



Original Research Article

doi: <https://doi.org/10.20546/ijcrbp.2021.808.001>

Phytodiversity of agroforestry systems with coffee trees and degree of Loranthaceae infestation in the department of Daloa (Central-West, Côte d'Ivoire)

AMON Anoh Denis-Esdras¹*, SAKO Hamed El Amine¹, MRANKPA Agnero Stephane¹,
SEGUENA Fofana², DRO Bernadin¹, KOUASSI Kouadio Henri¹, SORO Dodiomon²

¹Agroforestry Training and Research Unit, Jean Lorougnon Guédé University, PO Box, 150 Daloa, Côte d'Ivoire

²Institute of Agropastoral Management, University Péléforo Gon Coulibaly, PO Box, 1328 Korhogo, Côte d'Ivoire
Botanical Laboratory, Biosciences Training and Research Unit, Félix Houphouët-Boigny University, 22 PO Box,
582 Abidjan 22, Côte d'Ivoire

*Corresponding author; e-mail: amonson77@yahoo.fr

Article Info

Abstract

Keywords:

Coffee plantations
Côte d'Ivoire
Degree of infestation
Floristic diversity
Loranthaceae

The floristic condition of the agroforestry systems established on coffee trees in Daloa, in the Central-West of the Côte d'Ivoire has been carried out. Surface surveys and itinerant surveys identified 123 species, 93 genera and 37 families. Euphorbiaceae and Moraceae are the most represented families. The study made it possible to count 52.03% of the species of the Guinean-Congolese region, 27.65% of the transition species (GC-SZ), 11.3% of the indeterminate species, 5.69% of the endemic species West African and 2.44% of the GCI block species. The degree of infestation of plant species evaluated shows that the values vary from 8.33% at *Alchornea cordifolia* to 79.17% in *Spondias mombin*. The results also indicated a significant difference between the degrees of infestation of plant species according to the DBH, the age of the coffee plantations. The rate of infestation of plant species is $33.35 \pm 9.84\%$ and the intensity of infestation is 2.83 ± 0.60 tufts/plant. The analysis of the degree of infestation among others of *Albizia zygia*, *Cecropia peltata*, *Cola nitida*, *Persea americana*, and *Spondias mombin* has made it possible to identify major problems of Loranthaceae infestation sources posed by the presence of these species in coffee plantations.

• Received: 25 August 2020 • Revised: 15 February 2021 • Accepted: 05 July 2021 • Published Online: 6 August 2021

Introduction

Côte d'Ivoire is an essentially agricultural country where cocoa, coffee, rubber, oil palm etc. has come at the expense of vast forest cover (Tiebre *et al.*, 2016). Indeed, the economic growth of the country generated

from 1960 to 1980 was mainly due to the performance of the agricultural sector with the spectacular development of cocoa and coffee crops (Esso, 2009). The coffee tree: (*Coffea Canephora* var. *robusta* Pierre ex Froehner) from the Rubiaceae family is a shrub native to Africa, from the province of Kaffa in Ethiopia.

Coffee growing generally takes place in a traditional way under natural semi-shade of the forest, where forest trees and shrubs are usually kept when plantations are created to provide shade for young plants (Schroth et al., 2004). In Sub-Saharan Africa and, in particular in Côte d'Ivoire, the interest in this culture rests mainly on its economic importance in the world. It employs nearly 380 000 planters and provides the country with nearly 100 billion XOF per year (Esso, 2009). Unfortunately, coffee growing faces many health constraints due in particular to fungi, caterpillars, bark beetles and bedbugs which destroy their leaves and fruits (CNRA, 2005). In addition, there is the threat of Loranthaceae attacks from numerous outbreaks of parasitic shade plant species present in plantations over the years (Sako, 2019).

The problem of this study is based on the fact that in the department of Daloa, no specific scientific study on the woody flora conserved in coffee plantations and their degree of infestation with Loranthaceae has been carried out to our knowledge, however, some of them are potential centers of infestation within this agroforestry system with economic and social interest. It therefore seemed important to carry out a qualitative floristic inventory of the woody flora present in the coffee plantations and to determine their degree of infestation with Loranthaceae.

Materials and methods

Study site The present study was carried out in two localities (Gonaté and Zépréguéhé) producing coffee in the department of Daloa, in West-Central Côte d'Ivoire with geographical coordinates 6°27'00" North latitude and 5°56'00" West longitude. The climate is of the equatorial type comprising two rainy seasons and two dry seasons. The monthly rainfall varies between 1 300 and 2000 mm. The vegetation belongs to the mesophilic sector of the Guinean domain (Guillaumet and Adjanohoun, 1971), today, consisting of forest fragments and savannas exploited for the benefit of agricultural plantations: cocoa trees, coffee trees, rubber trees, etc.

Material

The biological material is composed of woody plants saved in coffee plantations and Loranthaceae. The technical material includes a computer, a geographic positioning device (GPS), a digital camera, a ribbon

measure, sisal wire and stakes.

Methods

The works were carried out through the collaboration of village cooperatives who have a good knowledge of the coffee plantations existing in the study area. Twelve coffee plantations were chosen because of 6 coffee plantations in Gonaté and 6 coffee plantations in Zépréguéhé in the department of Daloa. The standard for choosing these coffee plantations were their area (≥ 2.5 ha), their age, their accessibility and their health status having plant species infested by Loranthaceae. The surface survey method, which consists of listing plant species on square or rectangular areas (Hall and Swaine, 1981) and traveling surveys have been adopted.

