohra adiantiformis* in the southern Cape forests: Implications for sustained management. Report FOR-DEA 758, Division of Forest Science and Technology. Pretoria: CSIR.

Geldenhuys, C.J., 1996. Fruit/Seed characteristics and germination requirements of Tree and Shrub species of the Southern Cape Forests. Report FOR-DEA 954, pp 72.

Geldenhuys, C.J., 2007. Growth, ingrowth and mortality patterns over stands and species in Manubi forest growth study site, Eastern Cape Province. Report on 2006 measurements. Report FW-01/07. Pretoria: FORESTWOOD cc.

Geldenhuys, C.J., Assede, P.S.E., Cawe, S.G., Kutta, S., Litye, K., Mengqani, N.K. & Stemele, X., 2013. Phase 2 report for the study to Review the Nqabarha Management Plan and to Develop

Natural Resource Use Guidelines: Forest resource assessment. Report number FW-02/13. Pretoria: FORESTWOOD cc.

Giordano, C.V., Sánchez, R.A. & Austin, A.T., 2009. Gregarious bamboo flowering opens a window of opportunity for regeneration in a temperate forest of Patagonia. *New phytologist*, 181, 880-889.

González, M.E., Veblen, T.T., Donoso, C. & Valeria, L., 2002. Tree regeneration responses in a Lowland Nothofagus-Dominated Forest after Bamboo Dieback in South-Central Chile. *Plant Ecology*, 161, 59-73.

Kigomo, B.N., 2007. Guidelines for Growing Bamboo. KEFRI Guideline Series: No. 4. Kenya Forestry Research Institute; Nairobi, Kenya, pp 45.

King, N.L., 1941. The Manubi Forest. Journal of the South African Forestry Association, 24-29.

Kleinhenz, V. & Midmore, D.J., 2001. Aspects of Bamboo Agronomy. *Advances in Agronomy*, 74, 99-153.

Lima, R.A.F., Rother, D.C., Muler, A.E., Lepsch, I.F. & Rodrigues, R.R., 2012. Bamboo overabundance alters forest structure and dynamics in the Atlantic Forest hotspot. *Biological Conservation*, 147, 32–39.

Lowe, R.G. & Walker, P., 1977. Classification of canopy, stem, crown status and climber infestation in natural tropical forest in Nigeria. *Journal of Applied Ecology*, 14, 897-903.

Marod D., Neumrat V., Panuthai S., Hiroshi T. & Sahunalu P., 2005. The forest regeneration after gregarious flowering of bamboo (Cephalostachyum pergracile) at Mae Klong watershed research station, Kanchanaburi. *Kasetsart Journal (Natural Science)*, 39, 588-593.

Mucina, L. & Geldenhuys, C.J., 2006. Afrotemperate, subtropical and azonal forests. In: Mucina L, Rutherford MC, The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia*, 19, 584-614.

Muller, I. & Rebelo, C., 2010. Bamboo Worldwide: the current market and future potential. EcoPlanet Bamboo Report, pp 30.

Putz, F.E., 1984. The natural history of lianas on Barro Colorado Island, Panama. *Ecology*, 65, 1713-1724.

Rabenantoandro, J., Randrihasipara, L. & Randriatafika, F., 2008. Testing the propagation and growth of the Liana. Biodiversity, ecology and conservation of littoral Ecosystems in Southeastern Madagascar, Tolagnaro. MadaRevisionsChap6Index, pp 363-368.

Ramanayake, S.M., 2006. Flowering in bamboo: an enigma. *Ceylon Journal of Science* (*Biological Sciences*), 35, 95-105.

Schnitzer, S.A., Dalling, J.W. & Carson, P.W., 2000. The impact of lianas on tree regeneration in tropical forest canopy gaps: evidence for an alternative pathway of gap-phase regeneration. *Journal of Ecology*, 88, 655-666.

Seifriz, W., 1920. The length of the life cycle of a climbing bamboo. A striking case of sexual periodicity in *Chusquea abietifolia Griseb*. *American Journal of Botany*, 7, 83-94.

