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(RESEARCH ARTICLE)

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Diversity and host range of Loranthaceae along the windward slope of mount Cameroon, South-West Cameroon

Ondoua Joseph Marie [1,*], Njojo Gisele Beri [1], Djibrilla Mana [1], Ngotta Biyon Jacques Bruno [2], Neba Godlov Ambe [1], Anyinkeng Neculina [1] and Kenne Martin [3]

[1] *Department of Plant Science, Faculty of Science, University of Buea, P. O. Box 63 Bue, Cameroon,*
[2] *Department of Plant Organism, Faculty of Science, University of Douala, P.O.Box 24157 Douala, Cameroon.*
[3] *Department of Animal organism, Faculty of Science, University of Douala, P.O. Box 24157 Douala, Cameroon*

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Abstract

The Loranthaceae are known parasites of natural forests, plantations, orchards and ornamental plants throughout the world and their rampant infestation of plants along the windward slope of mount Cameroon is a cause for concern. This research was designed to identify the species of Loranthaceae along the windward slope of mount Cameroon and identify the host range. Field assessment of the parasite and host range studies were done in a rectangular plot (200 x 50 m) laid within 16 localities each along the slope. Two Loranthaceae species, *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague were found to parasitize a total of 38 species belonging to 18 families. *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague were found to parasitize a variety of trees and shrubs species. *Phragmanthera capitata* (Sprengel) S. Balle, had the highest host range with 36 species while *Tapinanthus apodanthus* Sprague parasitized 27 species. Of the parasitized plants, 13 species were unique to *Phragmanthera capitata* while 2 species *Mangifera indica* and *Acacia sp.* were unique to *Tapinanthus apodanthus.* Twenty-three (23) species were common to both parasites. The Lauraceae had the highest number of individual infested species recorded, like *Persea americana* Mill, infested by both parasites. Euphorbiaceae and Fabaceae were the two families specious with 5 and 4 infested species respectively. Similarity indices for host species of *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague, showed that 0 - 249 m asl and 250 - 499 m asl were greatly similar.

Keywords: Loranthacea; Host range; Windward slope; Mount Cameroon

1. Introduction

Plants are ubiquitous in nature and very essential in life, although some do have detrimental effects [1]; without them, living organisms perish. The course of plant evolution echoed some angiosperms to lose their autotropism to become parasites to superior plants (host) [2]. Parasitic interactions between organisms play a fundamental role in ecosystems. Hence, parasitic angiosperms penetrate the tissues of their host plant with their haustoria and feed at the detriment of the plant. This trophic embezzlement generally leads to reduction of biomass of the host that result to yield reduction. Among these parasites are the shrubby aerial hemi-parasites of Loranthaceae commonly called “African Mistletoe”. Loranthaceae are phanerogams, hemiparasites, chlorophyllian and epiphytes which fix on aerian parts of their host [3]. These vascular parasites are responsible for varied economic, ecological, morphological and physiological damages on different cultures and ligneous vegetations [4]. They fix to their host using a specialized organ called haustorium, which establishes contact with the host at the level of the xylem conductive tissues [5]. These vascular parasites are present in all intertropical regions and in certain temperate zones and are sprawling to other regions. These plants in the form

* Corresponding author: Ondoua Joseph Marie.

of tufts, are anchored in the wood of the host through a sucker that establishes functional links with the driver of the host device [4]. Therefore, the parasite draws water, minerals and the additional organic matter it needs. This trophic embezzlement generally leads to a reduction in the biomass of the host which in turn leads to a reduction in yield. Parasitism by Loranthaceae is a highly prevalent environmental problem worldwide [6]. These epiphytic chlorophyllous parasitic plants are responsible for changing economic and morphogenetic damages depending on woody species parasitized [4]. More serious damage occurs in poorly managed orchards and/or under drought stress conditions, situations that often lead to the death of the host [7]. Their distribution and the damages they cause are variable [8]; [9]. Loranthaceae are remarkable and worrying in the agro ecosystems. Their distribution and the damages they cause are unpredictable. Moreover, this infestation has been a call for concern with fruit trees in agroecosytems in Cameroon. Most farmer and gardeners see mistletoes as notorious and devastating parasites which pose serious losses to economically-valuable fruit trees and medicinal plants gardens, orchards and wild forests. Host plants with high infestation suffer from poor growth, low productivity, quality harvest and death [10], with unfavourable edaphic and climatic conditions. Loranthaceae are widely distributed in tropical areas: America, Africa, and Australia; they extend to temperate regions with few representatives [11]; [12]. They are grouped into 950 species, distributed in 77 genera in temperate regions. [13] counted over 500 species in Africa and Arabia while [11] identified 7 genera and nearly 26 species in Cameroon. In Nkoemvone seed fields in the south Cameroon, 6 species of Loranthaceae have been identified [14]. In South West Cameroon, [15] identified only one specie. Loranthaceaea infestation of trees and fruit crops along the windward slope of the Mount Cameroon region has generated great concern to local communities, and trees and fruit plantation farmers. The problem of correct identification of type of species and their host range is perhaps a difficult issue as these hemi-parasitic plants are easily affected by weather and ecological factors. Although mistletoes are commonly spotted on fruit trees in the South Western Cameroon, no systematic survey have been made to document the different species. Given that the windward slope of Mount Cameroon has a favourable climate for tree crop production; these parasites (mistletoes) stand to pose threat to their cultivation.

2. Material and Methods

2.1. Study site

This study was conducted along the windward slope of Mount Cameroon from sea level to 1000 m and located within latitude 04°00' - 04°10'N and longitude 09°6'- 09°18' E, Fako division, South West Region of Cameroon (Figure 1). The location of Mount Cameroon, its volcanic nature and altitude have significantly influenced the soils, climate, vegetation and biological diversity of the region. The climate around the Mount Cameroon region is characterised by its seasonal and equatorial nature. There is a period of heavy rains occurring between the months of June and October, and a dry period extending from November to May. Mean annual rainfall decreases with altitude to approximately 4,000 mm at 1000 mm and to less than 3,000 mm above 2,000 m [16]. The temperature falls with increasing elevation. The air humidity remains at 75 to 80% throughout the year on the South Western side of the Mountain due to the marine influence and the incidence of mist and orographic cloud formation. Soils of Mount Cameroon are principally of recent origin, mostly on young volcanic rocks and are fertile, though often with poor water retaining capacity. Mount Cameroon is known for its exceptional plant diversity and high number of endemic species. The Mount Cameroon forest is highly valued as a source of natural medicines and many species are harvested with little impact on the forest resources. The windward slope of the Mt Cameroon is probably the most diverse and richest area of the mountain and appears to be the only area in West and Central Africa where there is an unbroken vegetation gradient from evergreen lowland rainforest at sea-level, through montane forest, to montane grassland and alpine grassland near its summit [17]. Agriculture is the most important source of livelihood in the Mt. Cameroon area accounting for about 80% of household income in most villages [18].