The floristic inventory consisted in delimiting plots of 60 m x 40 m (2 400 m²) due to two plots in each of the coffee plantations aged 15 to 30 years, grouped into four age classes: ≤ 15 years, [16 - 25 years], [26 - 30 years] and > 30 years old. To ease the inventory, the 2 400 m² unit plot has been subdivided into 6 square sub-plots (A, B, C, D and E) of 20 m x 20 m (400 m²) each (Fig. 1). Inside each 400 m² sub-plot, all woody plants were identified. Between two plots of 2 400 m², itinerant inventories were carried out for more exhaustive data. The inventory took into account the presence of Loranthaceae and their number of tufts on each plant species infested. The height of the woody species and their Diameter at Breast Height (DBH at 1.30 m from the ground) were also recorded. The identification of specimens of the harvested plant species was done using textbooks from Lebrun & Stork (1991, 1997) and Arbonnier (2000).

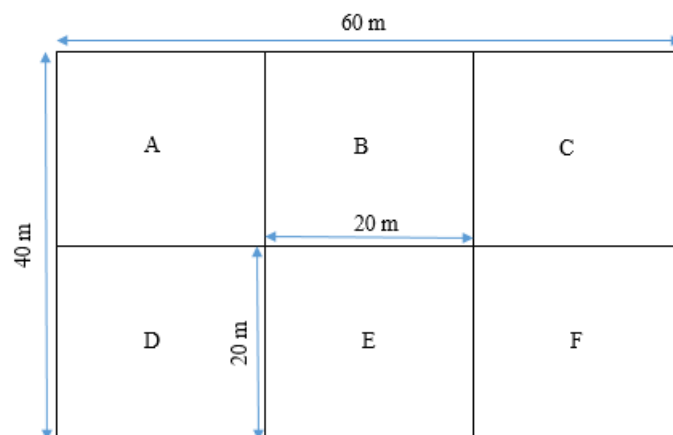


Fig. 1: Diagram of the reading device.

Data analysis

The analysis of qualitative floristic diversity consisted in noting for each identified species, the morphological type, the biological type, the chorological affinity which provides information on the origin of the species by comparing the floristic list established in coffee plantations with that of Jongkind. (2004) to determine the endemic species of Upper Guinea (UG) and those of Aké-Assi (1998). The quantitative floristic diversity on the one hand by the Shannon Diversity Index (H') and on the other hand by the degree of infestation of plant species by Loranthaceae were determined:

- the Shannon-Weaver index (H') to measure the agrobiodiversity of coffee plantations:

$$H' = -\sum((N_i / N) * \ln(N_i / N))$$

with Ni - Number of species I; N - Numbers of all species. It is expressed in bits. The value of the index varies from 0 to ln(S), with S - Total number of taxa in the middle. The higher the H' index, the greater the diversity.

-the degree of infestation of woody flora inventoried in coffee plantations according to the formulas used by Amon 2006:

- Infestation rate (Txi):

$$Txi = \frac{Nip}{Nti} \times 100$$

with Txi - Infestation rate; Nip - Number of individuals infested; Nti - Total number of individuals enumerated

- Infestation intensity (Ii):

$$Ii = \frac{Nt}{Ntii}$$

with Ii - Intensity of infestation; Nt - Total number of tufts of Loranthaceae; Ntii - Total number of infested individuals identified.

The data generated was analyzed using STATISTICA 7.1 software. Analysis of variances (ANOVA1) was carried out and Duncan's test at the 5% threshold ($\alpha < 0.05$) was used for ranking the means after the test noted the existence of significant differences.

Results

Qualitative plant diversity of coffee plantations

A total, 1102 individuals divided into 123 species, 93 genera and 37 families were inventoried in the coffee plantation (Table 1). Twelve families constitute 66.67% of the total species (Fig. 2). The most represented families are Euphorbiaceae and Moraceae with 10 species each, either 8.13%, Apocynaceae, Fabaceae and Meliaceae with 8 species each, either 6.50%. The families highlighted are those that represent more than 3% of the total of the listed species.

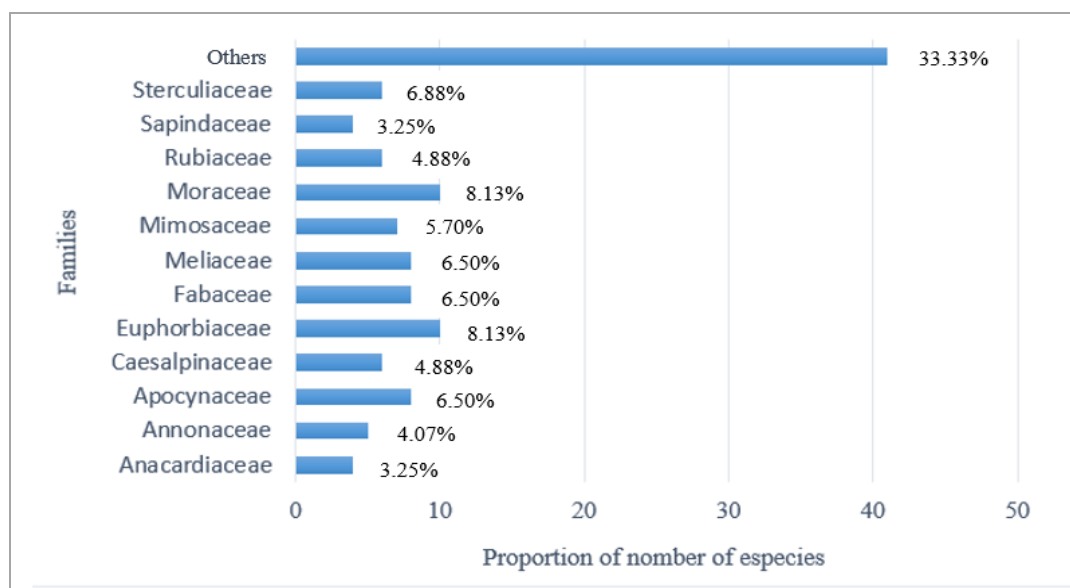


Fig. 2: Proportions of the most represented families in the total of the inventoried species.

Table 1. List of listed plant species and infestation status in coffee plantations.