Sills, E., Shanley, P., Paumgarten, F., De Beer, J. & Pierce, A., 2011. Non-Timber Forest Products in the Global Context. Tropical Forestry 7, DOI 10.1007/978-3-642-17983-9_2. S. Shackleton et al. (eds), http://www.springer.com/978-3-642-17982-2.

Soderstrom, T.R. & Calderon, C.E., 1979. A Commentary on the Bamboos (Poaceae: Bambusoideae). *Biotropica*, 11, 161-172.

Taylor, A.H. & Qin, Z., 1993. Bamboo regeneration after flowering in the wolong giant panda reserve, China. *Biological Conservation*, 63, 231-234.

Taylor, A.H., Huang, J. & Zhou, S., 2004. Canopy tree development and undergrowth bamboo dynamics in old-growth Abies-Betula forests in southwestern China: a 12-year study. *Forest Ecology and Management*, 200, 347-360.

Van Steenis, C.G.G.J., 1978. Gregarious flowering in the monocarpus Genus Isoglossa (Acanthaceae). *Bothalia*, 12, 553.

Veblen, T.T., Young, A.K.R. & Orme, A.R., 2007. The Physical Geography of South America. Oxford University Press, USA, South America, p 448.

Von Maltitz, G., Mucina, L., Geldenhuys, C.J., Lawes, M.J., Eeley, H., Aidie, H., Vink, D., Fleming, G. & Bailey, C., 2003. Classification system for South African Indigenous Forests. An objective classification for the Department of Water Affairs and Forestry. Unpublished report, No. ENV-P-C-2003-017, Environmentek. Pretoria: CSIR.

Widmer, Y., 1997. Life history of some Chusquea species in old-growth oak forest in the Cordillera de Talamanca, Costa Rica. In The Bamboos. Edited by G.P. Chapman. London: the Linnean Society, pp. 17-31.

Widmer, Y., 1998a. Flowering phenology of Chusquea bamboos with special reference to *Chusquea talamancensis* in Costa Rica. *Journal of the American Bamboo Society*, 12, 1-20.

Widmer, Y., 1998b. Pattern and Performance of Understory Bamboos (*Chusquea* spp.) under different canopy closures in old-growth oak forests in Costa Rica. *Biotropica*, 30, 400-415.

Widmer, Y., 1999. The ecological role of bamboo (*Chusquea* spp.) in the old growth Quercus forests of the Cordillera De Talamanca, Costa Rica. PhD dissertation: Zurich University.

Williams-Linera, G., 1990. Vegetation structure and environmental conditions of forest edges in Panama. *Journal of Ecology*, 78, 356-373.

Zhang, G., Song, Q. & Yang, D., 2006. Phenology of *Ficus racemose* in Xishuangbanna. Southwest China. *Biotropica*, 38, 334-341.

APPENDICES

Appendix 1: Flower bud presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	**Month**												
	A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of flower buds presence in each category													
All	0,03					0,13	0,13	0,10	0,67	0,67	0,70	0,27	
Edge E	0,10					0,30	0,30	0,20	0,90	0,90	1,40	0,20	
Edge W						0,10	0,10		1,00	1,00	0,60	0,30	
Interior I								0,10	0,10	0,10	0,10	0,30	
Number of clusters with flower bud in each category													
1 in E	1					1	1	0	1	1	2	2	
1 in W						1	1	0	1	1	1	3	
1 in I								1	1	1	1		
2 in E						1	1	1	1	1	3		
2 in W											1		
2 in I													
3 in E									2	2	2		
3 in W									3	3	1		
3 in I												1	
Total number of clusters with flower buds													
	1					3	3	2	9	9	11	6	
Mtambalala forest													
Mean intensity of flower bud presence in each category													
All	0,07	0,10	0,13	0,07	0,07	0,03	0,03				0,03		
Edge E		0,30	0,10			0,10					0,10		
Edge W	0,20		0,20	0,10	0,10								
Interior I			0,10	0,10	0,10		0,10						
Number of clusters with flower bud in each category													
1 in E		3	1			1					1		
1 in W			2	1	1								
1 in I			1	1	1		1						
2 in E													
2 in W	1												
2 in I													
3 in E													
3 in W													
3 in I													
Total number of clusters with flower buds													
	1	3	4	2	2	1	1				1		
[1]Legend: 1 = Few flower buds; 2 = Intermediate flower buds; 3 = Abundant flower buds													

