Ecologia

ISSN 1996-4021

Academic
Journals Inc.

www.academicjournals.com

OPEN ACCESS Ecologia

ISSN 1996-4021
DOI: 10.3923/ecologia.2020.101.109

Research Article
Loranthaceae Species Infesting Shea Trees (*Vitellaria paradoxa* Gaertn. C.F.) and Factors Involving Attacks in Northern Côte D'Ivoire

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Abstract

Background and Objective: Shea trees in agroforestry parklands in Northern Côte d'Ivoire are the main target of the Loranthaceae, parasite vascular plants that constitute a constraint for the availability of the shea genetic resources. The purpose of this study was to reveal the level of infestation of shea trees by Loranthaceae species and to identify some factors influencing the attacks in the parklands. **Materials and Methods:** The survey was conducted in October, 2019 in two shea parklands located at Ouangolodougou and Ferkéssédougou. The roving method was used to inventory infested shea trees on an area of 2 ha delimited in the visited parklands. **Results:** The results revealed that the two visited parks are infested by two species of Loranthaceae that are *Tapinanthus bangwensis* (Engl. and Krause) Danser and *Agelanthus dodoneifolius* (DC.) Polh et Wiens and infesting rates vary from 59.66-65.51%. *A. dodoneifolius* was the most frequent and abundant. The cartography of the infestation revealed an aggregate distribution of infested (Distribution Index or I varying from 1.10-2.54) and not infested (I varying from 1.70-1.90) suggesting a short-distance dissemination of the Loranthaceae seeds by the birds. **Conclusion:** These results demonstrate that the shea parks are threatened with disappearance seen the high level of the plant parasitic infestation. It is appeared essential that research elaborates strategies to struggle against the Loranthaceae to secure shea exploitation in Côte d'Ivoire.

Key words: Shea tree, Loranthaceae, infestation, distribution index, Northern Côte d'Ivoire

Citation: Yao, S.D.M., N. Diarrassouba, K.A. Alui, K.S.B. N'Goran, E.B.Z. Koffi and I.J. Fofana, 2020. Loranthaceae species infesting shea trees (*Vitellaria paradoxa* Gaertn. C.F.) and factors involving attacks in Northern Côte d'Ivoire. Ecologia, 10: 101-109.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Vitellaria paradoxa (C.F. Gaertn.), commonly called shea or "*Shi*" in Bambara, is a Sapotaceae endemic to the Sudanese savannahs of Southern Sahara Africa. *V. paradoxa* covers a geographical band of about 5000 km from Senegal to Uganda at latitudes varying between 2° and 8° North in East Africa, 7° and 12° North in Central Africa and between 9° and 14° North in West Africa[1]. The shea tree produces fruits with an edible pulp containing high-fat almonds[2]. Similarly, other organs of the shea tree are used in traditional rituals, pharmacopoeia, cosmetics, construction and food[2,3]. Despite the importance of the species, which provides a substantial income to women shea butter processors, it is severely threatened by parasitic plants of the Loranthaceae family[4,5].

Loranthaceae are vascular parasitic plant present in all inter-tropical regions and in some temperate zones[6]. In Côte d'Ivoire and also in countries such as Cameroon, Gabon, Burkina Faso, Ghana, Mali and many others, Loranthaceae cause significant damage to cultivated or natural trees and shrubs[6-9]. An infestation of shea trees by Loranthaceae significantly and negatively impacts tree viability and fruit yields[4]. Before the death of the infected and weakened host species (shea tree), the most apparent disturbances caused by Loranthaceae are: Invasion of the parasitized tree, defoliation of infested feet particularly in the attacked area and hypertrophy of the part of the branch located downstream from the point of attachment of the parasite[5]. In the shea tree, cavities caused by parasitic plants in the host make it more vulnerable to other pathogens and also lead to the depreciation of the quality of wood, which is highly valued in woodworking[4]. The inventory of Loranthaceae species specifically infesting the shea tree population at Tengrela revealed two species that are *Agelanthus dodoneifolius* (D.C.) Polh and Wiens and *Tapinanthus bangwensis* (Engl. and Krause) Danser[4]. In Northern Côte d'Ivoire, while the level of infestation of trees and shrubs in general by parasitic plants is estimated at 5.47% in Katiola[5], it is specifically reported on shea trees in Tengrela that 96% of individuals are parasitized[4]. Given the threat, it is necessary to assess the level of infestation in parks throughout the shea production zone in Côte d'Ivoire. The general objective of the study was to assess the level of infestation of two shea parks and identify determinants influencing parasitism in the Tchologo region covering the departments of Ferkéssédougou and Ouangolodougou.