Plant species	Type morp	Type biol	Chor	Localities		Total plants	Infested plants	Nb tufts	Inf rate	Intensity rate
				Gonaté	Zépregue					
Acanthaceae										
<i>Adhatoda robusta</i> C.B. Clarke	Ab	np	GCw	-	8	8	1	1	12.50	1
Anacardiaceae										
<i>Anacardium occidentale</i> L	Ab	Mp	me	-	12	12	2	2	16.67	1
<i>Pseudospondias microcarpa</i> (A.Rich.) Engl.	A	mP	GC-SZ	-	7	7	1	1	14.29	1
<i>Spondias cytherea</i> Sonner	A	mp	GCW	10	-	10	2	5	20	2.50
<i>Spondias mombin</i> L.	A	mp	GC-SZ	12	12	24	19	129	79.17	6.78
Annonaceae										
<i>Annona muricata</i> Linn.	A	Lmp	GC	10	-	10	4	15	40	3.75
<i>Monanthes barteri</i> (Baill.) Verdc.	Ab	Lmp	GC	-	8	8	1	2	50	2
<i>Monodora tenuifolia</i> Benth.	Ab	Mp	GC	5	-	5	1	2	20	2
<i>Xylopia aethiopica</i> (Dunal) A. Rich.	A	mP	GC-SZ	7	10	17	3	8	25	2.67
<i>Xylopia villosa</i> Chipp	Ab	Mp	GC	-	6	6	1	2	16.67	2
Apocynaceae										
<i>Alstonia boonei</i> De Wild.	A	MP	GC	12	12	24	11	38	45.83	3.45
<i>Funtumia africana</i> (Benth.) Stapf	A	mP	GC	9	-	9	1	2	11.11	2
<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz var. <i>floribunda</i>	Ab	mP	GC-SZ	-	5	5	1	2	20	2
<i>Motandra guineensis</i> (Thonn.) A. DC.	Ab	Lmp	GC-SZ	3	-	3	1	3	33.33	3
<i>Rauvolfia macrophylla</i> Ruiz et Pav.	Ab	mp	GC-SZ	-	8	8	1	2	12.50	2
<i>Rauvolfia vomitoria</i> Afzel.	Ab	Lmp	GC-SZ	12	12	24	7	17	29.17	2.43
<i>Tabernaemontana crassa</i> Benth.	Ab	mp	GC	-	6	6	1	1	16.67	1
<i>Voacanga africana</i> (Dun.) A. Rich.	Ab	mp	GC	-	12	12	5	16	41.67	3.20
Asclepiadaceae										
<i>Calotropis procera</i> (Aiton) W. T. Aiton	Ab	mp	GC-SZ	8	-	8	1	2	12.50	2
Asteraceae										
<i>Vernonia colorata</i> (Willd.) Drake	Ab	mp	GC-SZ	-	4	4	1	1	25	1
Bignoniaceae										
<i>Newbouldia laevis</i> (P. Beauv.) Seemann ex Bureau	Ab	mp	GC	12	12	24	6	15	25	1.25
Bombacaceae										
<i>Adansonia digitata</i> L.	A	mP	SZ	-	10	10	3	7	25	2.33
<i>Bombax buonopozense</i> P. Beauv.	A	MP	GC	5	9	14	4	19	28.57	4.75
<i>Ceiba pentandra</i> (L.) Gaerth.	A	MP	GC-SZ	3	12	15	3	11	20	3.67

Table 1. Cntd....

Plant species	Type morp	Type biol	Chor	Localities		Total plants	Infested plants	Nb tufts	Inf rate	Intensity rate
				Gonaté	Zépregue					
Caesalpinaceae										
<i>Afzelia bella</i> Harms	Ab	Mp	GCW	-	8	8	1	2	12.50	2
<i>Anthonota macrophylla</i> P. Beauv.	Ab	mp	GC	-	6	6	1	1	16.67	1
<i>Berlinia confusa</i> Hoyle	Ab	mP	GC	3	-	3	1	1	33.33	1
<i>Bussea occidentalis</i> Hutch.	Ab	mP	GC	-	7	7	1	2	14.29	2
<i>Delonix regia</i> Raf.	A	mp	GC-SZ	8	-	8	1	1	12.50	1
<i>Tamarindus indica</i> L.	A	mp	GC-SZ	-	10	10	2	5	20	2.50
Cecropiaceae										
<i>Cecropia peltata</i> L.	Ab	mp	GC	12	12	24	17	89	70,83	5.23
Clusiaceae										
<i>Garcinia afzelii</i> Engl.	A	mp	GC-SZ	7	-	7	1	1	14.29	1
<i>Garcinia kola</i> Heckel	Ab	mP	GC	3	11	14	6	25	42.86	4.17
Combretaceae										
<i>Terminalia catappa</i> L.	A	mp	i	-	2	2	1	2	50	2
<i>Terminalia ivorensis</i> A. Chev	Ab	mP	GC	2	5	7	2	4	28.57	2
<i>Terminalia superba</i> Engl. & Diels.	Ab	mP	GC	-	3	3	1	2	33.33	2
Connaraceae										
<i>Cnestis ferruginea</i> DC.	Ab	Lmp	GC	-	2	2	1	1	50	1
Ebenaceae										
<i>Diospyros canaliculata</i> De Wild.	Ab	mp	GC	-	5	5	1	1	20	1
Euphorbiaceae										
<i>Alchornea cordifolia</i> (Schumach. & Thonn.) Müll. Arg	Li	Lmp	GC-SZ	12	-	12	1	1	8.33	1
<i>Bridelia atroviridis</i> Müll. Arg.	Ab	mp	GC	-	5	5	1	1	20	1
<i>Bridelia aubrevillei</i>	Ab	mp	GC	2	-	2	1	2	50	2
<i>Bridelia grandis</i> Pierre ex Hutch.	A	mP	GC	2	8	10	2	5	20	2.50
<i>Hevea brasiliensis</i> Müll. Arg.	Ab	mP	i	11	12	23	18	92	78.26	5.11
<i>Jatropha curcas</i> L.	Ab	np	GC-SZ	10	-	10	2	5	20	2.50
<i>Macaranga heudelotii</i> Baill.	Ab	mp	GC	3	12	15	6	16	40	2.67
<i>Manihot esculenta</i> (Crantz)	Ab	mp	i	5	7	12	3	14	25	1.56
<i>Mareya micrantha</i> (Benth.) Müll.Arg.	Ab	mp	GC	-	8	8	2	4	25	2
<i>Margaritaria discoidea</i> (Baill.) Webster	A	mp	GC-SZ	4	9	13	3	9	23.08	3

Table 1. Cntd....