Appendix 2: Flower presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	**Month**												
	A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of flowers presence in each category													
All					0,03	0,10		0,07				0,80	0,07
Edge E					0,10	0,20						1,30	0,20
Edge W						0,10						1,00	
Interior I								0,20				0,10	
Number of clusters with flowers in each category													
1 in E					1	2						5	2
1 in W						1						5	
1 in I												1	
2 in E												1	
2 in W												1	
2 in I								1					
3 in E												2	
3 in W												1	
3 in I													
Total number of clusters with flowers													
					1	3		1				16	2
Mtambalala forest													
Mean intensity of flowers presence in each category													
All												0,10	
Edge E												0,30	
Edge W													
Interior I													
Number of clusters with flowers in each category													
1 in E												3	
1 in W													
1 in I													
2 in E													
2 in W													
2 in I													
3 in E													
3 in W													
3 in I													
Total number of clusters with flowers													
												3	
[1]Legend: 1 = Few flowers; 2 = Intermediate flowers; 3 = Abundant flowers													

Appendix 2.1: Example of calculating intensity of flowering (phenological state): Phenological table of intensity of flowering occurrence in *Flagellaria guineensis* in Bulolo Forest from April 2014 to April 2015 (+ = few; ++ = intermediate; +++ = abundant).

Cluster	2014									2015			
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
01													
02													
03						+						+	
04												+	
05						+						+	
06													
07													
08								++					
09													
10													
11													
12												+	
13													
14													
15					+							+	
16												+	
17													
18												+	
19													
20												++	
21												+++	+
22												++	
23												+	
24												+++	+
25						+						+	
26												+	
27												+++	
28												+	
29													
30													
Frequency of clusters with specific intensity of flowering (+, ++, +++)													
+					1	3						11	2
++								1				2	
+++												3	
Mean flowering intensity													
					0.03	0.10		0.07				*0.80	0.07

* This value is calculated as follows: ((11*1) + (2*2) + (3*3))/30=0.80. Peak flowering occurs in March and then declines in April. The amount of flowering at a particular time is a combination of the mean intensity of flowering, and how many clusters were flowering. This kind of information has practical value for preparing for seed collection, or to know how forest ecological processes fit together.

Appendix 3: Fruit presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	**Month**												
	A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of fruits presence in each category													
All	0,47	0,03		0,03			0,03	0,03		0,03	0,67	0,73	0,60
Edge E	0,20			0,10			0,10	0,10			1,00	1,10	1,00
Edge W	1,00	0,10									0,90	0,90	0,70
Interior I	0,20									0,10	0,10	0,20	0,10
Number of clusters with fruits in each category													
1 in E				1			1	1			2	3	5
1 in W	1	1									1	5	2
1 in I	2									1	1		1
2 in E	1										4	4	1
2 in W	3										1	2	1
2 in I												1	
3 in E													1
3 in W	1										2		1
3 in I													
Total number of clusters with fruits													
	8	1		1			1	1		1	11	15	12
Mtambalala forest													
Mean intensity of fruits presence in each category													
All	0,17										0,47	0,43	0,10
Edge E	0,30										0,90	0,70	
Edge W	0,20										0,50	0,60	0,20
Interior I													0,10
Number of clusters with fruits in each category													
1 in E	3										1	3	
1 in W												1	2
1 in I													1
2 in E											1	2	
2 in W	1										1	1	
2 in I													
3 in E											2		
3 in W											1	1	
3 in I													
Total number of clusters with fruits													
	4										6	8	3