MATERIALS AND METHODS

Study area: The study was conducted in October, 2019 in the Technology region in Northern Côte d'Ivoire covering Ferkéssédougou and Ouangolodougou departments (Fig. 1). These localities are situated between 9°31' and 9°35' North latitude and 5°11' and 6°29' West longitude. The climate is the Sudano-Guinean type with annual rainfall varying between 1200 and 1500 mm according to Diarrassouba *et al.*[3] The climate is marked by an alternation of two seasons: Dry season very marked by the harmattan between December and January with one of the heat peaks in March and April. The rainy season extends from May to October with maximum rainfall in July and August. The soils under shea tree populations in Ferkéssédougou and Ouangolodougou localities are of the Cambisol and Ferralsol types respectively[10].

Plant material: Shea trees which populate two parklands, one at Ferkéssédougou and the other at Ouangolodougou were observed. The shea parklands of Ferkéssédougou and Ouangolodougou have a density of 15 and 37.5 trees ha^{-1}, respectively.

Inventory of parasitic Loranthaceae and infestation intensities assessment: The study is based on observations made in the shea parkland studied. An area of 2 ha was delineated in each shea parkland. On this study area, all the shea trees were systematically observed. A total of 105 trees were observed, including 30 in Ferkéssedougou and 75 in Ouangolodougou. Parasitized or non-parasitized (healthy) shea trees were observed and quantified. The identification of Loranthaceae species parasitizing shea trees at the two study sites was carried out by comparison with those previously listed by some authors in previous studies[4,7] as well as specimens kept at the Centre National de Floristique (CNF) of the University of Félix Houphouet Boigny (UFHB), Abidjan, Côte d'Ivoire. To assess the level of infestation of each shea tree a scale from 0-7 was used with 0 for "not infested" and for infested shea trees the infestation intensities were 3 for "low", 5 for "middle" and 7 for "high" according to International Plant Genetic Resources Institute[11]. The Infestation Rate (IR) of shea parks was evaluated following mathematic expression[5]:

$$IR = \frac{n \times 100}{N} \quad (1)$$

where, n is the number of infested shea trees and N the total number of shea trees (infested and not infested).