Plant species	Type morp	Type biol	Chor	Localities		Total plants	Infested plants	Nb tufts	Inf rate	Intensity rate
				Gonaté	Zépregue					
Fabaceae										
<i>Aubrevillea platycarpa</i> Pellegr	Ab	mp	GC	-	3	3	1	2	33.33	3
<i>Baphia bancoensis</i> Aubrév.	Ab	mp	GCI	8	-	8	1	1	12.50	1
<i>Baphia nitida</i> Lodd.	A	mp	GC	12	12	24	3	7	12.50	2.33
<i>Baphia pubescens</i> Hook. f.	Ab	mp	GC	-	4	4	1	1	25	1
<i>Dialium dinklagei</i> Harms	Ab	mp	GC	5	-	5	1	1	20	1
<i>Millettia lucens</i> (Scott-Elliot) Dunn	Ab	Mp	GC	-	8	8	1	1	12.50	1
<i>Piptadeniastrum africanum</i> (Hook. f.) Brenan	Ab	Mp	GC	-	9	9	1	2	11.11	2
<i>Tetrapleura tetraptera</i> (Schumach. & Thonn.) Taub.	A	mP	GC	3	7	10	2	7	20	3.50
Lauraceae										
<i>Persea americana</i> Mill.	A	mp	i	12	12	24	17	153	70.83	9
Loganiaceae										
<i>Anthocleista djalonensis</i> A. Chev.	A	mp	GC-SZ	3	12	15	6	22	40	4.40
<i>Anthocleista nobilis</i> G. Don	A	mp	GCW	6	5	11	3	9	27.27	3
Malvaceae										
<i>Abelmoschus esculentus</i> (L.) Moench	Ab	mp	GC-SZ	2	-	2	1	2	50	2
<i>Theobroma cacao</i> L.	Ab	mp	i	9	12	21	13	68	61.90	5.23
Meliaceae										
<i>Azadirachta indica</i> A. Juss	Ab	mp	i	-	8	8	1	2	12.50	2
<i>Cedrela odorata</i> L.	Ab	mp	i	5	-	5	1	1	20	1
<i>Entandrophragma angolensis</i> (Welw.) C. DC.	A	MP	GC	3	-	3	1	3	33.33	3
<i>Khaya ivorensis</i> A. Chev.	A	MP	GC	5	3	8	2	3	25	1.50
<i>Trichilia djalonensis</i> A. Chev.	Ab	mp	GCW	3	8	11	2	1	11.11	1
<i>Trichilia grandiflora</i> Oliv.	Ab	Mp	GC	-	11	11	1	2	9.09	2
<i>Trichilia megalantha</i> Harms	Ab	Mp	GC	-	6	6	1	2	16.67	2
<i>Trichilia monadelphica</i> (Thonn.) J. J. de Wilde	Ab	Mp	GC	7	12	19	4	8	21.05	2
Mimosaceae										
<i>Acacia ataxacantha</i> DC.	Ab	Lmp	GC-SZ	6	-	6	1	2	16.67	2
<i>Albizia adianthifolia</i> (Schumach.) W.F. Wright	Ab	mP	GC	5	6	11	5	21	45.45	4.20
<i>Albizia ferruginea</i> (Guill. & Perr.) Benth.	Ab	mP	GC-SZ	9	10	19	11	48	57.89	4.36
<i>Albizia glaberrima</i> (Schum. & Thonn.) Benth.	Ab	mP	GC	3	5	8	5	25	62.50	5
<i>Albizia lebbek</i> (Linn.) Benth.	A	mp	GC-SZ	10	8	18	11	75	61.11	6.81

