INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 10, Issue 4, October-December: 721-732 www.ijcs.uaic.ro

STUDIES ON THONNINGIA SANGUINEA VAHL. (BALANOPHORACEAE) IN SOUTHERN NIGERIA. RANGE AND HOST PREFERENCE

Odoligie IMARHIAGBE[1,*], Emmanuel Izaka AIGBOKHAN[2]

[1]Department of Biological Sciences, Edo University Iyamho, Nigeria.
[2]Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria

Abstract

Studies on the host-parasite relationship are intrinsically linked with the nature of parasitic plants. No such records have been recorded for Thonningia sanguinea (Balanophoraceae), a rare, cryptic, obligate holoparasitic plant endemic to tropical Africa. This study reports on its host range and preference in Southern Nigeria. Its presence and current distribution ranges were plotted from reconnaissance surveys conducted across selected forested areas in Southern Nigeria, comprising, national parks, forest reserves, and community-managed forests. To detect specific hosts, soil excavation leading from parasite to host was conducted. The results showed a broad host range with a special preference for native trees and members of the Euphorbiaceae and Urticaceae. Among the common host trees were: Guarea cedrata (Meliaceae), Lophira alata (Ochanaceae), Musanga cecropiodes (Urticaceae), Myrianthus arboreus (Urticaceae), and Ricinodendron heudelotii (Euphorbiaceae). Only Hevea brasiliensis and Theobroma cacao were of exotic origin. Lophira alata was the most susceptible infected host plant with a percentage infestation rate of 28.77, while Musanga cecropiodes had the highest percentage occurrence as host with 31.57 %. This finding could have significant implications on the conservation status of the plant, which accounting for current IUCN status is Not Evaluated (NE). In situ conservation is however recommended.

Keywords*: Parasitic plant; Cryptic; Host range; Conservation; Thonningia sanguinea*

Introduction

The family Balanophoraceae is mostly herbaceous, perennial root parasites, arising from underground tubers attached to the roots of the host [1]. Worldwide, there are 18 representative genera and 44 species, mostly tropical [2-3]. Some notable genera such as *Corynaea, Helosis, Langsdorffia, Lophophytum, Ombrophytum* and *Scybalium* have a neotropical distribution, while *Thonningia, Sarcophyte, Dactylanthus* are restricted to paleotropical region. However, *Thonningia sanguinea* is the only example of this family that is common in West Africa. Members of this family are normally found in moist inland forests growing on tree roots and have an above ground inflorescence with the overall appearance, similar to that of a fungus, composed of numerous minute flowers. The inflorescences develop inside the tuberous underground part of the plant, before rupturing and surfacing.

Several ecological studies carried out on common genera, such as *Balanophora* [4-5] *Corynaea crassa* [6], *Ombrophytum* [7], *Langsdorffia* [8] and the New Zealand endemic *Dactylanthus* [9] have attested to the catholic host utilization of the family. Due to their

* Corresponding author: imarhiagbe.odoligie@edouniversity.edu.ng

holoparasitic nature, the distribution of its members is largely limited by host availability, host quality, host resistance to parasitism, and parasite preference [10-13]. Therefore, a fundamental aspect of the ecology of these species is to understanding their host-parasite interaction, which also is a prerequisite step to their conservation [8, 14].

Thonningia sanguinea (Balanophoraceae) is a cryptic obligate holoparasitic plant endemic to tropical Africa. It is a fleshy dioecious herb growing from a branching, yellow underground tuber which extends horizontally up to 10 or 15 centimeters through the soil with which it forms bulb-like swellings at the point where it attaches to the roots of its host plants [15]. Records from literature and databases revealed little available records on *T. sanguinea*. Apart from narratives on its habit [15] and bioassay on its medicinal properties [16-18], very few studies exist on the ecology of *T. sanguinea*. Therefore, the present study was conducted based on the following objectives: (i) delineate the scope of *T. sanguinea* (ii) document its host species and (iii) identify its host preference in Southern Nigeria.

Materials and Methods

Population Location

Due to the cryptic and non-random nature of *Thonningia sanguinea* distribution within the forest environment, *T. sanguinea* populations were located using the following: meander searches, published materials, and personal communications.