[1]Legend: + = Few fruits; ++ = Intermediate fruits; +++ = Abundant fruits

Appendix 4: Leaf shoot presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	Month												
	A	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest													
Mean intensity of leaf shoots presence in each category													
All	2,40	2,40	2,40	2,40	2,03	1,63	1,50	1,70	2,23	2,40	1,43	1,70	1,77
Edge E	2,70	2,80	2,80	2,80	2,40	2,00	1,90	2,30	2,10	2,30	1,70	2,10	2,30
Edge W	2,40	2,30	2,30	2,30	2,00	1,40	1,30	1,70	2,60	2,80	1,20	1,90	1,80
Interior I	2,10	2,10	2,10	2,10	1,70	1,50	1,30	1,10	2,00	2,10	1,40	1,10	1,20
Number of clusters with leaf shoots in each category													
1 in E	0	1	1	1	2	4	3	1	3	1	3	1	2
1 in W	2	2	2	2	3	7	6	4	1	0	4	1	4
1 in I	2	3	3	3	6	6	8	9	2	3	5	8	8
2 in E	0	0	0	0	2	2	5	5	3	5	4	7	3
2 in W	2	3	3	3	4	2	2	2	2	2	4	6	4
2 in I	5	3	3	3	1	3	1	1	3	3	3	0	2
3 in E	9	9	9	9	6	4	2	4	4	4	2	2	5
3 in W	6	5	5	5	3	1	1	3	7	8	0	2	2
3 in I	3	4	4	4	3	1	1	0	4	4	1	1	0
Total number of clusters with leaf shoots													
	29	30	30	30	30	30	29	29	29	30	26	28	30
Mtambalala forest													
Mean intensity of leaf shoots presence in each category													
All	2,57	2,57	2,57	2,43	2,30	1,87	1,50	1,63	2,60	2,63	1,63	1,33	1,63
Edge E	2,70	2,60	2,60	2,50	2,30	1,80	1,60	1,90	2,60	2,60	2,10	1,20	1,90
Edge W	2,50	2,60	2,60	2,40	2,40	1,90	1,60	1,70	2,40	2,50	1,50	1,50	1,60
Interior I	2,50	2,50	2,50	2,40	2,20	1,90	1,30	1,30	2,80	2,80	1,30	1,30	1,40
Number of clusters with leaf shoots in each category													
1 in E	0	0	0	0	0	4	4	3	1	1	3	7	3
1 in W	1	0	0	1	1	3	6	4	2	1	5	6	6
1 in I	1	1	1	1	1	1	7	7	0	0	7	7	5
2 in E	3	4	4	5	7	4	6	5	2	2	3	1	5
2 in W	3	4	4	4	4	5	2	5	2	3	5	3	2
2 in I	3	3	3	4	6	9	3	3	2	2	3	3	3
3 in E	7	6	6	5	3	2	0	2	7	7	4	1	2
3 in W	6	6	6	5	5	2	2	1	6	6	0	1	2
3 in I	6	6	6	5	3	0	0	0	8	8	0	0	1
Total number of clusters with leaf shoots													
	30	30	30	30	30	30	30	30	30	30	30	29	29
[1]Legend: + = Few Leaf shoots; ++ = Intermediate Leaf shoots; +++ = Abundant Leaf shoots													