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Plant species	Type morp	Type biol	Chor	Localities		Total plants	Infested plants	Nb tufts	Inf rate	Intensity rate
				Gonaté	Zépregue					
<i>Albizia zygia</i> (DC.) J.F. Macbr.	A	mP	GC-SZ	4	6	10	6	38	60	6.33
<i>Parkia biglobosa</i> (Jacq.) Benth.	A	mp	SZ	4	3	7	4	23	57.14	5.75
Moraceae										
<i>Antiaris toxicaria</i> var. <i>africana</i> (Engl.) C.C. Berg	Ab	mP	GC-SZ	-	3	3	1	2	33.33	2
<i>Antiaris welwitschii</i> Engl.	Ab	Mp	GC-SZ	-	2	2	1	2	50	2
<i>Chlorophora excelsa</i> (Welw.) Benth. & Hook. f.	Ab	MP	GC	4	-	4	1	2	25	2
<i>Ficus artocarpoide</i> Warb.	Ab	epi	GC	3	-	3	1	2	33.33	2
<i>Ficus capensis</i> Thunb.	A	mp	GC-SZ	-	2	2	1	1	50	1
<i>Ficus exasperata</i> Vahl	Ab	mp	GC-SZ	12	12	24	9	24	37.50	2.67
<i>Ficus sur</i> Forsk.	A	mp	GC-SZ	2	-	2	1	2	50	2
<i>Milicia excelsa</i> (Welw.) C. C. Berg	Ab	Mp	GC	-	3	3	1	5	33.33	5
<i>Treculia africana</i> subsp. <i>africana</i> var. <i>africana</i> Decne.	Ab	mp	GC	-	8	8	1	2	12.50	2
<i>Pycnanthus angolensis</i> (Baill.) Warb	Ab	mP	GC	9	12	21	6	19	28.57	3.17
Myrtaceae										
<i>Psidium guajava</i> Linn.	Ab	mp	i	6	10	16	9	48	56.25	5.33
Napoleonaceae										
<i>Napoleonaea vogelii</i> (Hook. f.) Planch.	Ab	mp	GC	2	-	2	1	2	50	2
Rhamnaceae										
<i>Lasiodiscus mannii</i> Hook. f.	Ab	mp	GC	-	3	3	1	1	33.33	1
Rubiaceae										
<i>Belonophora hypoglauca</i> (Welw. ex Hiern) A. Chev	Ab	mp	GC	2	-	2	1	3	50	3
<i>Bertiera spicata</i> (C. F. Gaertn.) K. Schum.	Ab	mp	GCW	-	3	3	1	2	33.33	2
<i>Coffea canephora</i> A. Froehner	Ab	mp	GC	12	12	24	2	5	8.33	2.50
<i>Morinda longiflora</i> G. Don	Ab	Lmp	GC-SZ	8	-	8	2	3	25	1.50
<i>Morinda lucida</i> Benth.	Ab	mp	GC-SZ	-	3	3	1	1	33.33	10
<i>Morinda morindoides</i> (Baker) Milne-Redh.	Ab	Lmp	GC	-	2	2	1	2	50	2
Rutaceae										
<i>Citrus limon</i> Burn. f.	Ab	mp	i	-	5	5	1	3	20	3
<i>Citrus sinensis</i> (L.) Osbeck	Ab	mp	i	12	12	24	17	82	70.83	4.82
<i>Vepris verdoorniana</i> (Engl. & Mendonça)	Ab	Mp	GC	5	-	5	1	1	20	1
Sapindaceae										
<i>Allophylus africanus</i> P. Beauv.	Ab	Mp	GC-SZ	-	3	3	1	1	33.33	1
<i>Blighia sapida</i> K. D. Koenig	A	mP	GC-SZ	6	-	6	1	2	16.67	2

Table 1. Cntd....

Plant species	Type morp	Type biol	Chor	Localities		Total plants	Infested plants	Nb tufts	Inf rate	Intensity rate
				Gonaté	Zépregue					
<i>Blighia welwitschii</i> (Hiern) Radlk.	Ab	mP	GC	9	-	9	1	2	11.11	2
<i>Deinbollia grandifolia</i> Hook. f.	Ab	mp	GC	-	3	3	1	2	33.33	2
Sapotaceae										
<i>Chrysophyllum albidum</i> G. Don	Ab	Mp	i	2	-	2	1	2	50	2
<i>Chrysophyllum giganteum</i> A Chev.	A	MP	GC	2	-	2	1	3	50	3
<i>Vitellaria paradoxa</i> C.F.Gaertn.	Ab	mp	SZ	7	9	16	9	28	25	3.11
Simaroubaceae										
<i>Harrisonia abyssinica</i> Oliv.	Ab	mp	GC-SZ	-	2	2	1	2	50	2
Solanaceae										
<i>Solanum melongena</i> L.	He	np	GC-SZ	5	-	5	1	2	20	2
<i>Solanum rugosum</i> Dun.	Ab	mp	GC	3	-	3	1	3	33.33	3
Sterculiaceae										
<i>Cola cordifolia</i> (Cav.) R. Br.	Ab	Mp	GCW	-	5	5	1	3	20	3
<i>Cola nitida</i> (Vent.) Schott & Endl.	A	mP	GC	12	12	24	17	98	70.83	5.76
<i>Mansonia altissima</i> (A. Chev) A. Chev	Ab	mP	GC	-	2	2	1	2	50	2
<i>Nesogordonia papaverifera</i> (A. Chev.) R. Capuron	Ab	MP	GC	-	7	7	2	4	28.57	2
<i>Sterculia tragacantha</i> Lindl.	A	mP	GC-SZ	5	10	15	2	4	13.33	2
<i>Triplochiton scleroxylon</i> K. Schum.	Ab	Mp	GC	3	-	3	1	3	33.33	3
Tiliaceae										
<i>Glyphaea brevis</i> (Spreng.) Monachino	Ab	mp	GC	4	-	4	1	1	25	1
Ulmaceae										
<i>Celtis mildbraedii</i>	A	MP	GC	-	3	3	1	2	33.33	2
<i>Celtis philippensis</i> Blanco	Ab	mp	GC	-	5	5	1	1	20	1
Urticaceae										
<i>Myrianthus libericus</i> Rendle	Ab	mp	GC	-	6	6	1	3	16.67	3
<i>Myrianthus serratus</i> (Trec.) Benth.	Ab	mp	GC	5	-	5	1	1	20	1
Verbanaceae										
<i>Gmelina arborea</i> Roxb.	Ab	mp	i	2	3	5	2	4	40	2
<i>Tectona grandis</i> Linn.f.	Ab	Mp	i	5	6	11	4	12	36.36	3
<i>Vitex micrantha</i> Gürke	Ab	Mp	GC	2	-	2	1	2	50	2
Violaceae										
<i>Rinorea oblongifolia</i> (C.H. Wright) M. ex C.	Ab	Mp	GC	-	2	2	1	1	50	1

Meaning of abbreviations: morp - morphological; biol - biological; Nb - Number; inf - infestation; A - Tree; Ab - Shrub; He - Grass; Li - Liane; GC - Guinean-Congolese; GCW - Endemic West African; GCI - Endemic to Côte d'Ivoire; GC-SZ - Transition species, SZ - Soudano-Zambézienne; indeterminate (i); MP - megaphanerophytes; mP - mesophanerophytes; Lmp - microphanerophyte lianas; np – nanophanerophytes.

Table 2. Floristic diversity and Shannon indices of coffee plantations by study location.

