Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/20698
DOI URL: http://dx.doi.org/10.21474/IJAR01/20698

RESEARCH ARTICLE

INFLUENCE OF WOODY FRUIT SPECIES SUSCEPTIBLE TO LORANTHACEAE ON THE LEVEL OF INFESTATION OF COCOA TREES: CASE OF AGROFORESTRY COCOA FARMING SYSTEMS IN DALOA (COTE D'IVOIRE)

Amon Anoh Denis-Esdras[1], Sylla Moussa[1], Kouadio Affoue Roseline[1] and Soro Dodiomon[2]

1. Laboratoire d'Amélioration de la Production Agricole (APA) UFR Agroforesterie, Université Jean Lourougnon Guédé, BP 150 Daloa, Côte d'Ivoire.
2. Laboratoirede Botanique _UFR Biosciences, UniversitéFélix Houphouët-Boigny, Abidjan, 22 BP 582 Abidjan 22, Côte d'Ivoire.

Manuscript Info

Manuscript History
Received: 05 February 2025
Final Accepted: 08 March 2025
Published: April 2025

Key words:-
Cocoa, Fruit Species, Loranthaceae, Incidence, Correlation, Daloa

Abstract

Objectives: Cocoa farms integrate silvicultural practices into agricultural operations, making it possible to build agroforestry systems favoring the conservation of useful woody and fruit species. Unfortunately, these species are parasitized to varying degrees by Loranthaceae, thus becoming foci of infestation within cocoa plantations. The present study was undertaken to gain a better understanding of these Loranthaceae parasites of fruiting species in cocoa plantations and to assess the influence of susceptibility to these species on the degree of infestation of cocoa trees.

Methods: Floristic inventories carried out in 16 agroforestry cocoa-growing systems in four localities around Daloa.

Results: Three Loranthaceae species: *Phragmanthera capitata*, *Tapinanthus bangwensis* and *T. globiferus* parasitize 60 woody fruit species both wild and cultivated. *T. bangwensis*, with a high preponderance of host taxa, is the main parasitic species. These 60 fruit species belong to 44 genera in 25 families. The families most affected are the Rutaceae (7 taxa), followed by the Anacardiaceae, Annonaceae and Myrtaceae (6 taxa each). The results revealed an incidence of Loranthaceae parasitism of 39.66 ± 7.07% on woody fruit trees and 40.65 ± 4.26% on cocoa trees. A positive correlation was observed between the incidence of Loranthaceae on these woody fruit trees and that observed on cocoa trees.

Conclusion:The results underline the importance of selecting woody species associated with cocoa trees that are less susceptible to Loranthaceae. Further research is recommended to identify these species and develop sustainable cocoa management strategies.

Introduction:-

In Côte d'Ivoire, cocoa agroforestry systems resulting from cultivation clearings are systems in which farmers reconcile, to mutual benefit, between agricultural and forestry activities (Nair et al., 2021). These systems are

Corresponding Author:- Amon Anoh Denis-Esdras
Address:- Laboratoire d'Amélioration de la Production Agricole (APA)_UFR Agroforesterie, Université Jean Lourougnon Guédé, BP 150 Daloa, Côte d'Ivoire.

commonly referred to as agroforests. They incorporate slash-and-burn species as well as woody fruit species associated with cocoa trees, which represent an additive source of income for rural populations (Kpangui et al., 2015). More specifically, cocoa agroforests are agricultural practices associating cocoa trees with other plants, whether wild or cultivated (Guichard, 2022). In Côte d'Ivoire, cocoa farming is crucial to the national economy. It provides around 40% of the world's supply of cocoa beans and has enabled the country to rank first among producers for over thirty years (ICCO, 2020). Cocoa production contributes more than 10% to Ivorian GDP and is the main source of income for over four million smallholders in rural areas (POGCI, 2023). At present, cocoa alone accounts for 30% of Côte d'Ivoire's exports, providing significant economic support to the Ivorian state. However, one of the main biotic enemies encountered by farmers in cocoa plantations, brown pod rot caused by Phytophthora spp. and mirids (Sahlbergella singularis and Distantiella theobromae), is among the most formidable bio-aggressors due to its documented damage (Kébé et al., 2005). In addition to these cryptogamic diseases, parasitic plants of the Loranthaceae family (Soro, 2010) attack cocoa trees and many wild trees or cultivated fruit trees introduced into plantations (Houenon et al., 2012; Amon, 2014). Loranthaceae are small, epiphytic, chlorophyllous shrubs that live as haemiparasites on the branches of other wild or cultivated trees and shrubs (Balle &Halle, 1961).These clump-like parasitic plants, once attached to a branch, anchor themselves in the host's wood by means of a sucker that establishes functional links with the tree's conducting apparatus. In this way, the parasite obtains the water and mineral elements it needs from the host. Their distribution and the economic and ecological damage caused by Loranthaceae vary widely (Mrankpa, 2018; Yao, 2020). These parasitic plants, with a more or less broad host spectrum, attack numerous fruit species present in cocoa agroforestry plots in Côte d'Ivoire (Sako, 2019; Kouadio, 2023), increasing the risk of cocoa infestation. Today, one of the major concerns of agroforestry cocoa farming systems is whether the presence of fruit species in cocoa fields and their degree of susceptibility to Loranthaceae actually influence the level of cocoa infestation.Furthermore, the question of the influence of Loranthaceae fruiting woody species on the level of infestation of cocoa trees has never been evaluated. It therefore seems necessary to identify the Loranthaceae species involved and their host fruit trees present in cocoa plantations in order to assess the influence of their neighborhood on the level of infestation of cocoa trees. The present study was undertaken with this in mind in order toidentify the Loranthaceae species effectively parasitizing woody fruit trees, assess their impact on these fruit trees and cocoa trees and determine the relationship between this impact and the degree of infestation observed on these species and cocoa trees.