Study Sites

A total of 24 locations habouring *T. sanguinea* were randomly selected from eight (8) Okomu National Park, five Cross River National Park, one Akure Ofosu Forest Reserve, two International Institute of Tropical Agriculture (IITA) Forest Reserve, one Idanre Forest Reserve, two Oba Hills Forest Reserve, four Community Managed-Forests (namely: Okokhuo, Ehor Nu Wire, Okuor and Iyanomo Rubber Plantation Forest (Fig. 1).

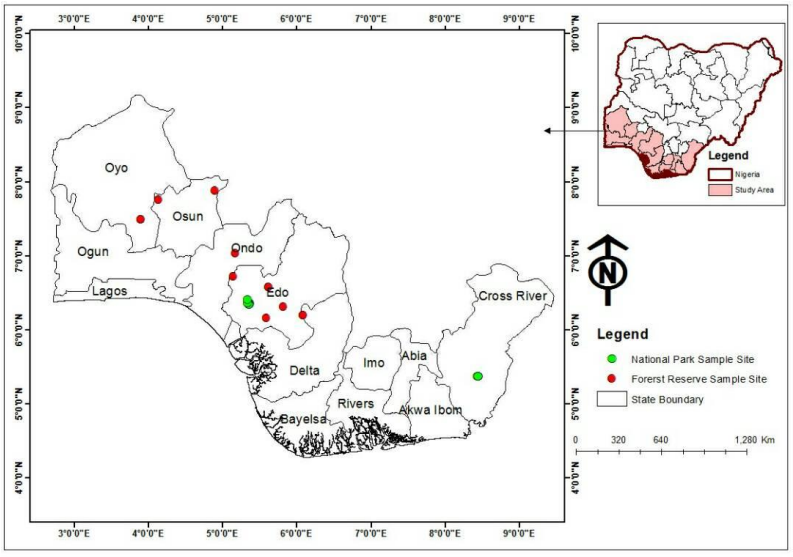

Fig. 1. Map of Nigeria (inset) showing study sites in selected southern states

Sampling

The distribution of *T. sanguinea* within forested location was assessed using a stratified sampling method to mark and quantify the number of populations present in each sampling location. On host–parasite distance determined from the previous preliminary study shows that

host species do not extend beyond an average of 3.4 meters away from the parasite. Hence, a 10×10m quadrat was adopted to accommodate host trees present [19].

Host species

To identify the host plants, *Thonningia* haustoria were excavated manually using cutlass, trowels and soil scoops following the procedure reported by *M.A. Marvier and D.L. Smith* [14]; *M.A. Piehl* [20]; *T.I. Chuang and L.R. Heckard* [21]; *C.C. Gibson and A.R. Watkinson* [22], and the host-plant roots were traced to the main stem and from which a determination was made using: floras [23], manuals [24-27] and checklists [28]. Plants whose identity presented some challenges were pressed and preserved and subsequently determined using a standard taxonomic key as outlined by *W.L. Applequist* [29].

Table 1. Host species and Sites Habouring *Thonnimgia sanguinea* in Southern Nigeria