Culture	Study localities	Number of plots	Number of individuals	Number of species	Number of genera	Number of families	H'/coffee
Coffee plantations	Gonaté	12	465	75	60	29	4.160
	Zépréguéhé	12	644	88	69	33	4.372

These include Euphorbiaceae, Moraceae, Apocynaceae, Fabaceae, Meliaceae, Mimosaceae, Caesalpiniaceae, Rubiaceae and Sterculiaceae (Fig. 2). The 25 other families, each with less than 3% of the total species, are grouped under the term "others" (33.33% of the species). Among the 123 species inventoried, there are many woody species such as *Azalia bella*, *Albizia zygia* (Fig. 3), *Alstonia boonei*, *Anthocleista djalonenis*, *Funtumia Africana*, *Parkia biglobosa*, *Piptadeniastrum africanum*, *Spondias mombin* (Fig. 4) and *Xylopiya aethiopicum*.



Fig. 3: *Albizia zygia* heavily infested by Loranthaceae in a coffee field.



Fig. 4: *Spondias mombin* heavily infested by Loranthaceae in a coffee field.

Considering the chorology of these species, six groups of plant species are distinguished (Table 1). These are: species from the Guineo-Congolese region (GC), endemic West African species (GCW), endemic to Côte d'Ivoire (GCI), transition species (GC-SZ), the Sudano-Zambezi region (SZ) and indeterminate species (i).

Among these groups of species, those from the Guineo-Congolese region are the most represented with 64 species, either 52.03% of the total number of taxa. Next come the GC-SZ species with 34 species (either 27.65%), the indeterminate with 14 species (11.3%) and the West African endemics with 7 species (either 5.69%). The GCI block species are the least represented in the workforce with 2.44% of the inventoried species. Shannon-Weaver (H') indices of coffee plantations by specific study location show that the woody flora of coffee plantations in Zépréguéhé is more diverse in species than in Gonaté (Table 2).

On the morphological level, the 123 species fall into four groups (Table 1). These are the shrubs with 88 species, either 71.55% of the species, the trees with 33 species (26.83%), the grasses and the lianas which include 1 species each (either 0.81%). In terms of biological type, the inventoried plant species are divided into four groups (Table 1). We cite: the mesophanerophytes (mP) which are most represented in coffee plantations with 82 species, either 66.67% of all the species inventoried. Next comes, the megaphanerophytes (MP) with 28 species (22.76%), the microphanerophyte (Lmp) with 9 species (7.32%) and the nanophanerophytes (np) with 3 species (2.44%). Epiphytes are the least represented with 1 species (0.81%). On a plot scale, the floristic diversity within the coffee plantations varies respectively between 29 and 53 species at Gonaté and between 44 and 59 species at Zépréguéhé (Fig. 5).

Degree of infestation of plant species

The average rates of infestation of the 123 plant species by Loranthaceae recorded in coffee plantations from the

24 surveys vary between 8.33% in *Alchornea cordifolia* and *Coffea canephora* and 79.17% in *Spondias mombin* (Table 1). Regarding the intensity of infestation of these plants, the infestation values vary between 1 tuft/plant in species such as *Anthonota macrophylla*, *Bridelia atroviridis*, *Morinda lucida*, *Pseudospondias microcarpa*, *Rinorea oblongifolia* and *Tabernaemontana crassa* and 9 tufts/plant in *Persea americana* (Table 1). Among these species, *Spondias mombin* (79.17%), *Hevea brasiliensis* (78.26%), *Cecropia peltata*, *Citrus sinensis*, *Cola nitida* and *Persea americana* each with 70.83%, *Albizia glaberrima* (62.50%), *Theobroma cocoa* (61.90%), *Albizia lebeck* (61.11%) and *Albizia zygia* (60%) are the most attacked taxa (Table 1). *Alchornea cordifolia* and *Coffea canephora* with 8.33% each are the least parasitized taxa.

Infestation rate and intensity according to age classes

The infestation of plant species identified according to the age classes of coffee plantations shows that the Loranthaceae attack more woody individuals in coffee plantations of age classes between 26 and 30 years ($34.65 \pm 4.5\%$) and > 30 years ($40.96 \pm 1.76\%$) with high infestation rates. The analysis of variance of the horizontal structure carried out effectively indicates a significant difference a, ab and b ($p = 0.07$) between 3 statistical groups (Fig. 6). Also, the values of infestation

intensities of plant species of age class > 20 years (3.75 ± 0.23 tufts / plant) differ numerically from those of the other three classes.

The analysis of variance carried out shows a statistical difference a and b ($p = 0.01$) between the intensities of infestation of woody plants by Loranthaceae according to the age classes of the coffee plantations (Fig. 7). The rate of infestation of the plant species identified in the coffee plantations of Gonaté and Zépréguéhé taken together is around $33.35 \pm 9.84\%$. Also, the infestation rate of coffee plantations taken together is $23.57 \pm 1.21\%$

Infestation rate according to diameter and height classes

The infestation rates of the listed plant species according to the diameter classes evaluated indicate that Loranthaceae parasitize the most large-diameter individuals with high infestation values. The analysis of variance of the horizontal structure carried out indicates a significant difference ($p = 0.009$) between 6 statistical groups a, ab, abc, bcd, cd and d (Fig. 8). Analysis of the vertical structure also showed a significant difference between the rate of plant species infestation by Loranthaceae according to their height classes ($p = 0.013$). The infestation rates differ statistically across 4 homogeneous groups a, ab, bc, cd and d according to the height classes of the plant species (Fig. 9).