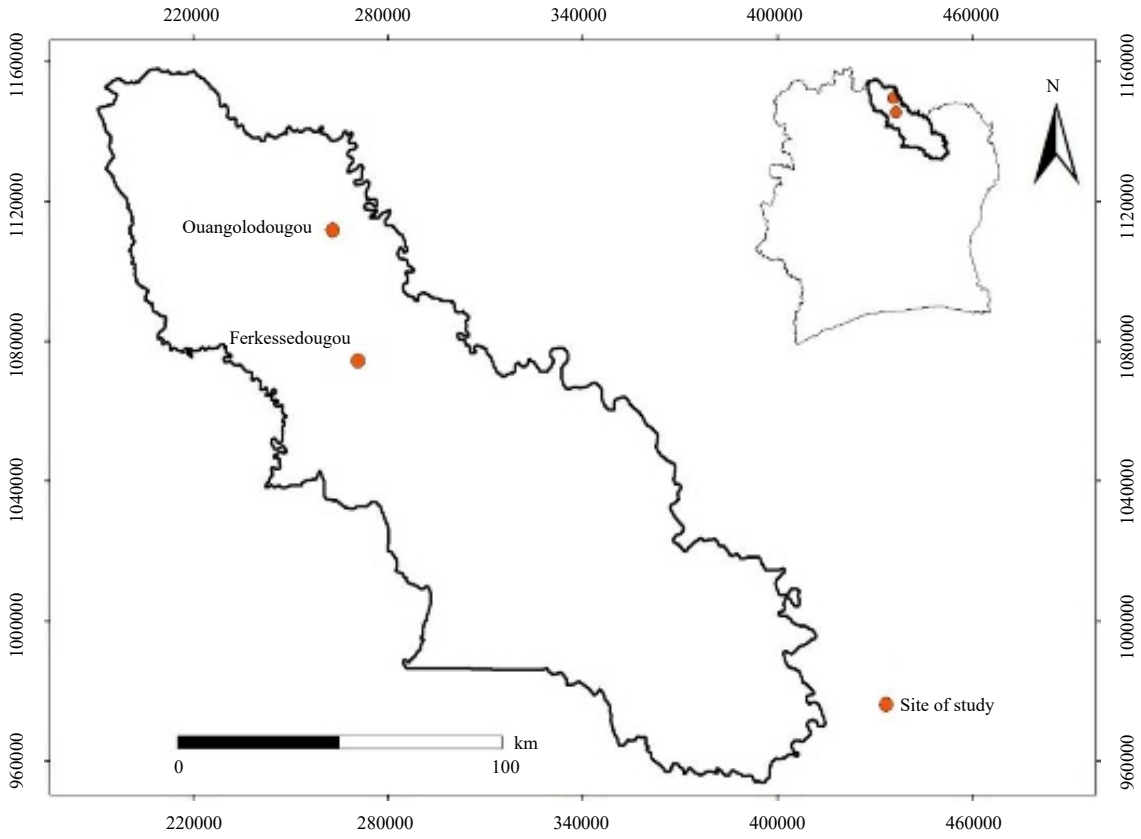

Fig. 1: Map showing the two sites of study; Ouangolodougou and Ferkessedougou
Source: Shea breeding program of Côte d'Ivoire

Cartography and spatial structure of infestations: In order to evaluate the infestation mapping at the scale of the delimited area in the parkland, geographical coordinates of all shea trees with theirs associated infestation intensity was carried out using a Global Position System (GPS). The quadrat method was used to define the spatial structure of the infestation at the scale of the delimited area in the shea parkland[12]. The quadrat method consists to cover the study site with regularly shaped K-meshes. The trees under consideration were represented as points after geo-location using the geographic coordinates processed with ArcGIS software. The average number of infested or not-infested shea trees per mesh is equal to m = A/K. Each mesh Ki has been associated with a number Ai of infested or non-infested trees. Then, the variance (δ^2) was calculated in order to deduce the Distribution Index (I) from the health status of the tree (infested or not-infested) according mathematical expression established by Canard and Poinsot[12] in Eq. 2:

$$I = \frac{\delta^2}{\mu} \quad (2)$$

with δ^2 the variance of the number of individuals (infested or not infested shea trees) per quadrat or mesh and μ the average number of individuals (infested or not infested shea trees) per quadrat or mesh.

Statistical analysis: The degrees of association between infestation and locality were assessed using crosstab, Pearson's Chi-square tests and Cramer's V associated measures with 5% probability thresholds. Analyses were performed using SPSS version 20 (IBM Corp., USA). The dispersion index test was used to test the significance of the Distribution Index (I) relative to 1 (random assignment) [12]. When I is significantly different to 1 then the distribution is aggregated (I>1) or regular (I<1) [12].

RESULTS

Diversity of parasitic Loranthaceae infesting shea trees: Shea trees populated the two parklands were infested by two species of Loranthaceae from two genera (*Agelanthus* and *Tapinanthus*). These are *Tapinanthus bangwensis* (Engl. and

Fig. 2(a-c): View of an (a) Infested shea tree branch, (b) *Tapinanthus bangwensis* (Engl. and Krause) Danser and (c) *Agelanthus dodoneifolius* (DC.) Polh and Wiens inventoried in the shea parklands at Ferkessédougou and Ouangolodougou in Northern Côte d'Ivoire

Table 1: Presence or absence of two species of parasitic plants from *Loranthaceae* family identified in Ouangolodougou and Ferkéssedougou shea parklands