Study Location	Sites	Host species	Coordinates	Altitude (m)
Okomu National Park	Compartment 33	*Guarea cedreta*	06°24.113" 005° 19.440"E	5.4
	Compartment 52	*Myrianthus arboreus*	06°21.381" 005°19.889" E	77.5
	Compartment 53	*Guarea cedreta*	06°20.937" 005°20.685" E	102.6
	Compartment 53	*Myrianthus arboreus*	06°20.135" 005°20.470" E	94.8
	Compartment 54	*Musanga cecropiodes*	06°21.062" 005°21.398" E	59.6
	Compartment 55	*Ricinodendron heudelotii*	06°21.656" 005°21.587" E	10.2
Cross River National Park	Buffer zone	Host unknown	05°21.863″ 008°26.438″ E	139.2
	Buffer zone	*Lophira alata*	05°22.172" 008° 26.182" E	167.6
	Rock formation Zone	*Musanga cecropiodes*	05°21.863" 008° 26.438" E	139.2
	Forest interior	*Lophira alata*	05°21.925" 008°26.350" E	123.6
	Rock surface	Host unknown	05°21.863" 008°26.438" E	139.5
Idanre Forest Reserves	Cocoa plantation	*Theobroma cacao*	07°01.954" 005°09.868" E	196.6
IITA Forest Reserves	Forest interior	Host unknown	07°29.820" 003^{0}53.530" E	214.5
Ofosu Forest Reserves	Cocoa plantation	*Musanga cecropiodes*	06°43.278" 005^{0}07.852" E	188.6
Oba hills forest Reserves	Cocoa plantation	Host unknown	07°45.275" 004°07.752" E	253.3
	Ehor Nu Wire Forest	*Hevea brasiliensis*	06°18.342" 005° 48.598" E	99.1
Community forest	Okokhuo Forest	*Hevea brasiliensis*	06°34.909" 005° 36.415" E	25.3
	Okour Forest	*Hevea brasiliensis*	06°11.962" 006° 04.928" E	148.6
Plantation Forest	Iyanomo Forest	*Hevea brasiliensis*	06°09.746" 005°34.898" E	35.3

Degree of infestation

The hastorium of *Thonningia sanguinea* possesses several ramifications, growing in a rather irregular horizontal manner below the ground which makes it difficult to quantify the number of parasites attached to a host. The number of inflorescence attached to each host was recorded and used to estimate the degree of infestation following the procedures of *C.J. Thorogood, S.J. Hiscock* [30].

Statistical Analysis

Data collected on the occurrence of host plants in study sites and the degree of infestation on different host species were presented in a graphical format. All statistics were performed using SPSS ver. 23**.**

Results and Discussion

The cryptic nature of *T. sanguinea* and the fact that it has attracted little research attention makes it imperative to investigate its host range and preference as a fundamental step towards developing a conservation strategy for these understudied species. The majority of studies concerning host range in root parasites have concentrated mostly on examination of parasite performance in pots with different host species as an alternative to excavation study [31]. However, pot-based studies are not appropriate for a full understanding of the host range of a parasitic plant. According to *C.J. Thorogood et al.* [32], pot-based studies may result in an

ambiguous predictive pattern of host use in the wild. To arrive at a more encyclopedic host list that supports the populations of *T. sanguinea* in Southern Nigeria, the present study investigated the host range of *T. sanguinea* in its habitat which consists of natural and plantation forests.

The result from the study revealed that *Thonningia sanguinea* individuals parasitized six host species, of different angiosperm families (Table. 1). This finding suggests a broad host range for *T. sanguinea* with members of the Euphorbiaceae and Urticaceae being the most susceptible. Except for the few exotic ones (*Hevea brasiliensis* and *Theobroma cacao*), the host species of *T. sanguinea* in Southern Nigeria were native, they include *Ricinodendron heudelotii* (Euphorbiaceae), *Myrianthus arboreus* (Urticaceae), *Musanga cecropiodes* (Urticaceae), *Lophira alata* (Ochanaceae), and *Guarea cedreta* (Meliaceae). The implication of *Thonningia sanguinea* embraces host species from different taxonomic families, suggest that the choice of host type could be based on the quality of hosts in the local plant community of its distribution range in Southern Nigeria. The broad host range occurrence had previously been observed in other members of Balanophoraceae, such as *Ombrophytum subterraneum*, which parasitizes 10 different hosts distributed in four angiosperm families and also in *Langsdorffia hypogaea*, which parasitizes six hosts in five different angiosperm families; both in Brazil [2]. But unlike *L. hypogaea* with which showed no specificity in terms of the life-form of the host species, parasitizing species of lianas, tree, and even cactus [8], host species of *T. sanguinea* were all long-lived mature perennials, trees and as such are capable of a long term support for the parasite (Table 1). According to *M.A. Marvier and D.L. Smith* [14], the majorities of parasitic plants have opted for a mature perennial host for successful growth and in so doing, affords them the opportunity of utilizing the advantages of an already established deep root system of the host. The generalist phenomenon in *T. sanguinea* as regard host use further corroborates the previously held notion that members of Balanophoraceae are not specific to a single host and are mostly catholic in their choice of host. They may have evolved this broad generalist strategy to increase their survival chances since they are obligate parasites that cannot exist in the absence of a host. *D.L. Nickrent* [33], suggested that the lack of host specialization in members of Balanophoraceae could be the reason for their occurrence in tropical regions where the forests are characterized by a high potential host diversity.