Materials and Methods:-

Study site

The study was carried out in the cocoa agroforestry systems of four Daloa rural localities: Zépréguhé (06°54'09.27" N and 06°21'28.84"W), Toroguhé (06°56'41.01" N and 06°27'49.77" W), Zakoua (06°48'06.24" N and 06°27'07.58" W) and Bribouo (06°52'09.88" N and 0630'20.45" W). Located 400 km from the economic capital, Abidjan, and 140 km from Yamoussoukro, the political capital, the Daloa department, capital of the Haut-Sassandra region, lies between 6°55'0.01" Nand 6°87'00" N latitude and 6°27'00" and -6°30'0.00" Wlongitude (Figure 1).

The Daloa area, like the entire Haut-Sassandra region, is characterized by a humid sub-equatorial climate with four seasons (Eldin, 1971): a long rainy season from April to mid-July; a short dry season as a transitional regime from mid-July to mid-September; a short rainy season from mid-September to November and a long dry season from December to March. The vegetation, which used to consist of dense forests, is now characterized by a wide variety of flora, including a few native trees and shrubs such as Triplochiton scleroxylon and savannahs whose plant composition depends on the nature of the soil or human activities (Koffié-bikpo & Kra, 2013). In addition, agricultural activities and bush fires in this region have profoundly altered the natural vegetation, which has given way to vast cocoa plantations, wastelands and recruits (N'Guessan et al., 2014).

Collection of floristic data

For the inventory, we used two complementary inventory techniques. These were the surface survey and the roving survey. The surface survey consisted of delimiting a 50 m x 50 m plot, representing a total surface area of 2,500 m² (Figure 2) in the selected cocoa plantations. For an accurate count of all cocoa trees, parasitized and non-parasitized fruit trees, as well as clumps of different Loranthaceae species, the 2,500 m^2 plot was subdivided into ten 50 m x 5 m strips using BTP tape (Figure 2).

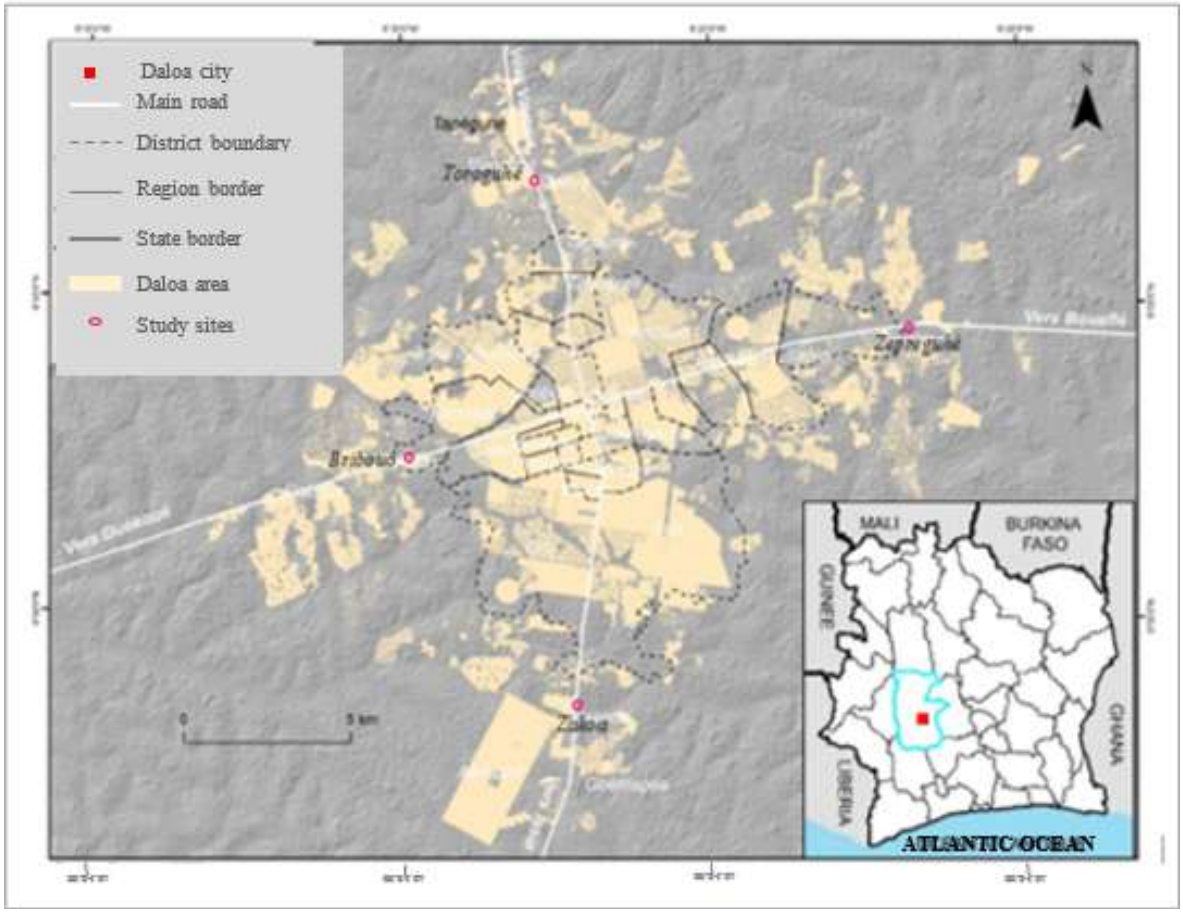
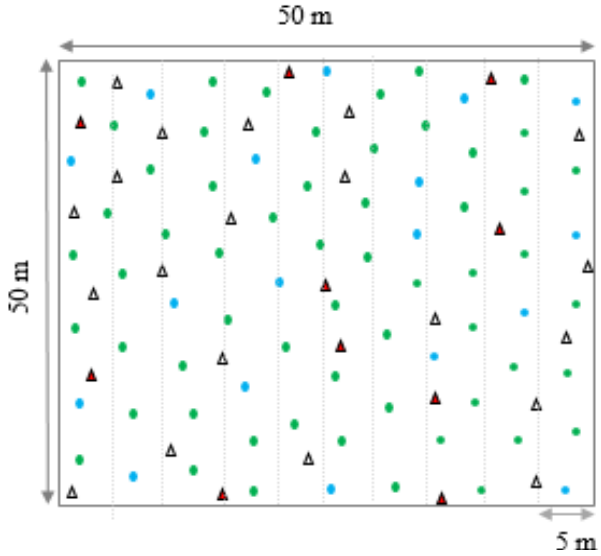