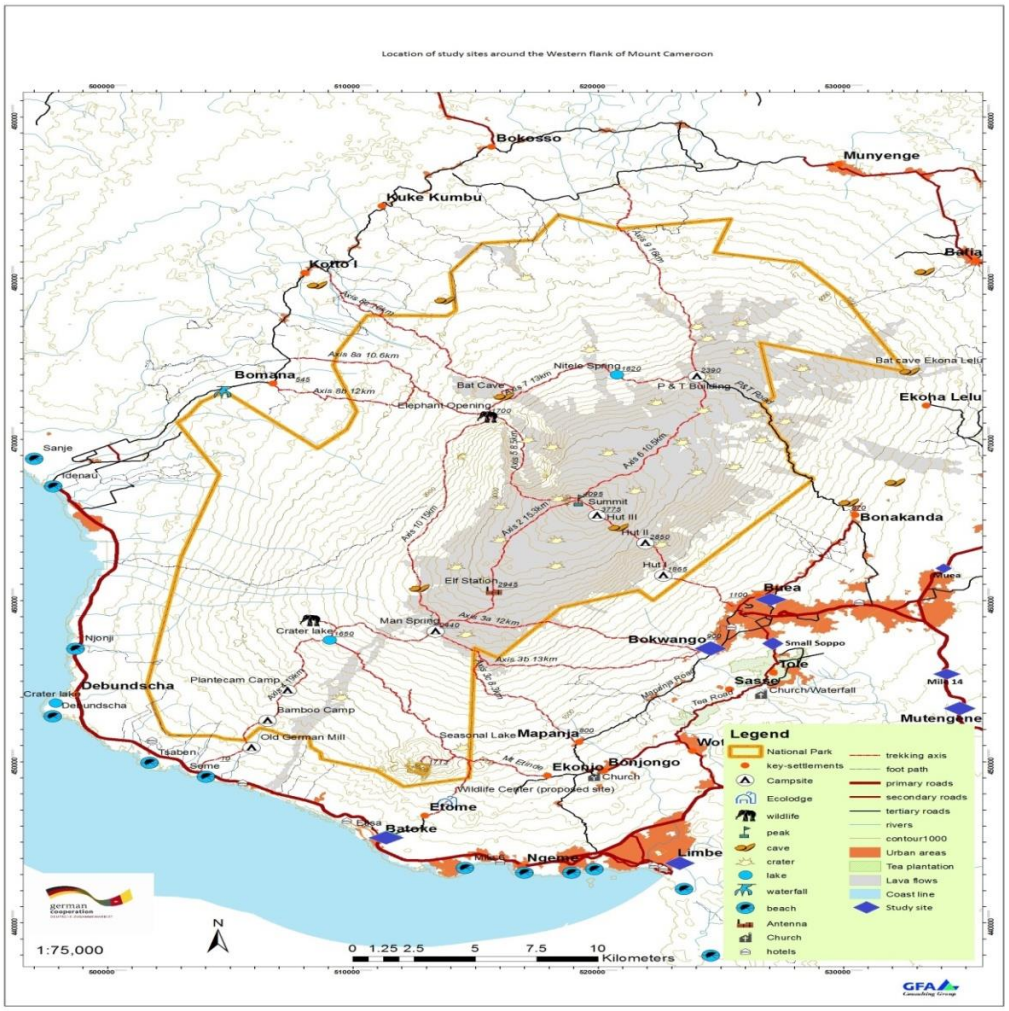

Figure 1 Location of the study area [17]

2.2. Sampling method

2.2.1. Site mapping

This study was carried out along the windward slope of Mount Cameroon in the Fako division, South West region of Cameroon. A reconnaissance survey was first carried out to identify the different study areas. It was conducted based on the different altitudinal gradients along the base of the mountain ranging from the sea to 1000 m above sea level (asl). The study site was arbitrarily divided into four (4) altitudinal zones (Table 1). Within each zone, at least 4 villages were randomly selected for sampling. A total of 16 different villages were selected for the study.

Table 1 Altitudinal ranges of study sites

Zones	Altitudinal range (m asl)	Sites
Zone1	0-249 m asl	Ombe, Mile 4 (Bonadikombo), ½ Mile Limbe, Batoke
Zone 2	250-499 m asl	Mile 16 (Bolifamba), Mile14 (Dibanda), Muea, Mutengene
Zone 3	500-749 m asl	Santa Barbara, Bonduma, Bwintigi, Molyko
Zone 4	750-999 m asl	Bokwaongo, Clerks Quarters, Great Soppo, Small Soppo

These areas are characterised by urban settlement, farmlands and the wild. At these levels (sea level to 950 m asl), the forest has greatly been replaced by shifting cultivation or organized commercial plantations, mainly oil palms, banana and rubber. This farming system is scattered over the Southern slopes of the mountain [16].

2.2.2. Field survey

This study was conducted from May 2021 to August 2021. This period was during the wet season of the year, when most of the plants flowers had undergone anthesis. This period hastened easy identification of plants (mistletoes and host) through their floral parts. In each site, a rectangular plot of 200 m × 50 m was laid. This was to estimate the various host of the parasites in relation to each area and to record the species of the parasites found. Field surveys and collections were carried out by examining the vegetation within each plot for the presence of mistletoes. Plants (host) infested with mistletoes which were found within transects were counted and recorded for data collection. A binocular (8×12, Field 7º, 122 m/ 1000 m) was used to observe tall trees for the presence of mistletoes.

Both descriptive survey and field assessment were carried out. Plants (host) identified with parasite(s) infestation had the following information recorded on them; life form (tree, shrub, herbs) and the host species.