Table 2. Phytogeographical status and life-form of the host plant species of *Thonningia sanguinea* in Southern Nigeria

Host species	Family	Phytogeographical status	Life form	Forest type
Gurea cedrata (A. Chev.) Pellegrin	Meliaceae	Native	Tree	Secondary forest
Hevea brasiliensis Mull.Arg.	Euphorbiaceae	Exotic	Tree	Plantation forest
Lophira alata Banks ex Gaertn.	Ochnaceae	Native	Tree	Secondary forest
Musanga cecropiodes R.Br. & Tedlie	Urticaceae	Native	Tree	Secondary forest
Myrianthus arboreus P. Beauv.	Urticaceae	Native	Tree	Secondary forest
Ricinodendron heudelotii (Baill.) Heckel	Euphorbiaceae	Native	Tree	Secondary forest
Theobroma cacao L.	Malvaceae	Exotic	Tree	Plantation forest

According to *P.R. Atsatt* [34], parasitic plants can be able to attack many host species throughout its range, whereas the local population of parasite remains quite host-specific. In the present study, although *T. sanguinea* utilizes different host species within the scope of its distribution in southern Nigeria, However, we did not observe two or more host species for a local population of the parasite. *R.N. Glover et al.* [35] reveal that different host species make different kinds of nutritional contribution to sustaining the general population of the parasite. This further suggests that *T. sanguinea* seems sufficiently contented with its choice of host and as such precludes the chances of seeking another within a local environment.

Aside from the definitive host species recorded certain species like *Albizia lebbeck*, *Allanblankia floribunda, Barteria fistolosa, Cleistopholis patens, Funtumia elastica, Harugana madagascariensis, Strombosia grandifolia*, and *Voacanga africana* were also observed to show

a high frequency of association with *T. sangunea*. These species observed to show regular association with *T. sanguinea* could be regarded as potential hosts (Fig. 2).