Species of parasite plant	Ouangolodougou (Infestation rate)	Ferkéssedougou (Infestation rate)
Tapinanthus bangwensis (Engl. et Krause) Danser	Absent	Present (3.44%)
Agelanthus dodoneifolius (DC.) Polh et Wiens	Present (100%)	Present (99.56%)

Krause) Danser and *Agelanthus dodoneifolius* (DC.) Polh and Wiens (Fig. 2a-c) corresponding respectively to the herbarium numbers UCJ011701 and UCJ011685 of the Centre National de Floristique, Abidjan, Côte d'Ivoire. The parasitic plant species *T. bangwensis* and *A. dodoneifolius* were found on both shea trees at the Ferkéssédougou parkland while only *A. dodoneifolius* was infested shea trees at the Ouangolodougou parkland (Table 1). From an epidemiological point of view, when *T. bangwensis* was present in Ferkessedougou, this species infested only 3.44% of shea trees whereas *A. dodoneifolius* infested 96.56% of shea trees (Table 1).

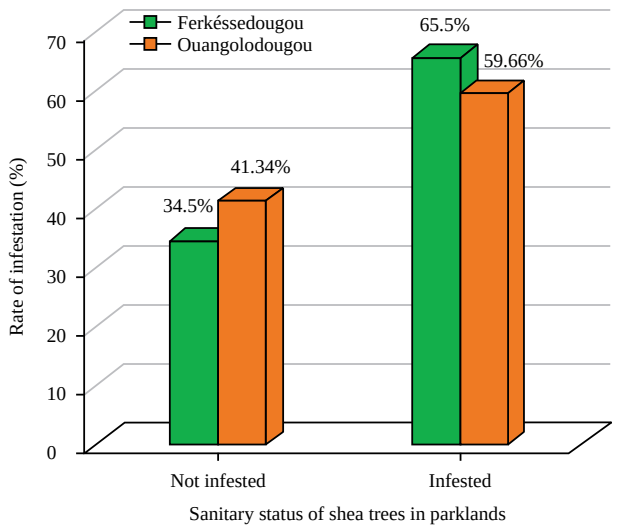

Fig. 3: Infestation pressure by parasitic plants (*A. dodoneifolius* et *T. bangwensis*) in shea parklands in Ferkéssedougou and Ouangolodougou localities

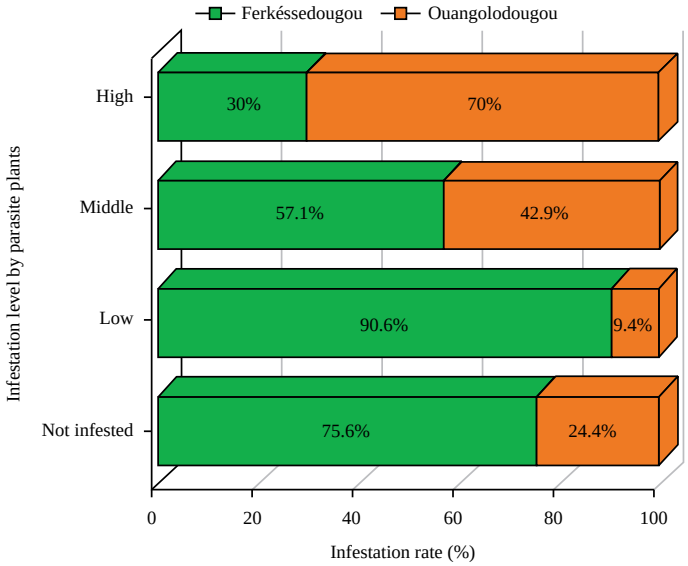

Fig. 4: Parkland infestation intensities by parasitic plants (*A. dodoneifolius* et *T. bangwensis*) in Ferkéssedougou and Ouangolodougou localities

Intensity of shea trees infestations by *A. dodoneifolius* and *T. bangwensis* in parklands: The shea parkland of Ferkéssédougou recorded the highest parasitic pressure (65.51%) compared to the Ouangolodougou parkland where 59.66% of the shea trees were infested (Fig. 3). From total number of observed shea trees in two parklands (105 trees), the rate of not infested shea trees were 24.4% at Ferkéssédougou and 75.6% at Ouangolodougou, low infested was 9.4% at Ferkéssédougou and 90.6% at Ouangolodougou, middle infested were 42.9% at Ferkéssédougou and 57.1% at Ouangolodougou and highly infested were 70% in Ferkéssédougou and 30% in Ouangolodougou (Fig. 4). The association test carried out using the crosstab revealed a significant association between locality and shea trees infestation by *T. bangwensis* and *A. dodoneifolius* (χ^2 = 16.862; p = 0.001). The significant association between locality and infestation had a mean magnitude translated by Cramer's V statistic (Cramer's V value = 0.403; p = 0.001) (Table 2).