Figure 1: Map of study sites



Circles represent cocoa trees in the plot (healthy trees in green, parasitized trees in blue). The triangles represent individuals of fruit trees associated with cocoa trees (healthy individuals in white, parasitized individuals in red).

Figure 2: Surface survey device

To make the data representative, this plot was applied twice in 20 plantations following a randomized Fisher design, i.e., a total of 40 surveys in all the cocoa plantations studied. In each 2500 m² plot, all parasitized cocoa trees were marked in blue and parasitized fruit trees in red (Figure 2). In these plots, all parasitized and non-parasitized cocoa trees and fruit trees were sampled.Itinerant surveys were also carried out in all directions to record all Loranthaceae species and parasitic fruit trees encountered on the basis of their presence, regardless of their abundance (Aké-Assi, 1984). This type of inventory was carried out to complete the general floristic list. During these inventories, herbarium samples of the various parasitic and fruit-bearing species were taken.

Determination of species

Loranthaceae species were determined mainly using the reference work by Balle & Hallé (1961) entitled "Loranthaceae de la Côte d'Ivoire," documents by Boussim (2002), Soro (2010), Amon (2014) and the herbarium specimen collection of the National Floristic Center (CNF) in Abidjan, Côte d'Ivoire. Host species were identified on site or in the laboratory using the illustrated floras of Arbonnier (2002), Bongers et al. & Stork (1995, 1997) and the documents by Aké-Assi (2002).

Data analysis

Floristic composition

Floristic composition here refers to the number of fruit-bearing woody species inventoried and their distribution by family and genus.

Analysis of tree infestation levels

Average number of Loranthaceae per parasitized tree

The average number of clumps (ANcl) corresponds to the number of Loranthaceae clumps per tree parasitized in a given biotope (Houenon et al., 2012). It has been used in Cameroon (Sonké et al., 2000; Ngotta Biyon et al., 2022) and Côte d'Ivoire (Kouadio, 2023) to assess the average number of parasite clumps on parasitized trees according to the following formula:

$$ANcl = \frac{\text{Total number of Loranthaceae clumps}}{\text{Total number of parasitized trees}}$$

Assessment of host tree susceptibility

The degree of susceptibility of cocoa and fruit trees to Loranthaceae in selected cocoa farms was assessed by the incidence. The incidence of Loranthaceae (IL) on cocoa and fruit trees was used to measure the percentage of their parasitism on these trees (Asare-Bediako et al., 2013), according to the following relationship:

$$IL = \frac{\text{Number of parasitic trees}}{\text{Total number of trees assessed}}$$

Statistical processing

Data were sorted and plotted using Microsoft Excel 2016. To compare the infestation parameters of the host fruit trees inventoried, a one-factor analysis of variance (ANOVA) was performed. ANOVA is used to test for significant differences between the means of more than two groups. In the event of a significant difference at the 5% level ($\alpha < 0.05$), a Newman-Keuls post-hoc test was applied to identify statistically distinct groups (a, b, c). Normality and homogeneity of variances were verified using the Shapiro-Wilk test. All statistical tests were performed using Statistica version 7.1 software.

Results:-

Loranthaceae species present on cocoa and fruit trees

A total of three Loranthaceae species were recorded on cocoa and fruit tree species (Table 1). These are*Phragmanthera capitata* (Spreng.) Ballé (Figure 3), *Tapinanthus bangwensis* (Engl. and K. Krause) Danser (Figure 4) and *T. globiferus* (A. Rich.) Danser. They are divided into two genera, *Phragmanthera* and *Tapinanthus*. The *Tapinanthus* genus contains 2 species, i.e. 50%.

Figure 3: Flowering shoots of *P. capitata***Figure 4**: Flowering shoots of *T. bangwensis*

Average number of Loranthaceae tufts per parasitized tree

Comparative analysis of the average number of tufts of each Loranthaceae species per parasitized individual revealed significant differences in infestation between cocoa and fruit trees (F = 51.36; P = 0.000012). (Table 1).

Table 1:- Average number of clumps per Loranthaceae species on fruit and cocoa trees

Loranthaceae species	Cocoa	Fruit species	Average number of clumps/parasite
Phragmenthera capitata	1504,50±412,42b	126,50±82,51b	815,50±247,46b
Tapinanthus bangwensis	4015,33±553,94c	191±63,80b	2103,33±308,87c
T. globiferus	335,67±780,09a	10,25±3,30	172,96±391,65a
Average number of clumps	1871,75±1765,65	109,25±95,25	1030,59±315,99

In the columns, the means assigned the same letters are not different (Newman-Keuls test, p > 0.05).

This average number of tufts is significantly higher on cocoa trees (1871.75 ± 1765.65 tufts) than on fruit trees (109.25 ± 95.25 tufts) present in the cocoa farms studied. The average number of tufts compared between the different Loranthaceae species found on cocoa trees and on the parasitized fruit species enables them to be grouped into three distinct groups. A comparison of the average number of tufts between the different Loranthaceae species found on cocoa trees and the fruit species parasitized enables them to be grouped into three distinct groups (Table 1). *T. bangwensis* is the most abundant in cocoa plantations, with 6357.55 ± 966.13 tufts, followed by *P. capitata* (815.50 ± 247 tufts) and *T. globiferus* (172.96 ± 391.65 tufts). Analysis of variance of the average number of tufts per Loranthaceae species shows a significant difference between the three parasitic species (F = 51.36; p = 0.000012).