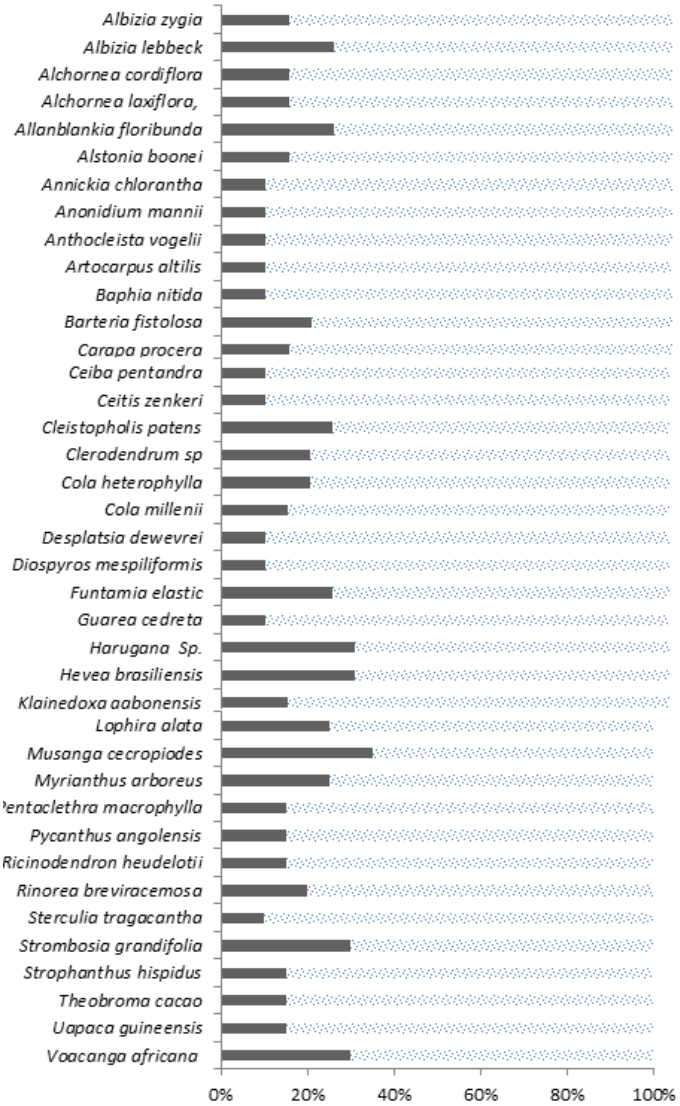

Fig. 2. Tree species showing percentage frequencies of association with *T. sanguinea* sites in Southern Nigeria

The capacity of *T. sanguinea* to utilize exotic species as a host demonstrates the tendency to interact with non-native species of its distribution range. Such an association may have occurred through the cultivation of such exotic species on the site previously inhabited by *T. sanguinea* thereby resulting in re-establishment from seeds remaining in the soil after the native forest was cleared off. The likelihood of seed dispersal from adjacent close native forest to areas now occupied by exotic host species such as *Hevea brasiliensis* and *Theobroma cacao* can also be responsible for such an association.

Previous parasitic host researchers have revealed that parasite performance varies greatly with the availability of different host species and the relative importance of particular host

species may not immediately be obvious [14]. Several factors determine the suitability of hosts, which further increases the frequency of infestation on host *vis-à-vis* host preferences. Some of these factors include the probability of contracting and successfully attacking a host, the quality of the host and host duration. In the present study, *Lophira alata* with a percentage infestation of 28.77% was the most susceptible host plant. The level of susceptibility for *Myrianthus arboreus, Ricinodendron heudelotii, Musanga cecropiodes, Hevea brasiliensis, Guarea cedreta, Theobroma cacao* were 21.57%, 14.89%, 10.68%, 8.88%, 8.73%, 6.46% respectively (Fig. 3). Although a number of reasons might be responsible for the unequal percentage of infestation on various hosts, we believe insights into the biochemical assessments of host plants could help explain their palatability and compatibility.

The analysis of the percentage occurrence of host species on the different sites shows *Musanga cecropiodes* had the highest occurrence with 31.57 % followed by *Hevea brasiliensis* with 26.31 %; others had a varying degree as follows: *Myrianthus arboreus* ≥ *Lophira alata* ≥ *Theobroma cacao* > *Ricinodendron heudelotii* > *Guarea cedreta* (Fig. 4). This finding shows *Musanga cecropiodes* represents a well distributed host species in forested areas of Southern Nigeria, as inferred by its high percentage frequency of occurrence as host.

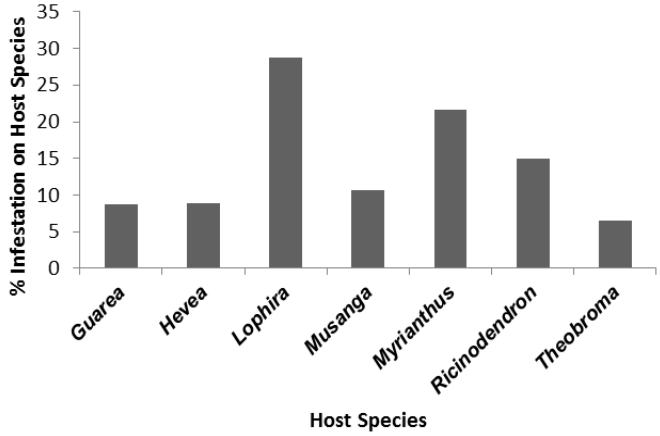

Fig. 3. Percentage infestation rates of *Thonningia sanguinea* on different host species

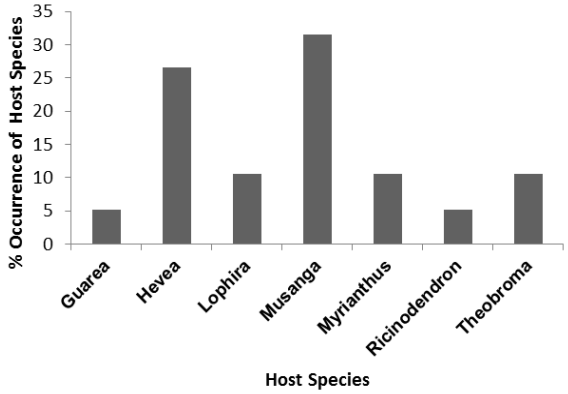

Fig. 4. Percentage occurrence of host plants in surveying sites

Implication for conservation

Conservation concerns about parasitic plants pose a challenge that requires us to view parasitism from an uncommon perspective, therefore, we must cast off our usual attitude regarding parasites and determine how best to increase their abundance and reproductive success.