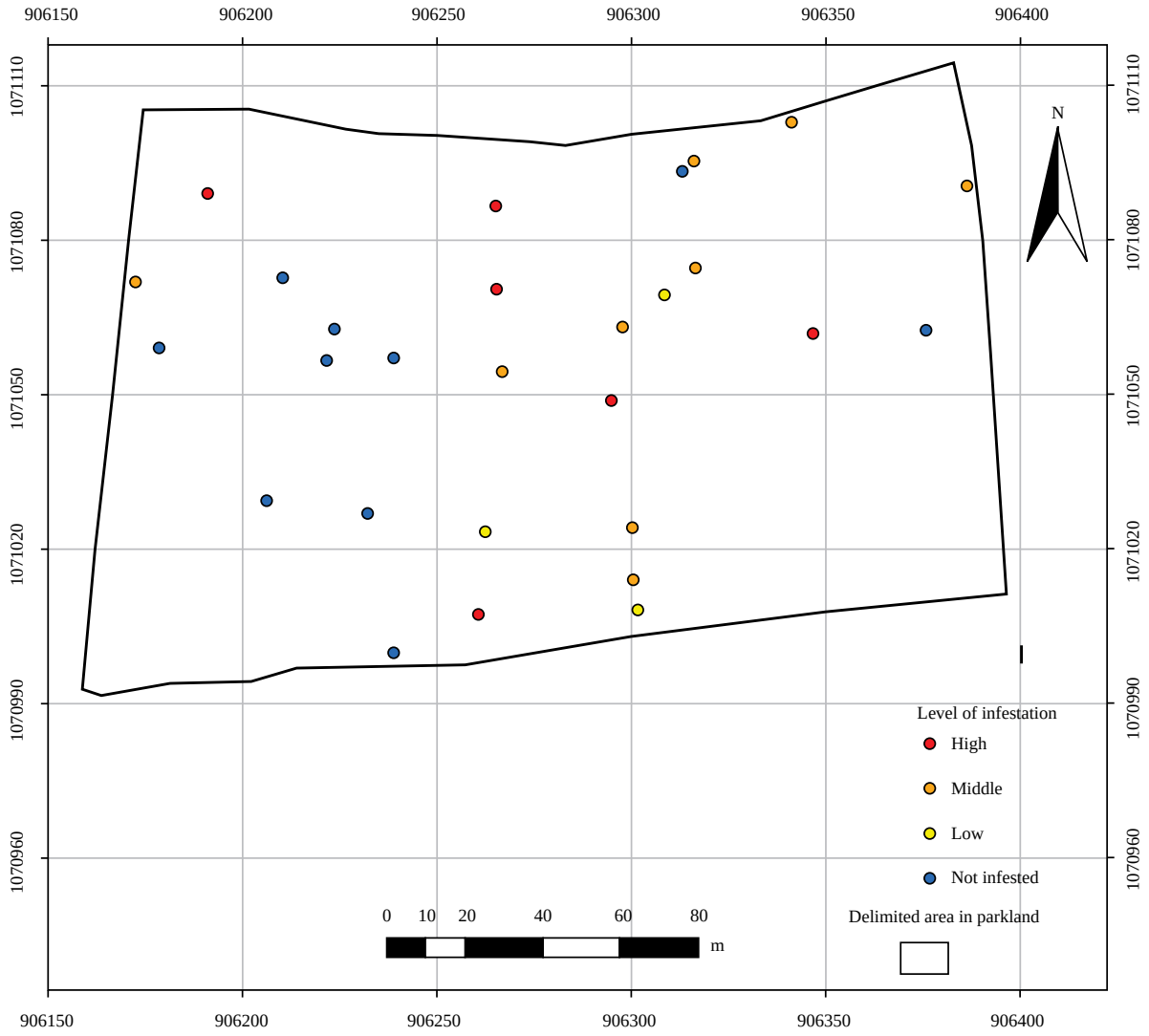

Fig. 5: Infestation map showing spatial repartition of infestation levels of shea trees by *Loranthaceae* species at the studied parkland scale in Ferkéssedougou