Furthermore, mistletoes on host plants were counted as number of tufts. The number of tufts per host was counted, where their attachment positions on the host (plant) were also observed. In addition, species of tufts were identified and differentiated *in-situ* based on the inflorescence colour and abaxial (back) appearance on their leaves. Also, diagnostic features like leaf type, leaves arrangement and colour, and fruit type were used. Inflorescences were collected into labelled containers with 25% alcohol. They were taken to the Life Science Laboratory of University of Buea for detailed observation. Five (5) individual flowers were selected from each species. Their shape, arrangement, colour, stamen arrangement, and petals colour were observed using hand-lens. The attachment point of the mistletoes on the host plant was also recorded. Photographs of the various species were taken using a digital camera (Canon ixus 145, 8x optical zoom).

Voucher specimens of Loranthaceae were also collected for confirmation of identity and storage. Host plants were also identified *in-situ* based on their morphology. Voucher specimens of unknown host plants were pressed and taken to the Limbe Botanical Garden herbarium for further identification.

Purposive sampling was used to capture species peculiar to very restricted host and host which are scarce. This method was used to enhance the information gathered on measured plots and to ensure that target species were recorded. It entailed the collection of data on Loranthaceae and its host with peculiarities. Identification of the local plant names was carried out by consulting the inhabitants of that locality and farmers who tend to have great ideas about plants. Scientific names were obtained from the APG III system of classification, journals and manuals.

2.3. Data Analysis

Data sets were collected; checklist of Loranthaceae and its host ranges. Data generated were subjected to statistical analysis. Microsoft Excel© 2013 was used for descriptive statistics to produce charts and tables for the different parameters carried out in the field. Data were presented as frequency distributions and percentages. The percentage of each species (either the parasite or the host) was calculated using the formulae:

$X/Y \times 100$.....Equation (1)

Where

X = number of a host species or Loranthaceae species
Y= total number host plants or parasite

The plant species parasitized by mistletoe during the field survey were tabulated. The scientific names and families assigned to each plant species produced a checklist of the host ranges. However, frequency of Loranthaceae species and host ranges, were expressed in charts. The statistical package used is Microsoft Excel© 2013 and Minitab version17

The similarity indices for host species of Loranthaceae were calculated separately for each zone and the data presented in a matrix. These similarity indices were calculated using the Sorenson similarity index (Equation 2):

$$Sim = \frac{2\sum nc}{\sum n1 + \sum n2}$$ .....Equation (2)

Where

nc= the common species between sites;
n1= the species of group A and
n2= species of Group B

The values range from 0 to 1 with the higher value suggesting greater similarity.

3. Results

3.1. Species of Mistletoes Infesting Plants along the Windward Slope of Mount Cameroon

From the survey, two (2) genera of Loranthaceae were identified. These included *Phragmanthera* Van Tieghem and *Tapinanthus* Blume. Two species of Loranthaceae attack plants in these study sites: *Phragmanthera capitata* (Sprengel) S. Balle (Figure 2) and *Tapinanthus apodanthus* Sprague (Figure 3). This species can be found alone or in association with one another on a host plant.

3.2. Phragmanthera capitata (Sprengel) S. Balle

Phragmanthera capitata (Figure 2) is characterized by dark yellow inflorescence with red tips.

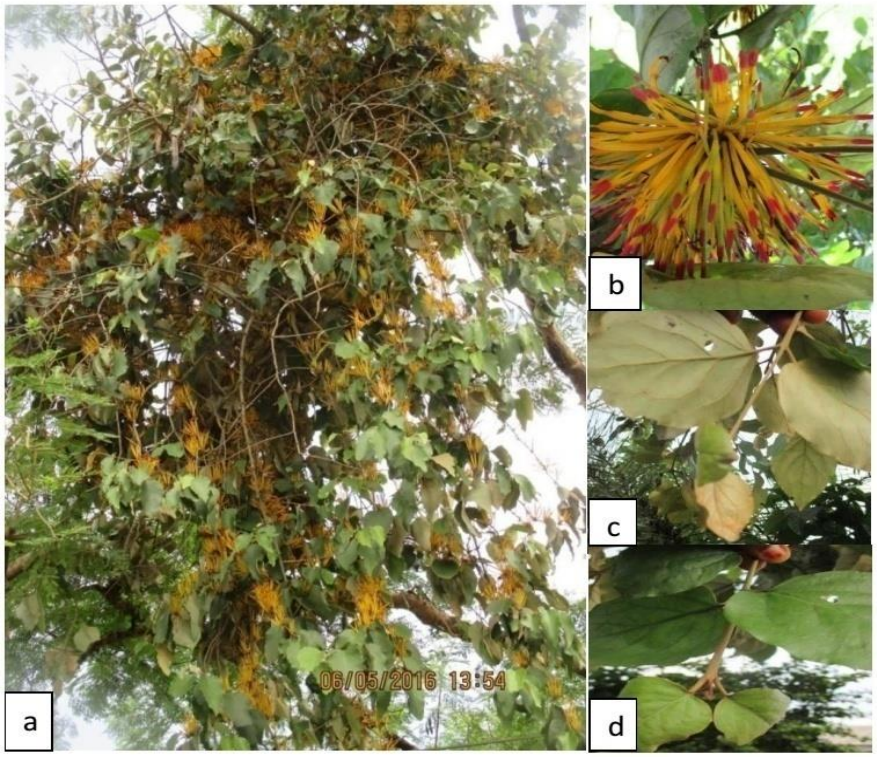

Figure 2 Phragmanthera capitata (Sprengel) S. Balle

a, Phragmanthera capitata on host plant; b, inflorescence arranged in an umbel; c, abaxial part of the leaves covered with dendritic hair (brown colour); d, adaxial surface of the mistletoe leaf

Corolla is 5-lobed with a short V-slit at anthesis while the stamens are epipetalous. The corolla is tubular with no swollen base. The inflorescence is arranged in an umbel with approximately 5-6 flowers borne per floral axis. Leaves have dendritic hairs on the abaxial part (dorsal) of the leaves. However, the leaves are alternate, unifoliate and have wavy

margins The fruit is a berry which has colours, bluish green or red. *Phragmanthera capitata* can be found attached on the branches or the top of its host plants.