The host population has serious implications for holoparasitic plant species due to their total dependence on the host. M.A. Marvier and D.L. Smith [14] reported that a good conservation and restoration practice for parasitic plants must necessitate the management of thoughtfully selected host populations. The present study has identified *T. sanguinea* host plants to include both native and exotic tree species (*Guarea cedrata Hevea brasiliensis Lophira alata Musanga cecropiodes Myrianthus arboreus*, *Ricinodendron heudelotii*, and *Theobroma cacao*). While the native host species support the majority of *Thonningia sanguinea* populations in protected sites (National Parks and Forest Reserves). The exotic host supports the population of *T. sanguinea* in community forests (unprotected sites) (Fig. 5). Therefore, the continued survival of *T. sanguinea* in these habitats is largely dependent on the sustainable protection of the host population. In Nigeria, National Parks are to some extent protected with little or no habitat destruction; however, Forest Reserves appear to have been intensely invaded by the local people living around it. Most of the Forest Reserves like Idanre and Ofosu lack proper protective boundaries, thereby allowing access to it.

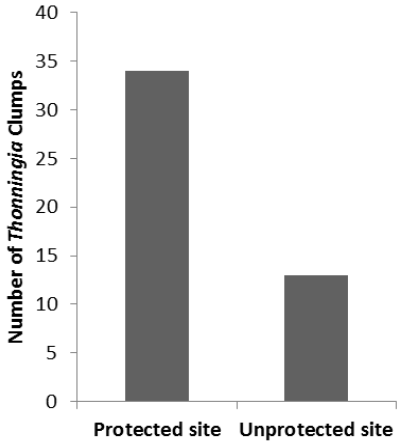

Fig. 5. Incidence of *Thonningia sanguinea* in protected and unprotected sites of Southern Nigeria **(**The unprotected sites consist of: Ehor Nu Wire forest, Iyanomo forest, Okour forest, Okokhuo Forest, while the protected sites were: Okomu National Park, Cross River National Park, Idanre Forest Reserves, Ofosu forest Reserve, Oba Hills Forest Reserves, and IITA Forest Reserves)

The IUCN red list category for *T. sanguinea* is "Not Evaluated" (NE). Consequently, concerted efforts needed to conserve *T. sanguinea* populations in Southern Nigeria must be put in place. At present, the seeds are quite rare and the mechanism of domestication is still elusive among scientists. Therefore *In situ* conservation is best recommended to sustain the current wild populations of the plant.

Conclusion

The relevance of host plant species to holoparasitic plants cannot be overemphasized. They serve as "lynchpins" for the continued existence of the parasite. The present study has demonstrated that *T. sanguinea* uses a wide range of host species from different angiosperm families, some of which are more heavily infested than others.

The key conservation recommendation is to maintain the forest margin paths, such as forest trails in National Parks and Forest Reserves where *T. sanguinea* seem to be prevalent. And also, protect the populations of *Hevea brasilienesis* and *Theobroma cacao* serving as host in community forests around Southern Nigeria.

Acknowledgement

The authors are grateful to the managements of the various National Parks and Forest Reserves for granting permission to carry out this research. This work was completely funded by the TETFUND 2017-2018 (Batch 12th) Research Project (RP) Intervention.