Table 2: Statistic parameters associated to crosstab analysis between locality and infestation level shea trees by *Loranthaceae* species

Statistic parameters	Value	p-value
Pearson chi-square	16.862	0.001
Cramer'V	0.403	0.001

Map and spatial structure of infestations at the shea parkland scale: At the scale of the studied shea parklands, the spatial distributions of infested and not-infested shea trees are shown in Fig. 5 and 6. The map show aggregated spatial repartition of infested and not-infested shea trees at the scale of the studied parkland at Ferkéssedougou (Fig. 5) where the distribution indices of shea trees by parasitic Loranthaceae were ranged from 1.10 (infested shea trees) to 1.90 (not infested shea trees) (Fig. 5, Table 3). Likewise, at Ouangolodougou studied parkland the spatial repartition of infested and not-infested shea trees is aggregated (Fig. 6). The distribution indices of not infested (I = 1.27) and infested (I = 1.27) shea trees shea trees by parasitic Loranthaceae showed aggregated spatial repartition of infested and not-infested shea trees at the scale of the studied parkland (Fig. 6, Table 3). These distribution indices are significantly higher than 1 (Table 3).

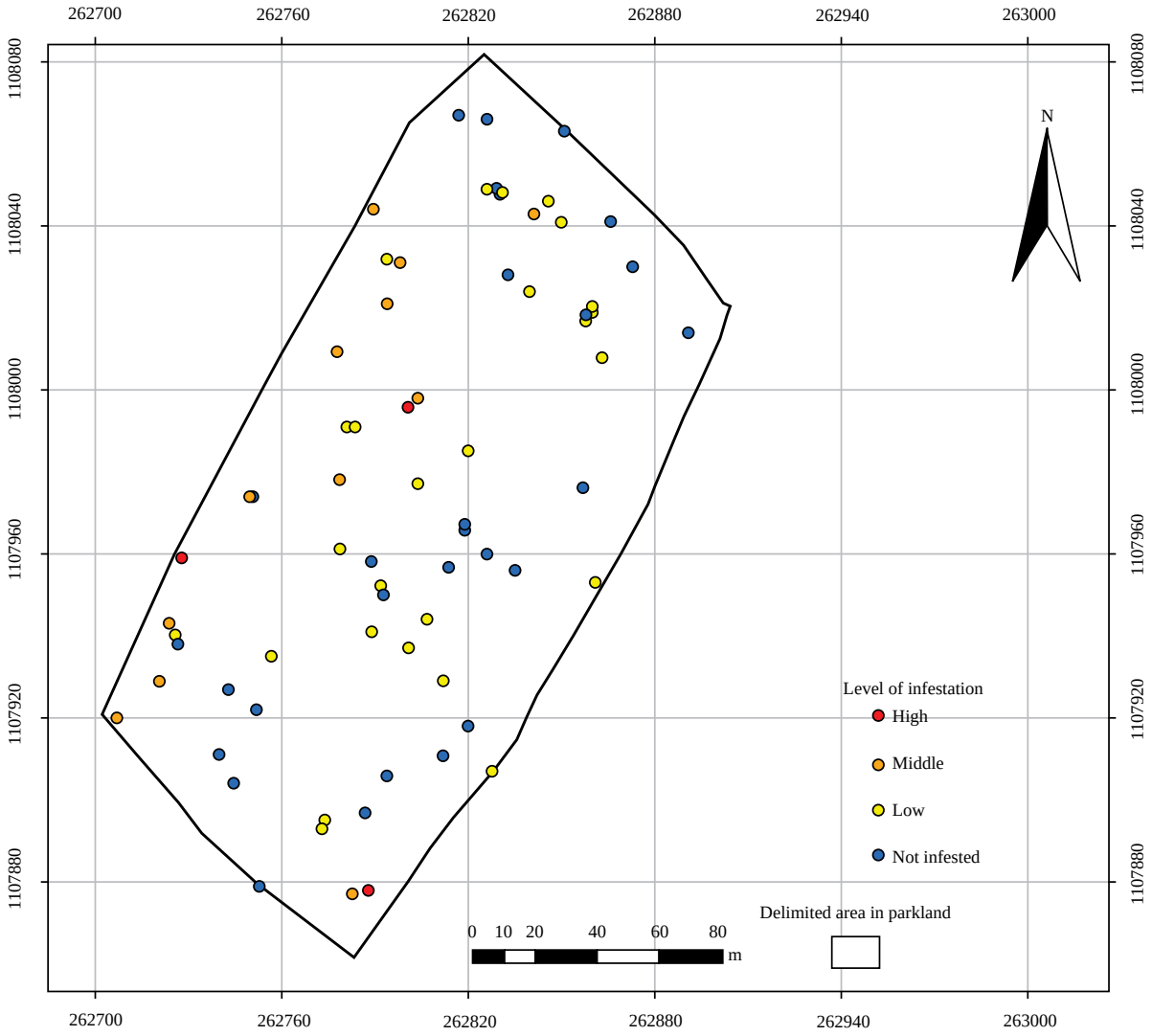

Fig. 6: Infestation map showing spatial repartition of infestation levels of shea trees by *Loranthaceae* species at the studied parkland scale in Ouangolodougou

Table 3: Spatial repartition of infested and no infested shea trees at the scale of studied parklands in Ouangolodougou and Ferkessedougou

	Ouangolodougou		Ferkessédougou	
	No infested shea trees	Infested shea trees	No infested shea trees	Infested shea trees
Repartition index (I)	1.27*	2.56*	1.90*	1.10*
Type of structure	Aggregate	Aggregate	Aggregate	Aggregate

*Value significantly superior to 1

DISCUSSION

Two parasitic Loranthaceae from two genera (*Tapinanthus* and *Agelanthus*) infest the shea trees populating the parks of the localities of Ferkéssedougou and Ouangolodougou. These are *Tapinanthus bangwensis* (Engl. and Krause) Danser and *Agelanthus dodoneifolius* (D.C.) Polh and Wiens. This result is similar to that of Soro *et al.