Fruit species inventoried

The floristic inventory identified 60 woody fruit species, 35 of which are wild or spontaneous trees and shrubs (Table 2). These species are divided into 25 families (Figure 5), the most important of which are :

- the Rutaceae family, represented by seven species;
- the Anacardiaceae, Annonaceae and Myrtaceae families, each represented by six species;
- the Moraceae family, with four species;
- the Fabaceae and Rubiaceae families, each represented by three species;
- the Apocynaceae, Caesalpiniaceae, Euphorbiaceae, Malvaceae, Meliaceae, Mimosaceae and Sapotaceae families, each represented by two species.

Table 2:- Non-exhaustive spectrum of Loranthaceae host fruit species observedin Daloa cocoa farms.

Familles	Species	Parasitic species		
		Tg	Pc	Tb
Anacardiaceae	**Anacadium occidentale*Linn.	-	+	+

	Pseudospondias microcarpa (A. Rich.) Engl.	-	+	-
	Spondias cytherea Linn.	-	-	+
	Spondias mombin Linn.	+	+	+
	Spondias purpurea Linn.	-	-	+
	Trichoscypha acuminata Engl.	-	+	-
Annonaceae	**Annona muricata*Linn.	-	+	+
	**Annona senegalensis* Pers.	+	+	+
	**Annona squarnosa*Linn.	-	-	+
	Monodora myristica (Gaert.) Dumal	-	-	+
	Xylopia aethiopica(Dunal) A. Rich.	-	+	+
	Xylopia parviflora (A. Rich.) Benth.	-	-	+
Apocynaceae	*Calotropis procera*(Aiton) W. T. Aiton	-	-	+
	Landolphia dulcis (Sabine) Pichon	-	+	-
Bixaceae	*Bixa orellena* Linn.	-	+	+
Bombacaceae	**Adansonia digitata*Linn.	-	-	+
Burseraceae	*Dacryodes macrophylla* (Oliv.) H. J. Lam	-	+	+
Caesalpiniaceae	*Detarium microcarpum* Guill. & Perr.	-	+	+
	**Tamarindus indica* Linn.	-	+	+
Clusiaceae	*Garcinia kola*Heckel	+	+	+
Combretaceae	**Terminalia catappa*Linn.	-	+	+
Euphorbiaceae	**Jatropha curcas*Linn.	-	-	+
	Ricinodendron heudelotii(Baill.) Pierre ex Pax	-	+	+
Fabaceae	*Lonchocarpus sericeus* (Poir.) DC.	-	-	+
	Prosopis africana (Guill. & Perr.) Taub.	-	-	+
	Pterocarpus santalinoides DC.	-	-	+
Irvingiaceae	*Irvingia gabonensis*(Audrey-Lecomte ex O'Rorke) Baill.	-	+	+
Lamiaceae	*Vitex simplicifolia Oliv.*	-	+	-
Lauraceae	**Persea americana*Mill.	+	+	+
Loganiaceae	*Strychnos spinosa* Lam.	-	+	+
Malvaceae	**Cola gigantea* A. Cev. var. glabrescens Brenan & keay	-	-	+
	**Cola nitida* (Vent.) Schott & Endl.	-	+	+
Meliaceae	**Azadirachta Indica* A. Juss.	-	+	+
	*Carapa procera*DC. De Wilde	-	-	+
Mimosaceae	**Parkia bicolor* A. Chev.	-	-	+
	Tetrapleura tetraptera (Schum. & Thonn.) Taub.	-	-	+
Moraceae	*Antiaris toxicaria* Welwitshii (Engl.) C. C. Berg.	-	-	+
	Ficus exasperata M. Vahl	-	+	+
	Ficus lutea M. Vahl	-	+	+
	Ficus vallis-choudae Del.	-	+	+
Myrtaceae	**Eugenia jambos* (L.) Alston	-	-	+
	**Eugenia malaccensis* Linn.	+	+	+
	**Eugenia miegeana* Aké Assi	-	-	+
	**Eugenia owariensis* P. Beauv.	-	+	+
	**Psidium guajava* Linn.	-	+	+
	Syzygium guineense (Willd.) DC.	-	+	+
Olacaceae	*Coula edulis* Baill.	-	+	-
Rubiaceae	**Coffea robusta* Pierre ex A. Froehner	-	-	+
	Gardenia erubescens Stapf & Hutch.	-	-	+
	**Morinda lucida* Benth .	-	-	+

Rutaceae	*Citrus aurantifolia* (Christm.) Swingle	-	+	+
	*Citrus aurantium*Linn.	+	+	+
	Citrus maxima (Burm.) Merr.	-	-	+
	*Citrus limon*Burn. f.	-	-	+
	Citrus reticulata Blanco	-	+	+
	Citrus sinensis(L.) Osbeck	+	+	+
	Zanthoxylum zanthoxyloides Lam. Zep. & T.	-	-	+
Sapindaceae	*Blighia sapida*C. Konig.	-	+	+
Sapotaceae	*Baillonella toxisperma* Pierre	-	+	-
	Chrysophyllum albidum G. Don	-	+	+
Total		7	36	54

Meaning of abbreviations : Pc - *Phragmanthera capitata;* Tb - *Tapinanthus bangwensis*; Tg - *Tapinanthus globiferus*; (+) - Presence of parasite on host; (-) - Absence of parasite on host; * Introduced fruit species

The remaining 11 families, grouped under the heading "Others," are each represented by a single species. Generic diversity is also high, with 44 genera identified (Table 2).The families Anacardiaceae (four genera), Annonaceae, Myrtaceae and Fabaceae (three genera each) are the most diverse, followed by Apocynaceae, Caesalpiniaceae, Euphorbiaceae, Meliaceae, Mimosaceae, Moraceae, Rutaceae and Sapotaceae, each with two genera (Figure 5). The remaining fifteen families are mono-generic.The results also revealed that the *Citrus*genus was the most parasitized with six taxa, followed by *Eugenia*with four taxa, *Annona, Ficus* and *Spondias* with three taxa each, and *Blighia*, *Cola*and *Xylopia* with two taxa each. In addition, *T. bangwensis* and *P. capitata* were dominant on 54 and 36 host taxa, respectively (Table 2).