3.3. *Tapinanthus apodanthus* Sprague (TA)

Tapinanthus apodanthus Sprague (Figure 3) is characterized by inflorescence having violet corolla and dark coloured tips at maturity. Corolla is 5-lobed with a short V-slit at anthesis while the stamens are epipetalous. The corolla is tubular with swollen base. The inflorescence is arranged in an umbel with approximately 4-7 flowers borne per floral axis. Leaves are green both on the abaxial part (dorsal) and adaxial part. The leaves lack dendritic hair. However, the leaves are alternate, unifoliate and have wavy margins. The fruit is a berry which has colour red or brown. *Tapinanthus apodanthus* can also be found attached on the branches or the top of its host plants

Figure 3 *Tapinanthus apodanthus* Sprague

3.4. Host Range of Phragmanthera capitata (Sprengel) S. Balle and Tapinanthus apodanthus Sprague

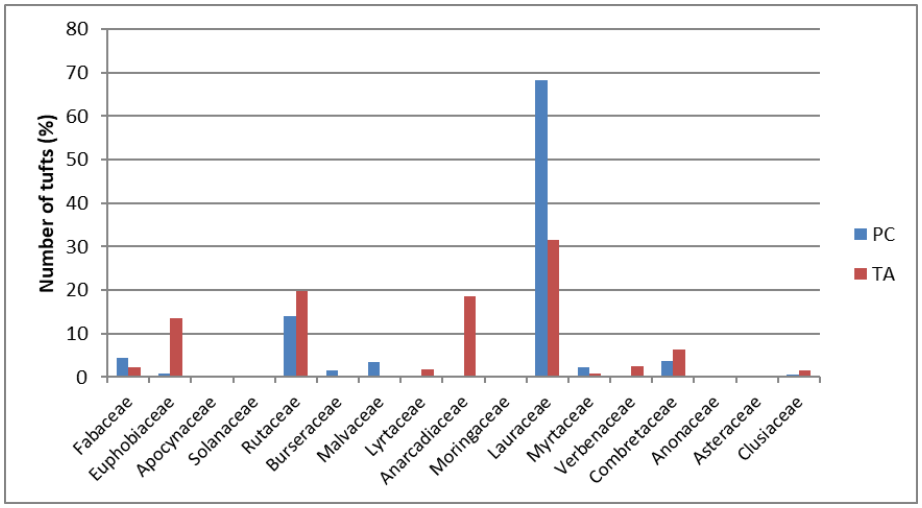

Figure 4 Distribution of Loranthaceae among host families along the windward slope of Mount Cameroon.

Note : *PC= Phragmanthera capitata ; TA= Tapinanthus apodanthus*

A total of 36 species belonging to 18 families were found to be infested by *Phragmanthera capitata* (Sprengel) S. Balle while 27 species in 14 families were infested by *Tapinanthus apodanthus* Sprague. The Lauraceae had the highest

number of individual species infested species recorded. It is infested by 68.2% of *Phragmanthera capitata* and 31.4% of *Tapinanthus apodanthus* Sprague (Figure 4).

3.5. Distribution of Loranthaceae and infested host species among different plant growth forms.

Majority of the species infested by the Loranthaceae were trees (56%) with a few being shrubs (44%) (Figure 5). *P. capitata* (47.4%) was more frequent on trees than *T. apodanthus* (44.0%) while *T. apodanthus* (56.0%) is more frequent on shrubs than *P. capitata* (52.6%) (Figure 6). Neither herbs nor lianas were found to be infested.

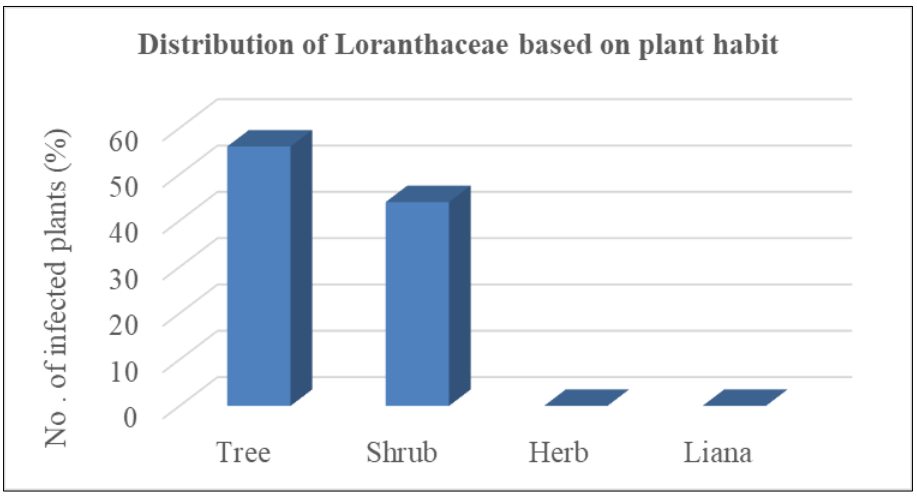

Figure 5 Distribution of Loranthaceae among the different host based on plant habit.

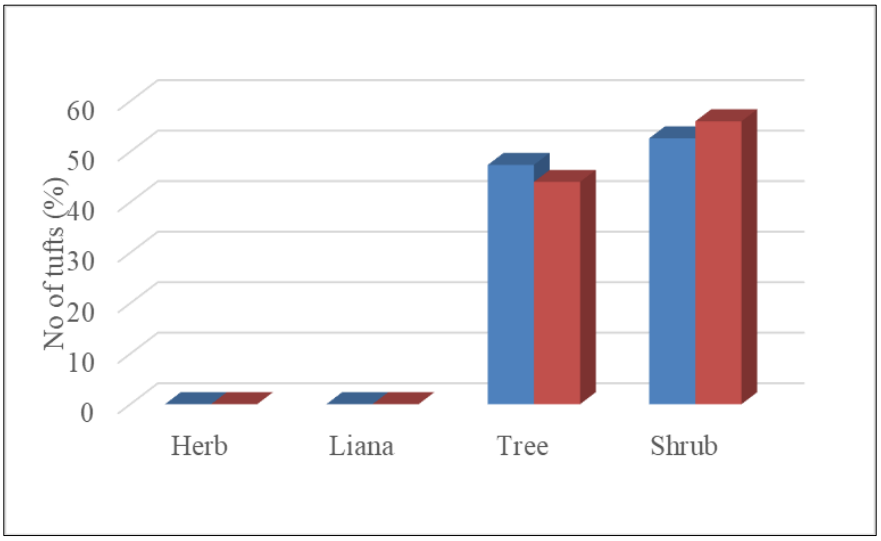

Figure 6 Infestation rate of Loranthaceae on the various plant habits

3.6. Categories of host species

The host species consist of economic plants which include fruit tree crops, cash crops; others are ornamental plants which include useful hedges, landscape trees and shrubs (Table 2).