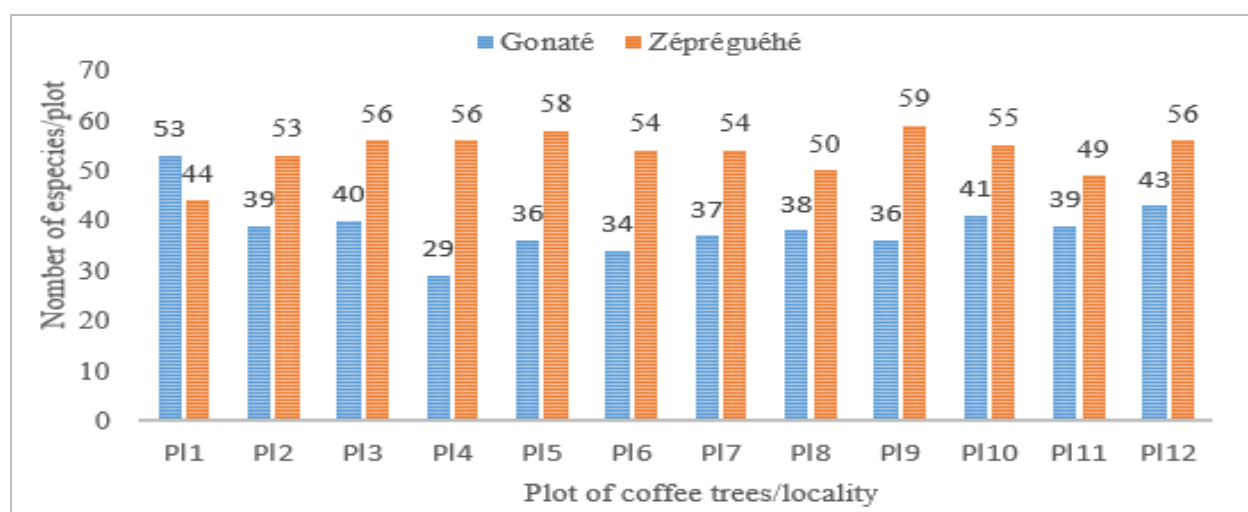


Fig. 5: Floristic diversity by plots according to the study localities.

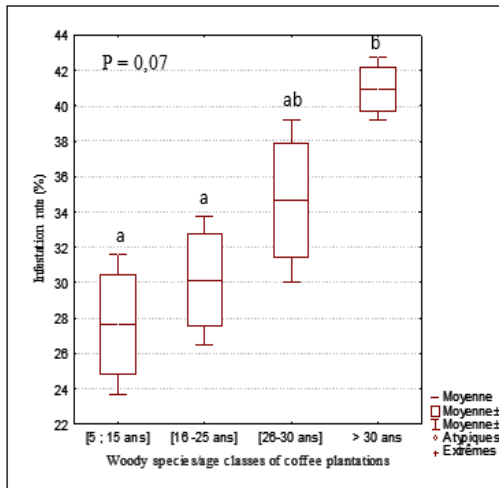


Fig. 6: Infestation rates of plant species according to the age classes of the coffee plantations.

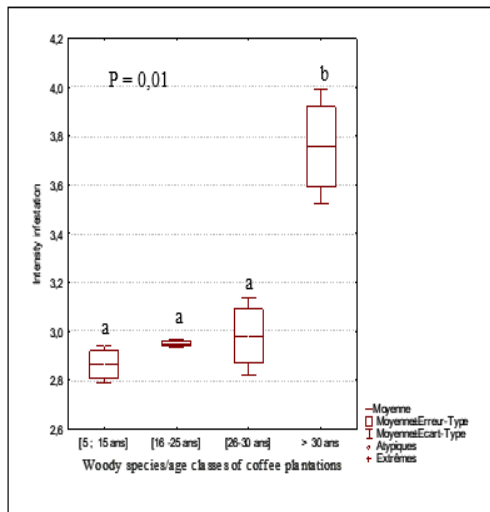


Fig. 7: Intensity of infestation of plant species according to the age classes of the coffee plantations.

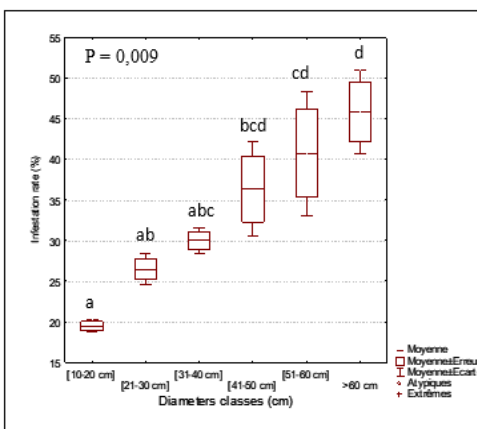


Fig. 8: Infestation rate of plant species according to the diameter classes (cm).

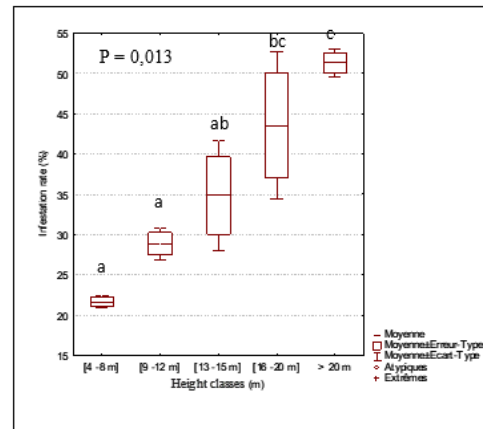


Fig. 9: Infestation rate of plant species according to height classes.

Infestation intensity according to the diameter and height classes

The intensity of infestation of plant species by Loranthaceae identified in coffee plantations evaluated is numerically high according to their diameter classes. Analysis of the horizontal structure effectively shows a significant difference between 6 statistically different groups a, ab, bc, cd, de and e ($p = 0.0009$) between the intensity values of infestation of these woody species by Loranthaceae (Fig. 10). Also, the analysis of variance of the vertical structure indicates a significant difference between 5 statistically different groups a, ab, bc, cd and d ($p = 0.009$) the intensities of infestation of the infested woody species (Fig. 11). The intensity of infestation of plant species by Loranthaceae from coffee plantations taken together is 2.83 ± 0.60 tufts/plant. The intensity of infestation of coffee plantations taken together is around 1.43 ± 0.36 tufts/plant.