Appendix 5: Shoot presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	**Month**										
	J	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**
Bulolo forest											
Mean intensity of shoots presence in each category											
All	0,77	1,03	1,03	0,80	1,00	0,87	0,97	0,90	0,87	1,07	1,20
Edge E	0,50	0,50	0,70	0,50	0,50	0,90	0,90	0,60	0,40	0,80	0,60
Edge W	0,50	0,60	0,90	0,80	1,00	0,60	0,70	0,70	1,10	1,00	1,10
Interior I	1,30	2,00	1,50	1,10	1,50	1,10	1,30	1,40	1,10	1,40	1,90
Number of clusters with shoots in each category											
1 in E	5	5	7	5	5	5	6	6	2	8	6
1 in W	5	4	7	8	6	6	5	5	4	6	6
1 in I	2	2	6	5	4	8	4	3	7	3	1
2 in E	0	0	0	0	0	2	0	0	1	0	0
2 in W	0	1	1	0	2	0	1	1	2	2	1
2 in I	4	3	0	0	1	0	3	4	2	1	3
3 in E	0	0	0	0	0	0	1	0	0	0	0
3 in W	0	0	0	0	0	0	0	0	1	0	1
3 in I	1	4	3	2	3	1	1	1	0	3	4
Total number of clusters with shoots											
	17	19	24	20	21	22	21	20	19	23	22
Mtambalala forest											
Mean intensity of shoots presence in each category											
All	0,70	0,80	1,03	0,93	1,07	0,83	1,23	1,23	1,07	1,30	0,93
Edge E	0,60	0,70	0,80	0,90	0,90	1,00	1,20	1,20	1,20	1,50	0,90
Edge W	0,80	0,70	1,20	1,10	1,20	0,80	1,00	1,00	0,90	1,20	0,80
Interior I	0,70	1,00	1,10	0,80	1,10	0,70	1,50	1,50	1,10	1,20	1,10
Number of clusters with shoots in each category											
1 in E	6	5	8	7	5	8	6	6	5	6	5
1 in W	6	5	8	9	9	8	7	7	6	4	6
1 in I	7	6	9	8	9	5	6	6	7	7	7
2 in E	0	1	0	1	2	1	3	3	2	3	2
2 in W	1	1	2	1	0	0	0	0	0	4	1
2 in I	0	2	1	0	1	1	3	3	2	1	2
3 in E	0	0	0	0	0	0	0	0	1	1	0
3 in W	0	0	0	0	1	0	1	1	1	0	0
3 in I	0	0	0	0	0	0	1	1	0	1	0
Total number of clusters with shoots											
	20	20	28	26	27	23	27	27	24	27	23

[1]Legend: + = Few Shoots from rhizome; ++ = Intermediate Shoots from rhizome; +++ = Abundant Shoots from rhizome

Appendix 6: Seedling presence in 30 *Flagellaria guineensis* clusters in each of Bulolo and Mtambalala forests during the study period April 2014 to April 2015.

Category[1]	Month												
	A	M	J	J	A	S	O	N	D	J	F	M	A
Bulolo forest													
Mean intensity of seedlings presence in each category													
All	0,60	0,80	0,77	0,73	0,73	0,63	0,77	0,83	0,97	0,97	1,03	1,30	1,33
Edge E	0,50	0,50	0,40	0,20	0,40	0,40	0,80	0,30	0,30	0,30	0,20	0,80	0,80
Edge W	0,40	0,70	0,70	0,80	0,80	0,70	0,60	1,10	0,90	1,00	1,00	1,40	1,20
Interior I	0,90	1,20	1,20	1,20	1,00	0,80	0,90	1,10	1,70	1,60	1,90	1,70	2,00
Number of clusters with seedlings in each category													
1 in E	3	5	4	2	4	4	6	3	1	1	2	8	2
1 in W	2	5	5	4	6	5	4	4	2	1	1	3	1
1 in I	1	4	5	5	8	4	4	4	1	0	4	2	1
2 in E	1	0	0	0	0	0	1	0	1	1	0	0	0
2 in W	1	1	1	2	1	1	1	2	2	3	3	1	1
2 in I	1	1	2	2	1	2	1	2	2	2	3	3	2
3 in E	0	0	0	0	0	0	0	0	0	0	0	0	2
3 in W	0	0	0	0	0	0	0	1	1	1	1	3	3
3 in I	2	2	1	1	0	0	1	1	4	4	3	3	5
Total number of clusters with seedlings													
	11	18	18	16	20	16	18	17	14	13	17	23	17
Mtambalala forest													
Mean intensity of seedlings presence in each category													
All	1,07	1,17	0,90	0,93	0,97	0,93	0,77	1,23	1,33	1,33	0,93	1,60	1,70
Edge E	0,60	0,80	0,60	0,60	0,90	0,90	0,60	1,10	1,30	1,40	0,70	1,50	1,70
Edge W	0,70	1,00	1,10	1,20	1,10	1,00	0,80	0,80	0,90	1,00	0,70	1,40	1,30
Interior I	1,90	1,70	1,00	1,00	0,90	0,90	0,90	1,80	1,80	1,60	1,40	1,90	2,10
Number of clusters with seedlings in each category													
1 in E	2	4	6	6	5	7	6	5	4	4	4	4	4
1 in W	1	4	5	5	8	6	8	3	2	3	5	6	5
1 in I	2	3	6	7	9	9	7	4	3	3	6	4	2
2 in E	2	2	0	0	2	1	0	3	3	2	0	1	2
2 in W	3	3	3	2	0	2	0	1	2	2	1	4	1
2 in I	4	4	2	0	0	0	1	1	3	2	1	3	2
3 in E	0	0	0	0	0	0	0	0	1	2	1	3	3
3 in W	0	0	0	1	1	0	0	1	1	1	0	0	2
3 in I	3	2	0	1	0	0	0	4	3	3	2	3	5
Total number of clusters with seedlings													
	17	22	22	22	25	25	22	22	22	22	20	28	26
[1]Legend: + = Few Seedlings; ++ = Intermediate Seedlings; +++ = Abundant Seedlings													