Table 2 Categories of host range

Economic plants	Ornamental plants	Invasive plants
Annona muricata L.	*Albizia julibrissin* Durazz.	*Brugmansia suaveolens* (Humb & Bonpl ex Willd) Bercht & J. Prestl.
Citrus limon (L.) Osbeck	*Bauhinia variegate* (L.) Benth	
Citrus aurantifolia L	*Callistemon viminalis* (Sol ex Gaertn) G.Bon ex Loudon	
Citus sinensis (L.) Osbeck.	*Ceasalpina pulcherima* (L.) Sw.	
Cola nitidia (Vent.)Schott &Endl.	*Cassia grandis* L.	
Dacryodes edulis H. J. Hams	*Cordiaeum variegatum* (L.) A. Juss	
Theobroma cacao L.	*Duranta erecta* L.	
Garcina kola Heckel	*Duranta repens* L.	
Vernonia amygdalina Delile	*Eurphobia pulcherima* Willd. ex Klotzsch	
Moringa oleifera Lamk.	*Terminalia mantaly* L.	
Persea americana Mill	*Acalypha wilkesiana* Mull Arg.	
Psidium guajava L.	*Ixoria coccinea* L.	
Syzigium malacacense L. Merr & L. M. Perry	*Jatropha pandurifolia* L.	
Mangifera indica L.	*Leucaena leucocephala* (Lam) de Wit.	
Tectonia grandis Linn.	*Taliparitі sp.* L.	
	Taliparitі taliaceum (L.) Fryxell	
	Thevetia peruviana (Pers) K. Schum	
	Acacia sp. L.	

3.7. Unique hosts

Table 4 shows that *Acacia sp.* and *Mangifera indica* were the only species infested with only *Tapinanthus apodanthus* throughout the survey. However, *Mangifera indica* infestation was more prevalent with a total of 82 tufts giving a percentage of 98.8% while *Acacia sp.* had 1 tuft with a percentage of 1.2% (Table 4).

Table 4 Species unique to *Tapinanthus apodanthus*

Host type	Family	No. of tufts	Percentage (%)
Acacia sp. L.	Fabaceae	1	1.2
Mangifera indica L.	Anarcadiaceae	82	98.8

Note: No. = Number

Furthermore, host species infested only with *Phragmanthera capitata* includes 13 species belonging to 10 families. *Dacryodes edulis* was infested with a total of 148 tufts making a percentage of 28.8%. *Taliparitі sp.* (17.1%), *Leucaena leucocephala* (12.3%), *Hevea brasiliensis* (11.5%), *Cassia grandis* (10.9%), *Plumeria rubra* (10.5%). The percentages represent the number of tufts per total number of species. *Duranta repens* and *Vernonia amygdalina* had the least number of tufts with a percentage of 0.2% each (Table 5).

Table 5 Host plants unique to *Phragmanthera capitata* infestation

Host	No. of tufts	Percentage (%)
Albizia julibrissin Durazz.	3	0.6
Plumeria rubra L.	54	10.5
Cassia grandis L.	56	10.9
Citrus aurantifolia L.	18	3.5
Cola nitidia (Vent) Schott & Endl	17	3.3
Dacryodes edulis H. J. Hams	148	28.8
Duranta repens L.	1	0.2
Hevea brasiliensis Muell Arg	59	11.5
Leucaena leucocephala (Lam) de Wit	63	12.3
Moringa oleifera Lamk	2	0.4
*Taliparitisp.*L.	88	17.1
Taliparitis taliaceum (L.) Fryxell	4	0.8
Vernonia amygdalina Delile	1	0.2

Note: No. = Number

3.8. Host common to both parasites

Amongst all other host, *Persea americana* Mill (60.58% PC and 37.81% TA) was the most prevalent host parasitized by both parasite species. However, the least prevalent host parasitized by both parasites recorded was *Eurphobia pulcherima* and *Ixoria coccinea* (Table 6). Though *Persea americana* (60.58%) had the highest prevalent host parasitized to *Phragmanthera capitata* (PC), *Syzigium malacacense* followed with a prevalent host parasitized rate of 15.66%. The least was recorded by *Eurphobia pulcherima* and *Ixoria coccinea* L. (Table 6). Similar trend was followed by *Tapinanthus apodanthus* with *Citus sinensis* L. (19.18%) behind *Persea americana* Mill (37.81%) as the most prevalent host parasitized. However, *Thevetia peruviana* (0.30% for P.C, 0.82% for T.A), *Theobroma cacao* (0.11% for P.C, 0.27% for T.A), *Ixoria coccinea* (0.03% for P.C, 0.27% for T.A), *Eurphobia pulcherima* (0.03% for P.C, 0.27% for T.A) and *Annona muricata* (0.27% for P.C, 0.27% for T.A) had the least prevalent host parasitized rate (Table 6). Furthermore, it is observed that *Phragmanthera capitata* was prevalent more than *Tapinanthus apodanthus* (Table 6).

Table 6 Host plants common to *Phragmanthera capitata* and *Tapinanthus apodanthus*

Host type	PC	TA	PC (%)	TA (%)
Acalypha wilkesiana Mull Arg	2	4	0.05	1.10
Annona muricata L.	10	1	0.27	0.27
Bauhinia variegate (L.) Benth	22	5	0.59	1.37
Brugmansia suaveolens (Humb & Bonpl ex Willd) Bercht & J. Prestl.	7	2	0.19	0.55
Callistemon viminalis (Sol ex Gaertn) G. Bon ex Loudon	75	2	2.02	0.55
Ceasalpina pulcherima (L.) Sw	2	4	0.05	1.10
Citrus limon L. (Osbeck)	48	17	1.30	4.66
Citus sinensis L. (Osbeck)	396	70	10.69	19.18
Cordiaeum variegatum (L.) A. Juss	14	7	0.38	1.92
Duranta erecta L.	3	8	0.08	2.19