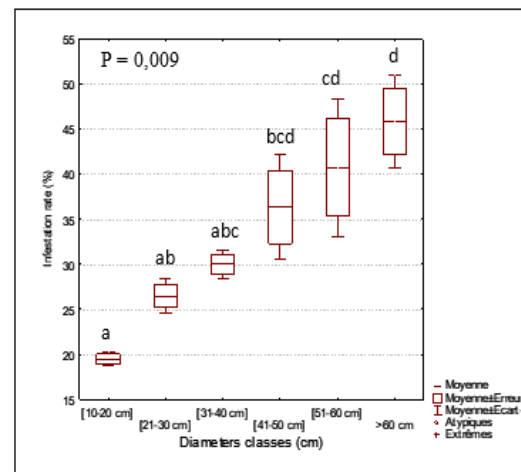


Fig. 10: Intensity of infestation of plant species according to the diameter classes (cm).

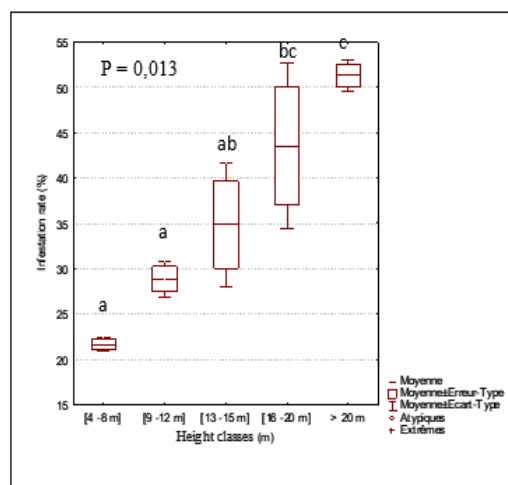


Fig. 11: Intensity of infestation of plant species according to height classes (m).

Discussion

The present study made it possible to inventory 123 species, 93 genera belonging to 37 botanical families in coffee plantations in Daloa, in the West-Central of the Côte d'Ivoire. This taxonomic diversity of 93 genera and 123 species is much greater than that of the 77 genera and 34 families obtained respectively by Amon *et al.* (2015) in agroecosystems in Sud-Comoé and the 41 species of shade trees recorded by Herzog (1994) in the coffee plantations of two villages in Côte d'Ivoire and to the 90 species listed by Moguel & Toledo (1999) in a sample of 10 traditional coffee plantations in Mexico city.

The dominant botanical families are Euphorbiaceae and Moraceae with 8.13% of species each, Apocynaceae, Fabaceae and Meliaceae with 6.50% of species each. This situation is contrary to those reported by Manga *et al.* (2013) in coffee plantations in the western highlands, in Cameroon, dominated by Arecaceae, Burseraceae, Lauraceae and Sterculiaceae and by Soto-Pinto *et al.* (2001) in Mexican coffee plantations dominated by Arecaceae, Arecaceae, Asteraceae, Fabaceae and Tiliaceae. This difference could be explained by the sampling methods used as well as the size of the agroforestry plots analyzed (Yann, 2001).

The overall rate of infestation of plant species identified by Loranthaceae in coffee plantations in Daloa in west-central Côte d'Ivoire is around $33.35 \pm 9.84\%$. This rate is much lower than that obtained by Amon *et al.* (2015) which is 37.4% recorded in agrosystems, in the South-East of the country.

The results also show that the plant species conserved in coffee plantations are variously attacked by Loranthaceae. Also, they highlight the high level of infestation in *Albizia lebbek*, *Albizia glaberrima*, *Albizia zygia*, *Cecropia peltata*, *Citrus sinensis*, *Cola nitida*, *Hevea brasiliensis*, *Persea americana*, *Theobroma cocoa* and *Spondias mombin*. The presence linked to the parasitism of these species by Loranthaceae, poses a major problem of centers of infestation in coffee plantations in Loranthaceae (Sako, 2019). The results also show that the degrees of infestation of the listed plant species are significantly influenced by the age of the coffee plantations as well as the classes of diameters and heights of these individuals. Indeed, the degrees of infestation of these species recorded in plantations aged 26 to 30 years ($34.65 \pm 4.5\%$) and > 30 years and over ($40.96 \pm 1.76\%$) are high. The same is true for large diameter and large plant species. These results confirm the work of Mrapka (2018).

Conclusions

The present study made it possible to inventory 123 species, 93 genera and 37 families in coffee plantations in Gonaté and Zépréguéhé, in the department of Daloa, in West-Central Côte d'Ivoire. Euphorbiaceae and Moraceae are the families most represented in the woody flora preserved in coffee plantations. The degree of infestation of plant species by Loranthaceae is significantly influenced by the age of coffee plantations and DBH. The values of infestation rate and intensity of plant species in coffee plantations are respectively around $33.35 \pm 9.84\%$ and 2.83 ± 0.60 tufts/plant. These results could be used as data to develop targeted control strategies against the identified outbreaks.

Conflicts of interest statement

The authors declare that there is no conflict of interest in this article.

Acknowledgements

Authors express their thanks to peasants.

Author's contributions

AADE and SHEA ensured the development of the research protocol, the collection, the data processing and the wording of manuscript. KAV, MAS, SF, DB,

KKH, SD proofread the versions and improved the scientific quality of the manuscript.

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How to cite this article:

Amon, A. D., Sako, H. E., Mrankpa, A. S., Seguenta, F., Dro, B., Kouassi, K. H., Soro, D., 2021. Phytodiversity of agroforestry systems with coffee trees and degree of Loranthaceae infestation in the department of Daloa (Central-West, Côte d'Ivoire). *Int. J. Curr. Res. Biosci. Plant Biol.*, 8(8): 1-13.

doi: <https://doi.org/10.20546/ijcrbp.2021.808.001>