Appendix 7: Host trees that *Flagellaria guineensis* was climbing in Manubi forest, Mnenga forest and Mtambalala forest. X-indicate that the species is used as a host in a specific forest.

Botanical name	Local name	Manubi Forest	Mnenga Forest	Mtambalala forest
Agave Americana	Ikhamanga		X	
Behnia reticulate	Ubulawu	X		
Buxus natalensis	IsiXesa	X		
Canthium ciliatum	Ubuchopho		X	
Canthium inerme	umNyushulube	X		
Celtis Africana	umVumvu	X		
Cestrum leavigatum	Munki	X		
Coddia rudis	inTsinde			X
Codea caffra	Msintshane	X		
Cola natalensis	umThenenende		X	X
Cordia caffra	umLovulovu	X		
Chaetachme aristata	umKhovothi		X	
Cussonia sphaerocephala	umSenge		X	X
Cynodon dactylon	uQaqaqa		X	
Dalbergia amata	Ibobo	X		
Dalbergia obovate	umZungu	X		
Dalbergia multijuga	Uzungu	X		
Dioscorea dregeana	Ingcolo	X		
Duvernoia adhatodoides	Isipheka		X	X
Englerophytum natalense	umThongwane	X	X	X
Ficus sur	umKhiwane		X	
Ficus thonningii	umThombe	X		
Foeniculum vulgare	iMbambosi	X		
Harpephyllum caffrum	umGwenya, Mkhwengwe	X	X	
Heywoodia lucens	umNebelele		X	
Iso-glossa species	Thlololwane	X		
Gymnosporia buxifolia	Mqaqobi		X	
Maytenus peduncularis	umNqai, umNqayi-nqayi	X		
Millettia grandis	umSimbithi		X	X
Philenoptera sutherlandii	umQunye			X
Monanthotaxis caffra	iDwabe	X	X	
Rhus/Searsia chirindensis	Mthlolokochane	X		

Botanical name	Local name	Manubi Forest	Mnenga Forest	Mtambalala forest
Ochna arborea	Umthentsema			X
Olinia radiate	umBovana			X
Olinia ventosa	umNonono	X		
Oxyanthus speciosus	umThlwethlwe			X
Phoenix reclinata	uSundu		X	
Podocarpus falcatus	umKhoba	X		
Podocarpus latifolius	umCheya	X		
Premna mooiensis	umTyatyambane	X		
Protorhus longifolia	uZintlwa	X		
Psidium cattleyanum	Cherry guava	X		
Schotia latifolius	Ixwanu	X		
Scutia myrtina	isiPhingo	X	X	
Trema orientalis	umBhangabhanga			X
Trichilia dregeana/emetic	umKhuhlu	X		X
Trichocladus grandiflora	Umthambo		X	
Trichocladus crinitus	iThambo		X	X
Vepris lanceolata	umZane	X		
Zanthoxylum davyi	umLungamabele			X
	Dondzane	X		
	Stledzambadza	X		
	Mthlongothi	X		
	Marimba	X		
	umHlakela		X	
	Mpumeledzi		X	
	Lusenge			X
	umPhambo			X