Eurphobia pulcherima Willd ex Klotzsch	1	1	0.03	0.27
Garcina Kola Heckel	17	7	0.46	1.92
Ixoria coccinea L.	1	1	0.03	0.27
Jatropha pandurifolia L.	7	47	0.19	12.88
Moraceae	62	4	1.67	1.10
Lagastroemia indica L.	2	7	0.05	1.92
Persea americana Mill.	2244	138	60.58	37.81
Psidium guajava L.	71	4	1.92	1.10
Syzigium malacacense L. Merr L. M. Perry	580	3	15.66	0.82
Host type	PC	TA	PC (%)	TA (%)
Tectonia grandis Linn.	11	3	0.30	0.82
Terminalia mantaly L.	123	28	3.32	7.67
Theobroma cacao L.	4	1	0.11	0.27
Thevetia peruviana (Pers) K. Schum	2	1	0.05	0.27

Note : PC= Phragmanthera capitata; TA= Tapinanthus apodanthus ; % = Percentage

3.9. Host families of *Phragmanthera capitate* (Sprengel) S. Balle

Table 7 Host families of *Phragmanthera capitate* (Sprengel) S. Balle

Host families	**Host species**	**Percentages (%)**
Eurphobiaceae	*Acalypha wilkesiana Mill Arg, Cordiaeum variegatum, Eurphobia pulcherima Willd ex Klotzsch, Hevea brasiliensis Muell Arg, Jatropha pandurifolia L.*	14.0
Fabaceae	*Albizia julibrissin Durazz, Bauhinea variegata, Cassia grandis, Ceasalpina pulcherima (L.) Sw.*	14.0
Annonaceae	*Annona muricata L.*	3.0
Apocynaceae	*Plumeria rubra, Thevetia peruviana*	6.0
Solanaceae	*Brugmansia suaveolens*	3.0
Myrtaceae	*Callistemon viminalis, Syzigium malacaccense, Psidium guajava L.*	8.0
Rutaceae	*Citrus limon L., Citrus aurantifolia L., Citus sinensis L.*	8.0
Malvaceae	*Theobroma cacao L., Cola nitidia*	6.0
Burseraceae	*Dacryodes edulis H. J. Hams*	3.0
Verbenaceae	*Duranta erecta L., Duranta repens L.,Tectonia grandis L.*	8.0
Lyrtaceae	*Lagastroemia indica L., Ixoria coccinea L.*	6.0
Moringaceae	*Moringa oleifera Lamk.*	3.0
Lauraceae	*Persea americana Mill*	3.0
Malvaceae	*Taliparitі sp. L. Taliparitі taliaceum L.*	6.0
Combretaceae	*Terminalia mantaly L.*	3.0
Asteraceae	*Vernonia amagdalina Del.*	3.0
Clusiaceae	*Garcina Kola Heckel*	3.0

Euphorbiaceae and Fabaceae (14.0%) had the highest number of species infestation. Infested species of the Euphorbiaceae and Fabaceae were more prevalent than the other families. Also, Myrtaceae, Rutaceae and Verbenaceae followed with a percentage of 8.0% each. However, Solanaceae, Annonaceae, Burseraceae, Combretaceae, Asteraceae, Clusiaceae had the least number of species infestation with a percentage of 3.0% (Table 7).

3.10. Host families of *Tapinanthus apodanthus* Sprague (TA)

Euphorbiaceae (16%) had the highest number of species infestation, followed by .Myrtaceae (12%) and Fabaceae (12%). However, Annonaceae, Apocynaceae Burseraceae, Lauraceae, Combretaceae, Asteraceae, Anarcadiaceae Clusiaceae recorded the lowest percentage of 4% each (Table 8).

Table 8 Host families of *Tapinanthus apodanthus* Sprague (TA)

Host families	Host species	Percentages (%)
Eurphobiaceae	*Acalypha wilkesiana,Cordiaeum variegatum, Eurphobia pulcherima, Hevea brasiliensis, Jatropha pandurifolia*	16.0
Fabaceae	*Albizia julibrissin, Bauhinea variegata,Ceasalpina pulcherima, Acacia sp.*	12.0
Annonaceae	*Annona muricata*	4.0
Apocynaceae	*Plumeria rubra, Thevetia peruviana*	4.0
Solanaceae	*Brugmansia suaveolens*	8.0
Myrtaceae	*Callistemon viminalis, Syzigium malacaccense, Psidium guajava* L.	12.0
Rutaceae	*Citrus limon* L., *Citus sinensis* L.	8.0
Sterculiaceae	*Theobroma cacao* L.	4.0
Verbenaceae	*Duranta erecta* L., *Tectonia grandis*	8.0
Lyrtaceae	*Lagastroemia indica* L., *Ixoria coccinea* L.	8.0
Lauraceae	*Persea americana* Mill	4.0
Combretaceae	*Terminalia mantaly* L.	4.0
Anarcadiaceae	*Mangifera indica* L.	4.0
Clusiaceae	*Garcina kola* Heckel	4.0

3.11. Altitudinal ranges of mistletoes species and its host ranges occurrence

The distribution of mistletoe species did not demonstrate any uniformity. The two species of Loranthaceae were found in all the altitudes. However, *Tapinanthus apodanthus* showed dominance in altitude 0 – 249 m asl and 500 – 749 m asl (Figure 7). Contrarily, *Phragmanthera capitata* dominated within altitude 250 – 499 m asl and 750 m - 999 m asl with 17.05% and 25.00% respectively (Figure 7).