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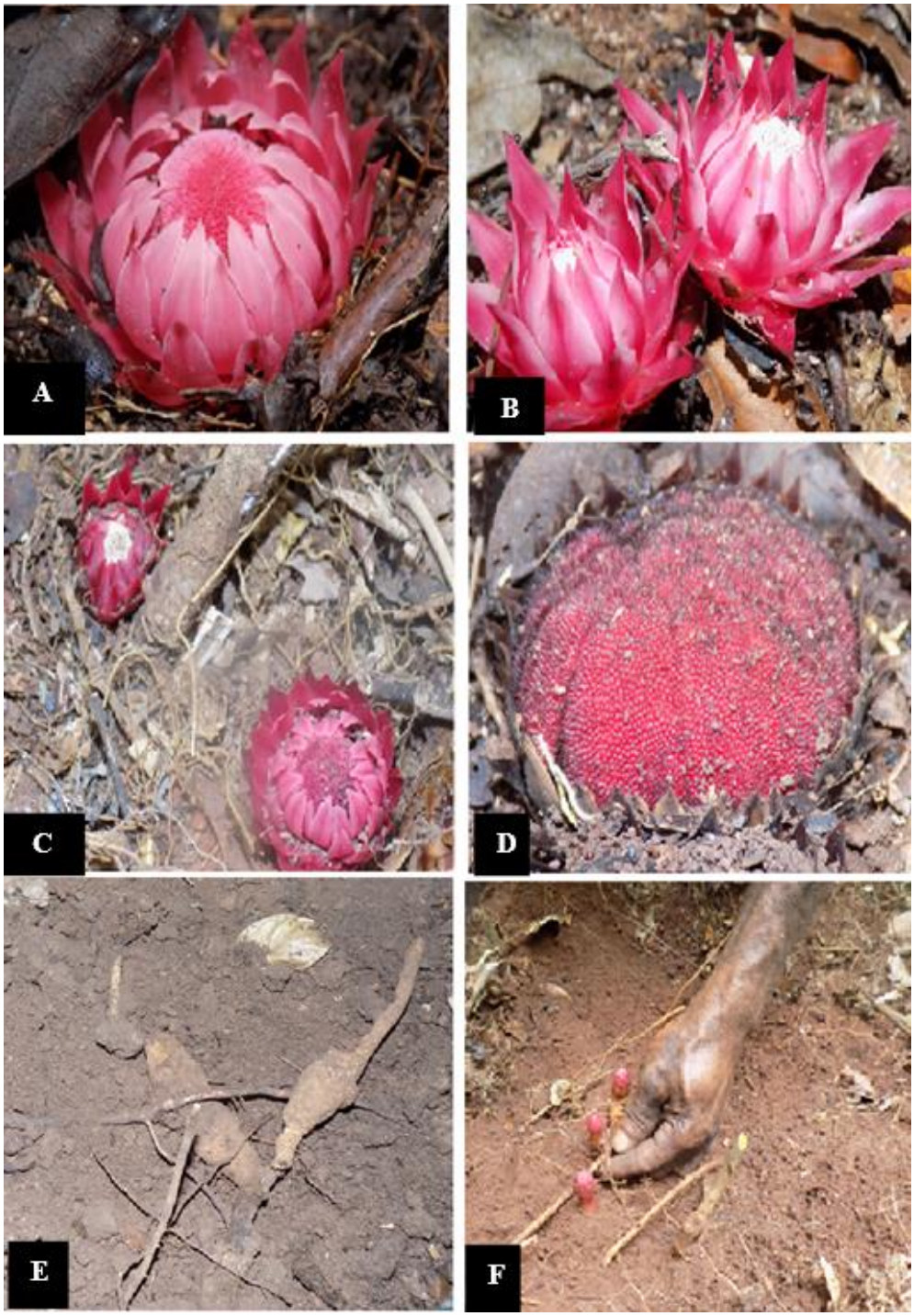
Received: March 01, 2019
Accepted: October 10, 2019