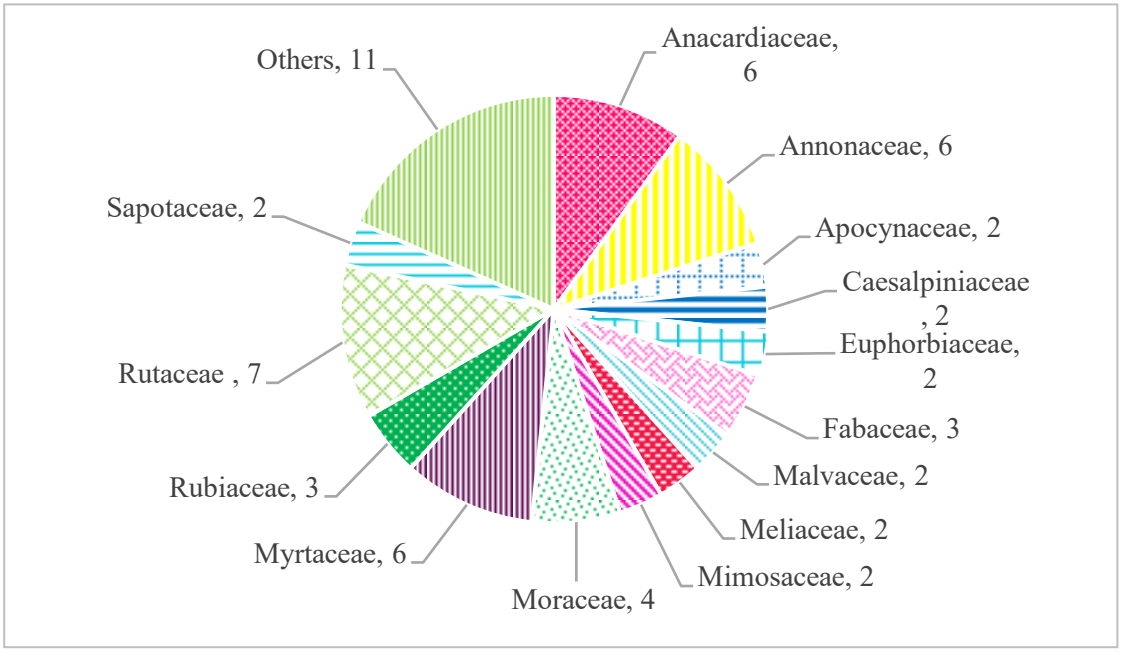


Figure 5: Spectrum of distribution of woody fruit host families

Incidence of Loranthaceae on woody fruit trees

The average incidence of Loranthaceae varies between taxa, from 12.50% in *Morinda lucida* to 100% in *Cola gigantea* (Table 3). The 12 most heavily parasitized woody fruit species were *Cola gigantea*, *Cola nitida*, *Citrus sinensis*, *Garcinia kola*, *Persea americana*, *Lonchocarpus sericeus*, *Pterocarpus santalinoides*, *Spondias mombin*, *Spondias purpurea*, *Strychnos spinosa*, *Terminalia catappa* and *Vitex simplicifolia*. Three species have an average incidence of over 50%, 9 species with an incidence of between 40% and 50%, 21 species with an incidence of

between 30% and 40% excluded, 22 species with an incidence of between 20% and 30% excluded and seven species with an incidence of less than 20% excluded. Furthermore, the results indicate that the most parasitized introduced fruit-bearing woody species are *Cola gigantea* (100%), *Persea americana* (60.60%) (Figure 6), *Cola nitida*, *Terminalia catappa*(Figure 7) with 50% incidence each and *Citrus sinensis* (42.10%). The most parasitized conserved species distributed throughout the cocoa plantations are six in number: *Spondias mombin* (55.38%), *Lonchocarpus sericeus*, *Pterocarpus santalinoides*, *Spondias purpurea*, *Strychnos spinosa* and *Vitex simplicifolia*, with 40% each and *Spondias mombin* 55.38%. The average incidence of Loranthaceae on all fruit trees and shrubs inventoried in the cocoa farms studied was 39.66 ± 7.07% (Table 3).

Table 3:- Impact of Loranthaceae on woody fruit species.