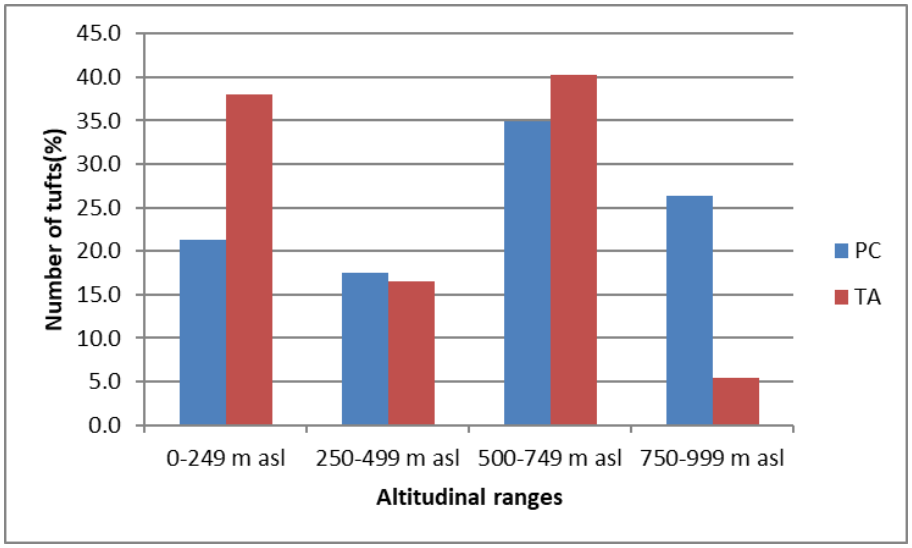

Figure 7 Distribution of mistletoes species along different altitudinal ranges

3.12. The distribution of host range did not demonstrate any uniformity along the altitudinal categories

Table 9 shows that, *Persea americana* L. showed susceptibility to both parasites at all the altitudinal levels, while infestation decreased with increasing altitudinal levels for both parasites on *Cordiaeum variegatum*, *Garcina cola* and *Citus sinensis* L. Moreover, *Mangifera indica* showed susceptibility at all altitude levels to *Tapinanthus apodanthus* Sprague

Table 9 Distribution of host ranges along the different altitudinal ranges.

Family	**Species**	**Altitudinal Ranges (m asl)**							
		0-249		250-499		500-749		750-999	
		PC	TA	PC	TA	PC	TA	PC	TA
Fabaceae	*Acacia sp.*	-	+	-	-	-	-	-	-
	Albizia julibrissin	-	-	-	-	-	-	+	-
	Bauhinea variegata	-	-	-	-	+	+	-	-
	Ceasalpina pulcherima	-	-	-	-	+	+	-	-
	Cassia grandis	+	-	-	-	-	-	+	-
	Leucaena leucocephala	+	-	+	-	+	-	+	-
Euphobiaceae	*Acalypha wilkesiana*	-	-	-	-	+	+	-	-
	Cordiaeum variegatum	+	+	-	-	-	-	-	-
	Eurphobia pulcherima	-	-	-	-	+	+	-	-
	Jatropha pandurifolia	-	-	-	-	+	+	-	-
	Hevea brasiliensis	-	-	-	-	-	-	+	-
Solanaceae	*Brugmansia suaveolens*	-	-	-	-	-	-	+	+
Rutaceae	*Citrus limon* L.	+	-	-	+	-	-	-	-
	Citrus aurantifolia L.	-	-	+	-	+	-	+	-
	Citus sinensis L.	+	+	+	+	+	+	-	-
	Citrus recticulata	+	-	-	-	-	-	-	-

Burseraceae	*Dacryodes edulis*	+	-	+	-	-	-	+	-
	Talipariti taliaceum	-	-	-	-	+	-	+	-
Malvaceae	*Theobroma cacao, Cola nitidia*	-	-	+	-	-	+	+	-
	Talipariti sp.	-	-	-	-	-	-	+	-
Lyrtaceae	*Ixoria coccinea*	-	-	-	-	+	+	-	-
	Lagastroemia indica	-	-	-	-	+	+	-	-
Anarcadiaceae	*Mangifera indica*	-	+	-	+	-	+	-	+
Moringaceae	*Moringa oleifera*	+	-	-	-	-	-	-	-
Lauraceae	*Persea americana* L	+	+	+	+	+	+	+	+
Myrtaceae	*Psidium guajava*	+	+	+	-	+	+	+	-
	Callistemon viminalis	+	-	-	-	+	+	+	-
	Syzigium malacacense	+	+	+	-	+	-	+	-
Verbenaceae	*Tectonia grandis*	-	-	-	-	+	+	+	-
Combretaceae	*Terminalia mantaly*	+	-	+	+	+	+	+	-
Anonaceae	*Annona muricata*	-	-	-	-	-	+	+	-
Apocynaceae	*Thevetia peruviana*	-	-	-	-	+	+	-	-
Asteraceae	*Venonia amagdalina*	-	-	-	-	+	-	-	-
Clusiaceae	*Garcina cola*	+	+	-	-	-	-	-	-

The four different altitudinal ranges were compared for similarity (Table 10). Similarity indices were done for host species of both *T. apodanthus* and *P. capitata* and the data presented in a matrix. Zones 1 and 2 show a greater similarity of 0.67 in terms of the occurrence of infested host species **by *P. capitata*. Zones 4 and 2 show less similarity of 0.34.**

Table 10 Similarity indices for host species of *P. capitata* between altitudinal ranges

Zones	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Zone 1	1			
Zone 2	0.67	1		
Zone 3	0.43	0.44	1	
Zone 4	0.47	0.34	0.36	1

NB: **Zone1** = 0 to 249 m asl, **Zone 2** = 250 to 499 m asl, **Zone 3** = 500 to 749 m asl, **Zone 4** = 750 to 999 m asl

Similarity indices done for host species of *T. apodanthus* shows a greater similarity of 0.56 in zones 1 and 2 whilst zones 3 and 4 show less similarity (Table 11).

Table 11 Similarity indices for host species of *T. apodanthus* between altitudinal ranges

Zones	**Zone 1**	**Zone 2**	**Zone 3**	**Zone 4**
Zone 1	1			
Zone 2	0.56	1		
Zone 3	0.32	0.22	1	
Zone 4	0.00	0.00	0.10	1

NB: **Zone1** = 0 to 249 m asl, **Zone 2** = 250 to 499 m asl, **Zone 3** = 500 to 749 m asl, **Zone 4** = 750 to 999 m asl

4. Discussion

4.1. Loranthaceae species and host ranges

In the course of the study, two (2) genera of Loranthaceae were identified: *Phragmanthera* Van Tieghem and *Tapinanthus* Blume. These mistletoes are ubiquitous in the studied sites. The two species of Loranthaceae recorded in these study sites includes *Phragmanthera capitata* (Sprengel) S. Balle and *Tapinanthus apodanthus* Sprague. The unopened tubular corolla is reminiscent of a matchstick. Both mistletoes produced obovoid berries in clusters, these results corroborate with the reports of [19] on some observations on the fruit set and incidence of mistletoes on rubber trees in Nigeria. These species can be found alone or in association with one another on a host plant attached to branches of tree trunks or on the tip of the plants on woody trees and shrubs. This associate with the work of [20] where they reported that mistletoe requires much light when establishing itself on a host; therefore, seeds that are deposited high in the canopy are often the most successful. The parasitic species usually appears as clumps on the host plants. Moreover, no herb or liana was recorded to be infested by the parasite during the survey. Most of the infested host plants include fruit crops, ornamental plants and hedges which are shrubs and trees. Though, both Loranthaceae species infest host plants which are trees and shrubs, it was observed that the number of tufts of both mistletoes were recorded more on trees than shrubs. This could be as a result of the vegetation type and vegetation cover. A total of 36 species belonging to 18 families were found to be infested by *Phragmanthera capitata* (Sprengel) S. Balle while 27 species in 14 families were infested by *Tapinanthus apodanthus* Sprague. The Lauraceae had the highest number of individual infested species recorded. This agrees with the report of [10] on the parasitism of host trees by the Loranthaceae in the region of Douala (Cameroon).