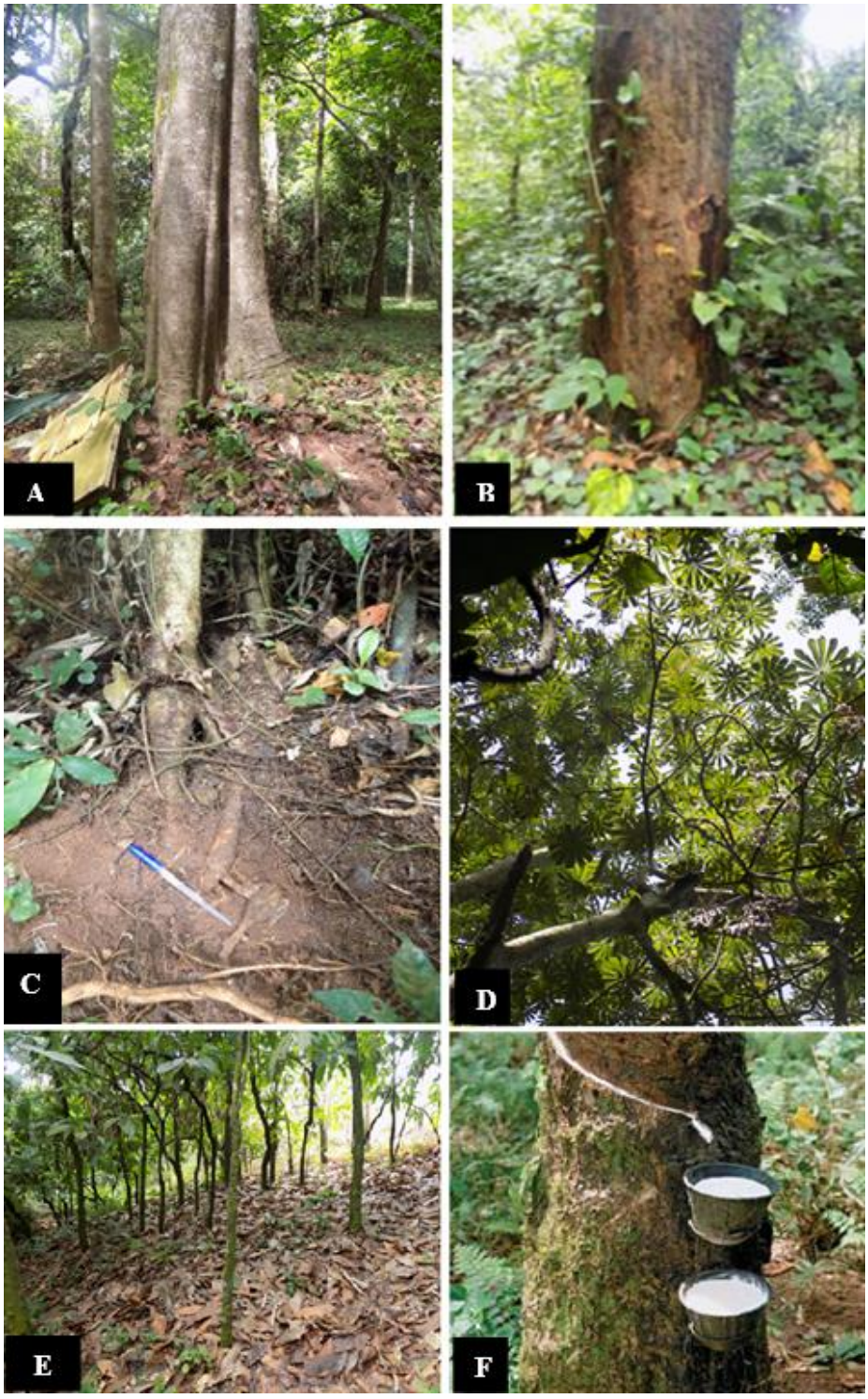
ANNEX 1.

Thonningia sanguinea showing (A) Female inflorescence (B) Male inflorescence (C) Male and female inflorescence head in close proximity (D) Fruiting head and (E) & (E) Growth pattern



ANNEX 2.

Some host species of *Thonningia sanguinea* in Southern Nigeria (A): *Ricinodendron heudelotii* (B) *Lophira alata* (C) *Musanga ceropiodes* (D) *Myrianthus arboreus* (E) *Theobroma cacao* (F) *Hevea brasiliensis.*



ANNEX 3.

Thonningia sanguinea Haustorium with multiple host root attachments (A); Haustorium attachment in *Thonningia* (B, C & D; (E) *Thonningia sangunnea* preference for *Richinodendron* as against *Trichilia monadelpha*