Families	Species	Incidence (%)
Anacardiaceae	**Anacadium occidentale*Linn.	19,71
	Pseudospondias microcarpa(A. Rich.) Engl.	33,33
	*Spondias cytherea*Linn.	26,32
	*Spondias mombin*Linn.	55,38
	*Spondias purpurea*Linn.	40
	*Trichoscypha acuminata*Engl.	33,33
Annonaceae	**Annona muricata* Linn.	27,58
	**Annona senegalensis*Pers.	30,76
	**Annona squarnosa* Linn.	33,33
	Monodora myristica(Gaert.) Dumal	25
	Xylopia aethiopica (Dunal) A. Rich.	26,67
	Xylopia parviflora(A. Rich.) Benth.	25
Apocynaceae	*Calotropis procera* (Aiton) W. T. Aiton	33,33
	Landolphia dulcis(Sabine) Pichon	33,33
Bixaceae	*Bixa orellena*Linn.	30
Bombacaceae	**Adansonia digitata* Linn.	33,33
Burseraceae	*Dacryodes macrophylla*(Oliv.) H. J. Lam	33,33
Caesalpiniaceae	*Detarium microcarpum*Guill. & Perr.	31,81
	**Tamarindus indica*Linn.	33,33
Clusiaceae	*Garcinia kola* Heckel	41,46
Combretaceae	**Terminalia catappa* Linn.	50
Euphorbiaceae	**Jatropha curcas* Linn.	2,17
	Ricinodendron heudelotii (Baill.) Pierre ex Pax	28,57
	Lonchocarpus sericeus(Poir.) DC.	50
Fabaceae	*Prosopis africana*(Guill. & Perr.) Taub.	22,22
	*Pterocarpus santalinoides*DC.	50
Irvingiaceae	*Irvingia gabonensis* (Audrey-Lecomte ex O'Rorke) baill.	29,41
Lamiaceae	*Vitex simplicifolia* Oliv.	50
Lauraceae	**Persea americana* Mill.	60,60
Loganiaceae	*Strychnos spinosa* Lam.	40
Malvaceae	**Cola gigantea*A. Cev. var. *glabrescens* Brenan & keay	100
	**Cola nitida*(Vent.) Schott & Endl.	60
Meliaceae	**Azadirachta Indica*A. Juss.	25
	Carapa procera DC. De Wilde	20
Mimosaceae	**Parkia bicolor*A. Chev.	33,33
	Tetrapleura tetraptera (Schum. & Thonn.) Taub.	28,51
Moraceae	*Antiaris toxicaria* Welwitshii (Engl.) C. C. Berg	33,33
	*Ficus exasperata*M. Vahl	24

	Ficus lutea M. Vahl	24
	Ficus vallis-choudae Del.	22,22
Myrtaceae	**Eugenia jambos* (L.) Alston	33,33
	**Eugenia malaccensis* Linn.	28,12
	**Eugenia miegeana* Aké Assi	20
	**Eugenia owariensis* P. Beauv.	28,57
	**Psidium guajava* Linn.	30,9
	Syzygium guineense (Willd.) DC.	27,27
Olacaceae	*Coula edulis* Baill.	33,33
Rubiaceae	**Coffea robusta* Pierre ex A. Froehner	17,85
	Gardenia erubescens Stapf & Hutch.	33,33
	**Morinda lucida* Benth .	12,5
Rutaceae	**Citrus aurantifolia* (Christm.) Swingle	33,33
	**Citrus aurantium*Linn.	34,78
	**Citrus maxima* (Burm.) Merr.	18,18
	**Citrus limon* Burn. f.	16,67
	**Citrus reticulata* Blanco	32
	**Citrus sinensis*(L.) Osbeck	42,10
	Zanthoxylum zanthoxyloides Lam. Zep. & T.	25
Sapindaceae	*Blighia sapida*C. Konig.	19,67
Sapotaceae	*Baillonella toxisperma* Pierre	25
	Chrysophyllum albidum G. Don	25
Average		39,66±7,07

Figure 6: *Persea americana* heavily parasitized by *T. bangwensis* in a cocoa farm

Figure 7: A branch of *Terminalia catappa* heavily parasitized and under the weight of Loranthaceae clumps

Table 4 presents data on the incidence of Loranthaceae on cocoa trees. It shows that the average incidence varies from 37.22 ± 4.29% (cocoa trees/Toroguhé) to 44.07 ± 2.12% (cocoa trees/Zepreguhé). Zepreguhé cocoa trees were the most parasitized, with an average incidence of 44.07 ± 2.12%, followed by Zakoua (41.69 ± 4.82%), Bribouo (39.64 ± 3.22%) and Toroguhé (37.22 ± 4.29%). However, analysis of variance revealed no significant difference in the average incidence of parasitized cocoa trees between the different cocoa farms according to the Newman-Keuls

test (F = 2.41; p > 0.05).The average total incidence of Loranthaceae on all the cocoa farms studied was 40.65 ± 4.26%.

Table 4:- Proportion of Loranthaceae incidence on cocoa trees.

Sites	Plantations	Incidence (%)	Average incidence (%)
Bribouo	Plt1	43,28	39,64±3,22a
	Plt2	40,28	
	Plt3	39,57	
	Plt4	35,45	
Toroguhé	Plt5	41,86	37,22±4,29a
	Plt6	39,41	
	Plt7	32,1	
	Plt8	35,51	
Zakoua	Plt9	48,77	41,69±4,82a
	Plt10	40,45	
	Plt11	38,02	
	Plt12	39,55	
Zepreguhé	Plt13	45,3	44,07±2,12a
	Plt14	44,52	
	Plt15	40,96	
	Plt16	45,52	
Average			40,65±4,26

In the columns, averages with the same letters indicate no differences (Newman-Keuls test, p > 0.05).

Relationship between the incidence of Loranthaceae infestation on fruit trees and the extent of attacks on cocoa trees

Table 5 shows the correlation between the average incidence of Loranthaceae recorded on fruit trees and infested cocoa trees. It shows a significant positive correlation between the incidence of Loranthaceae on ligneous fruit trees and that observed on cocoa trees (p = 0.000; r = 0.79).

Table 5: Correlation between the incidence of Loranthaceae infestation on fruit species and cocoa trees

Items	Incidence (%)/cocoa tree	Incidence (%)/woody fruit species
Incidence (%)/cocoa tree	1	
Incidence (%)/woody fruit species	0,79*	1

The value marked * shows a significant correlation at the threshold of α = 0.05 (Incidence (%)/cacaoyer-Incidence (%)/woody fruit species).