*[4] who also inventoried these two species of Loranthaceae family on shea trees in a Tengrela parkland in Far North of Côte d'Ivoire. The present results reinforce the idea that the parasitic Loranthaceae species dependent on shea trees are essentially *T. bangwensis* and *A. dodoneifolius* although both are ubiquitous. From an epidemiological point of view, when

T. bangwensis was present at Ferkessedougou, this parasitic plant species only infested 3.44% of the shea trees while *A. dodoneifolius* is very frequent and very invasive. This result has also been reported in the study of the Loranthaceae infesting trees and shrubs in Katiola (North-Central Côte d'Ivoire)[5].

The rates of shea trees infested by *T. bangwensis* and *A. dodoneifolius* in the parks of the localities of Ferkéssédougou and Ouangolodougou vary from 59.66-65.51%. This result revealed that more than half of the shea trees in the studied parkland are infested. However, this infestation rate was lower than that reported on shea parkland at Tengrela where 96% of shea trees are infested[4]. Also, the inventory of Loranthaceae infesting trees and shrubs in agroforestry systems at Katiola in North-Central of Côte d'Ivoire revealed the two species *T. bangwensis* and *A. dodoneifolius* as mainly infesting plants from the family of Sapotaceae from which shea tree is classified[5]. This could be explained by the fact that shea tree dominates the agroforestry system in the Northern Côte d'Ivoire. This heliophilous Loranthaceae preferring to settle on the periphery of the host trees would therefore have found shea trees as favorable candidates to fill their need from daylight. Indeed, Loranthaceae which are hemiparasites draws the water and mineral salts which it needs using their haustorial apparatus directly in the wood of the host plant. However, Loranthaceae must achieve their carbon nutrition through photosynthesis hence the increased need for daylight which can only be satisfied if they are installed on the branches in the tops of host plants[5-13]. It is also revealed that the germination of Loranthaceae seeds requires the addition of light[6].