Some host plants were found unique to each parasite whilst some were found common to both. Hasten to add, *Acacia sp.* and *Mangifera indica* were the only species infested with only *Tapinanthus apodanthus* throughout the survey. However, *Mangifera indica* infestation, by Loranthaceae is confirmed by the work of [10] and [21]. The resistance of *Mangifera indica* to Loranthaceae infestation according to the literature were found to be breached during the field survey. [22] reported that the resistance of *Mangifera indica* (Anarcadiaceae) to mistletoes was interspecific and can be attributed to the chemical composition or structural tissues of the host. However, the breach could be attributed to climatic or edaphic condition of the study area. Also, it could be the development of antidote chemical by Loranthaceae to that of *Mangifera indica*. The development of Loranthaceae was largely conditioning by the nature of the host. [23] sited in [24] identified that tannins, flavonoids and lignins are part of the factors involved in Gui (Mistletoes) resistance. Though it has been reported that mango tree has totally resistant to Loranthaceae parasitism in Burkina Faso and Cameroon [7] ; this finding has revealed that mistletoe could parasitize a variety of host plants, with special preference of potential suitable hosts. Contrary to the work of [10], on Loranthaceae at Edéa, Cameroon, they concluded that, Anacardiaceae is parasitized by *Phragmanthera capitata* and remains the only case known in the country.

Furthermore, Thirteen (13) species belonging to 10 families were infested only with *Phragmanthera capitata* throughout the survey. *Persea americana, Syzigium malacacense* and *Citus sinensis,* were the most prevalent host parasitized by both parasites. The encounter of trees by mistletoes and how frequently, depends on their avian dispersers. The preference of a particular tree species by dispersers for perching, feeding or nesting is likely to receive more mistletoe seeds than other tree species. The most parasitized host species was *Persea americana* Mill. The fruits rich in vitamins, mineral salts and proteins are much appreciated by the population concerned. The distribution of mistletoe species did not demonstrate any uniformity. More tufts were recorded within altitude 500 – 799 m asl. This could be governed by multiple factors such as forest disturbance, climatic factors (light, temperature, and moisture), geographical positioning, abundance and availability of dispersers and host species. This result agrees with [25] who reported that climatic factors were found to be important in determining mistletoe distribution in a research on diversity, distribution and host range of mistletoe in protected and unprotected areas of Central Nepal Himalayas.

The differences in number of genera and species between the various elevations could be attributed to the fact that the differences in altitudes had a marked effect on temperature, relative humidity and soil which in turn affects the type of vegetation found on the mountain slope [13].

The Euphorbiaceae and Fabaceae were families specious to *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague. This could be attributed to the phytochemicals of these families. Furthermore, Fabaceae being the largest plant family after Asteraceae could be a factor since most of the species of Fabaceae are shrubs and trees. However, more infested individual species of the Lauraceae were common to both parasites and had the highest number of tufts than any other species. Meanwhile Solanaceae, Annonaceae, Burseraceae, Combretaceae, Asteraceae, Clusiaceae had the less number of species. In the case of the Solanaceae, only a single plant of *Brugmansia*

suaveolens was recorded. This could be as results of majority of Solanaceae been herbs with few shrubs and trees, although they are visited by avian.

In tropical regions, mistletoe plants are much more difficult to observe, particularly because their bird dispersers tend to deposit seeds high in the canopy. The tufts of the parasite unite discreetly to the host branches so that the parasite is difficult to recognise from far. Mimicry is a strategy for an organism to conceal and to escape from the action of predators. The mimicry of Loranthaceae to *Acalypha wilkesiana* shows is a clear strategy for the parasite to escape their predators. In general, Loranthaceae mime the hosts on which they push, very evidently by the shape of their leaves, but this variation also spreads to the peel and to the colour. This agrees with the work by [26] who found mistletoes have a weak chemical defence and are often tasty for herbivores.

Similarity indices done for host species of both parasites concluded that zones 1 and 2 are greatly similar. This could be as result of anthropogenic factors which may have an impact, as the indigenes of this area may tend to plant host plants common to both mistletoes. Avian disseminators could also influence the dispersal of both host species and the parasites. Also environmental factors could be a cause as zone 1 and 2 are aligned. This similarity agrees with [26] who observed that the availability of host ranges for mistletoe species inhabiting a locality may be influence by anthropogenic, biological and geographical factors.

5. Conclusion

The Loranthaceae is known as shrubby aerial hemi-parasites of plants in the tropics and elsewhere. They are ubiquitous and also essential for human life. Mistletoes could parasitize a variety of tree species. Factors like abundance of host plant and vulnerability (host characteristics) of the host plant could influence the parasitisation of plant by mistletoe.

This work shows that two (2) species of Loranthaceae, *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague were found to parasitize a variety of trees and shrubs species. *Phragmanthera capitata* was concluded to be ubiquitous and is the highest species parasitizing plants within the four altitudinal ranges. Zones 1 and 2 showed greater similarity for host species of both *Phragmanthera capitata* (Sprengel) S. Balle, and *Tapinanthus apodanthus* Sprague. This similarity could be as a result of anthropogenic influence, avian disseminators which may spread of the seeds of the common host plants.

Euphorbiaceae and Fabaceae were specious that is with more prevalent infested species. However, 13 species were unique to *Phragmanthera capitata* while 2 species were unique to *Tapinanthus apodanthus* meanwhile *Persea americana* and *Citrus sinensis* were the species common to both parasites.

Persea americana happens to be the species with the highest number of tufts recorded in the field hence it is vulnerable the parasite attack.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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