Discussion:-

Studies carried out in cocoa agroforestry systems in the Daloa region have identified three species of Loranthaceae. These are *Phragmanthera capitata* (Sprengel) S. Balle, *Tapinanthus bangwensis* (Engler Danser) and *T. globiferus* (A. Richard) Van Tieghem. These parasitic species are not specific to either the fruit species or the cocoa plantations surveyed. The results confirm those of Ballé & Halle (1961) and Amon (2014), who have already reported the wide distribution of these parasites in several regions of Côte d'Ivoire. Of these three parasites, the ubiquity of *T. bangwensis*stands out. Highly abundant in cocoa plantations, the species presented a very broad spectrum of woody hosts compared with the other two species.Our results show 60 Loranthaceae woody fruit host species in the cocoa plantations studied. The fruit-bearing species are divided into 44 genera and 25 families.This number far exceeds the 19 host species recorded by Yao (2020) in village cocoa plantations around Daloa, as well as the 11 host species collected by Soro (2010) in Oumé, Gagnoa and Soubré, in west-central Côte d'Ivoire. The floristic richness observed in this study is thought to be due to the year-on-year extension of Loranthaceae proliferation within cocoa

orchards, affecting various wild or cultivated trees and shrubs (Sako, 2019; Yao, 2020).Furthermore, the families of the fruiting woody host spectrum of Loranthaceae in cocoa plantations are characterized by a dominance of the Rutaceae families (seven host species), the Anacardiaceae, Annonaceae and Myrtaceae (six host species each), the Moraceae (four host species) and the Fabaceae and Rubiaceae families (three host species each). This result corroborates that of Houenon et al. (2012) and Amon (2014), who previously reported the significant attack of species in the families Annonaceae, Moraceae and Rutaceae by Loranthaceae. A high incidence of these parasites was recorded on well-known fruiting ligneous plants that are very useful to farmers during the lean season, such as *Cola gigantea* (100%), *Persea americana* (71.43%), *Cola nitida* (60%), *Citrus sinensis* (50%) and *Psidium guajava* (47.05%). These results are in line with those published by Cleck (1978) in Ghana and Sako (2019) in Côte d'Ivoire on *Cola nitida*, Sonké et al. (2000) and Dibong et al. (2009) on *Persea americana* in Cameroon and Houénon et al. (2012) on *Citrus sinensis* in Benin.The presence of these fruit trees in cocoa plantations in tropical Africa, particularly in Côte d'Ivoire, under the influence of Loranthaceae, needs to be monitored and controlled by farmers to prevent them from becoming foci of infestation for cocoa trees. Our results revealed a significant positive correlation between the incidence of Loranthaceae on woody fruit trees and that observed on cocoa trees. This correlation suggests that the presence of woody fruit species found to be particularly susceptible to Loranthaceae infestations, such as *Persea americana* (60.60%), *Spondias mombin* (55.38%), *Cola nitida* (50%), *Psidium guajava* (47.05%) and *Citrus sinensis* (42.10%), would influence the expansion of these parasites on cocoa trees. Our results revealed a significant positive correlation ($p = 0.000$; $r = 0.79$) between incidence of Loranthaceae on woody fruit trees and that observed on cocoa trees. This correlation suggests that the presence of woody fruit species found to be particularly susceptible to Loranthaceae infestations, such as *Persea americana* (60.60%), *Spondias mombin* (55.38%), *Cola nitida* (50%), *Psidium guajava* (47.05%) and *Citrus sinensis* (42.10%), would influence the expansion of these parasites on cocoa trees.

Conclusion and Recommendations:-

The aim of this work was to identify Loranthaceae species and their fruiting woody hosts in cocoa plantations in order to assess the influence of their proximity on the level of infestation of cocoa trees. Surveys revealed three Loranthaceae species: *Phragmanthera capitata*, *Tapinanthus bangwensis* and *T. globiferus*, of which *T. bangwensis* was found to predominate. These species parasitize 62 fruit species present in Daloa's cocoa plantations. These host species are divided into 44 genera and 25 families. The families most affected are the Rutaceae (7 species), followed by the Anacardiaceae, Annonaceae and Myrtaceae (6 species each). The results showed that several well-known fruit trees, such as *Persea americana* (60.60%), *Spondias mombin* (55.38%), *Cola nitida* (50%), *Terminalia catappa* (50%), *Citrus sinensis* (42.10%) and *Garcinia kola* (41.46%), had a high incidence. The incidence of Loranthaceae on fruit species was $39.66 \pm 7.07\%$, compared with $40.65 \pm 4.26\%$ on cocoa trees. Furthermore, a significant positive correlation was found between the incidence of these parasites on woody fruit trees and that observed on cocoa trees. Future studies could explore other factors (agricultural practices, environmental conditions, etc.) likely to influence the expansion of Loranthaceae and identify species less vulnerable to these pests in order to integrate them into plots and promote sustainable cocoa agroforestry.

Acknowledgements:-

Our sincere thanks to the chiefs of the study sites and to the farmers for authorizing access to the cocoa farms surveyed.

Authors' contributions

All the authors contributed to the various stages of this work and approved the final version of the manuscript.

References:-

1. Aké-Assi, L. (1984). Flora of Côte d'Ivoire: A Descriptive and Biogeographical Study with Some Ethnobotanical Notes. Doctorate in Natural Sciences, Faculty of Science and Technology, National University, Abidjan, Côte d'Ivoire, 665 p.
2. Aké Assi, L. (2002). Flora of Côte d'Ivoire 2: Systematic Catalog, Biogeography, and Ecology. Conservatory and Botanical Gardens, Geneva, 401 p.
3. Amon, A.D.E. (2014). Loranthaceae (mistletoe), Vascular Hemiparasites of Trees and Shrubs in Agrosystems of the Sud-Comoé Region, in the Dense Evergreen Forest Zone of Côte d'Ivoire. Doctoral Thesis, Department of Biosciences, Félix Houphouët-Boigny University (Abidjan, Côte d'Ivoire), 213 p.

4. Arbonnier, M. (2002). Trees, shrubs and lianas of the dry zones of West Africa. CIRAD-MNHN, Paris, France, 576 p.
5. Asare-Bediako, E., Addo-Quaye, A.A., Tetteh, J. P., Buah, J.N., Van Der Puije, G.C. & Acheampong, R. A. (2013). Prevalence Of Mistletoe On Citrus Trees In The AburaAsebu-Kwamankese District Of The Central Region Of Ghana. *International Journal of Scientific & Technology Research* (2) 7: 122-127
6. Balle, S. & Halle, N. (1961). Les Loranthaceae de la Côte d'Ivoire. Édition Adansonia, 23 p.
7. Bongers, F., Poorter, L. & Hawthorne, W.D. (2005). The forests of Upper Guinea: gradients in large species composition. In: Poorter L., Bongers F., Kouamé F.N., Hawthorne W.D. (éd.). Biodiversity of West African Forest. An ecological atlas of woody plants species. Wallingford, Royaume-Uni, *CABI Publishing*: 41-52
8. Boussim, I.J. (2002). Parasitic phanerogams of Burkina Faso: inventory, taxonomy, ecology, and some aspects of their biology. Special case of Loranthaceae parasites of shea. State Doctorate Thesis in Natural Sciences, F.S.T., University of Ouagadougou (Ouagadougou, Burkina Faso), 285 p.
9. Clerk, G. (1978). *Tapinanthus bangwensis* in a Cola plantation in Ghana. PANS 24: 57-62.
10. Eldin, M. (1971). Climate. In: The Natural Environment of Côte d'Ivoire. ORSTOM Dissertation, 50, Paris, France: 73-108.
11. Guichard C. (2022). Influence of *Erythrina poeppigiana* on cocoa trees in Dominican agroforestry systems. Master's thesis in Plant Biodiversity and Tropical Ecosystem Management (BIOGET), University of Montpellier, France, 64 p.
12. Houenon, G.J., Yedomonhan, H., Adomou, A.C., Tossou, G. M., Akoegninou, A. & Traoré, D. (2012). Specific Diversity of Loranthaceae, Citrus Parasites and Their Impact on Citrus Production in Southern Benin. *European Journal of Scientific Research*: 527-538.
13. ICCO (2020). Annual Report 2019/2020. International Cocoa Organization (ICCO), London WC1A (United Kingdom), 5 p. https://www.icco.org/wp-content/uploads/Production QBCSXLVII-No.-4.pdf (accessed 17/03/2024)
14. Kébé, B.I., Koffi, N., Konan, A., N'guessan, K.F., N'goran, J. & Irié, B.Z. (2005). Growing Cocoa Well. Technical Sheet. National Center for Agronomic Research, August 2005, 4 p.
15. Koffie-Bikpo, C.Y. & Kra, K.S. (2013). The Haut-Sassandra Region in the Distribution of Agricultural Food Products. *Journal of Tropical Geography and Environment*, 2: 95-103
16. ICCO. (2020). Rapport annuel 2019/2020. International Cocoa Organization (ICCO), Londres WC1A (Royaume Uni), 5 p. (accessed 03/17/2024)
17. N'guessan, A.H., N'guessan, K.F., Kouassi, K.P., Kouamé, N.N. & N'guessan, P.W. (2014). Population dynamics of the cocoa stem borer, Eulophonotus mymeleon Felder (*Lepidoptera: Cossidae*) in the Haut-Sassandra region of Côte d'Ivoire. *Journal of Applied Biosciences* 8: 1-11
18. Nair, P.K.R., Kumar, B.M. & Nair V.D. (2021). Definition and Concepts of Agroforestry. In: Nair, P.K.R., Kumar, B. M., Nair, V.D. (eds.). An Introduction to Agroforestry: Four Decades of Scientific Developments. Cham: *Springer International Publishing*: 21 28. Available at: https://doi.org/10.1007/978-3-030-75358-0_2 (Accessed 12/04/2024).
19. Ngotta Biyon, J.B., Iyodi, A.B., Wafo Tchoue, Y.D., Ondoua, J.M. & Taffouo, V.D. (2022). Loranthaceae Parasitism on Theobroma cacao L. (Malvaceae) in the Tombel District (Southwest Cameroon). *International Journal of Biological and Chemical Sciences* 16(3): 1113-1122
20. POGCI: Official Portal of the Government of Côte d'Ivoire (2023). Coffee-cocoa sector: as of December 31, 2022. https://www.gouv.ci/_actualite-article.php?recordID=15024 (accessed 15/09/2024)
21. Sako, H. (2019). Loranthaceae Parasitism on Crops: Case of Plantations in the Riparian Zones of Jean Lorougnon Guédé University (Côte d'Ivoire). Master's Thesis in Bioresources and Agronomy, Agroforestry Department, Jean Lorougnon Guédé University (Daloa, Côte d'Ivoire), 58 p.
22. Sonké, B., Kenfack, D. & Tinto, M. (2000). Parasitism of Avocado (*Persea Americana*, Lauraceae) by Loranthaceae in the Yaoundé Region (Cameroon).*Fruit*s (55): 325-33.
23. Soro, K. (2010). Loranthaceae or mistletoes, vascular plants parasitic on cultivated and uncultivated trees and shrubs in western Côte d'Ivoire: the case of the Oumé, Gagnoa and Soubré departments. Single Thesis in Plant Ecology, Agroforestry option, University of Cocody (Abidjan, Côte d'Ivoire), 189 p.
24. Yao, K. M. (2020). Diversity and extent of Loranthaceae attacks in cocoa (*Theobroma cacao*L.) plantations in the Daloa region (Central-West, Côte d'Ivoire). Master's thesis in Bioresources-Agronomy, UFR Agroforestry, Jean Lorougnon Guédé University (Daloa, Côte d'Ivoire), 42 p.