Factors explaining *T. bangwensis* and *A. dodoneifolius* infestations in shea trees populate the studied parklands have been revealed. While the locality influences the level of infestation, the infestation itself is spatially distributed across the shea parkland. As far as the locality is concerned, the Ferkéssédougou shea parkland has a higher parasitic rate than that of Ouangolodougou. This could be explained by the fact that the shea trees in Ferkéssedougou parkland are infested by two different species of Loranthaceae whereas only one species has been found on the shea trees in Ouangolodougou. The interference pressure is therefore higher in Ferkéssédougou than in Ouangolodougou. In terms of the infestation spatial distribution, the results revealed that on the scale of a shea agroforestry park, the distribution of both infested and not infested individuals is aggregative. The probable cause of this aggregate distribution is the low dispersal capacity of Loranthaceae seeds compared to their reproductive capacities[12]. In the literature two dispersal mechanisms of the Loranthaceae seeds by animals (bird or mammal) have been described: short-distance dispersion and long-distance dispersion[14]. In the short-distance dispersal mechanism, Loranthaceae seed are spread by birds that feed on the viscin (sticky pulp) of their fruits. After consumption of the pulp, the seeds rejected via the droppings if the berries have been ingested (case of endozoochory) or the seeds impregnated with viscine remain stuck on the fine beak of the bird with a small throat. Thus, these seeds are transported and deposited from branch to branch or from tree to tree and give to new parasite plants after germination[6-14]. In the long-distance dispersal mechanism, also known as an epizoochory, the seeds of the berries cling to bird feathers or mammalian fur, ensuring long-distance transport[14]. In this study, the short-range seed dispersal mechanism seems the most likely to explain the aggregate distribution of the infestation. The birds are the main Loranthaceae seed disseminators from consumed berries in the shea parklands of Ferkéssédougou and Ouangolodougou. These disseminator birds participate in the over-infestation of branches of a tree or neighboring trees showing infested shea trees in some spot at shea parkland scale[14].

The results generated in the present survey reinforce the idea that two Loranthaceae species infest shea trees in the agroforestry parks in Northern Côte d'Ivoire. The short-range seed dispersal mechanism by the birds of the Loranthaceae seed has been clearly revealed. In spite of the species of the birds implied in the Loranthaceae, seed dispersion have been not identified in the present study these results suggest the using some agroforestry techniques such as infested branches cutting to control parasitic Loranthaceae in shea parklands.

CONCLUSION

Two species of Loranthaceae that are *Tapinanthus bangwensis* (Engl. and Krause) Dancing and *Agelanthus dodoneifolius* (D.C.) Polh and Wiens infest the shea trees in Ferkéssedougou and Ouangolodougou localities. Infestation rates range from 59.66-65.51%. In the studied shea parkland, *A. dodoneifolius* is more frequent and invasive than *T. bangwensis*. The search for determinants influencing the distribution of the infestation revealed two factors, namely the locality and the aggregate spatial distribution of the infestation, suggesting a short-distance spread of Loranthaceae seeds by birds. The knowledge generated in this study are useful in the efficient management of shea genetic resources in Côte d'Ivoire.

SIGNIFICANCE STATEMENT

This study has discovered that two Loranthaceae species, *Tapinanthus bangwensis* (Engl. and Krause) Dancing and *Agelanthus dodoneifolius* (D.C.) Polh and Wiens, infest shea trees in Northern Côte d'Ivoire. Likewise, it has shown the short-range seed dispersal mechanism at the origin of the infestation dynamic in shea parklands. These knowledge can be beneficial for researchers and help them to control the shea trees bio-aggressors and to define or improve shea genetic resource conservation programs in Côte d'Ivoire. Basis of the infestation dynamic at the scale of shea parkland a new theory about the control of the Loranthaceae species parasitizing shea trees may be arrived at.

ACKNOWLEDGMENTS

The authors thank to the Fond Compétitif pour l'Innovation Agricole (FCIAD) of Côte d'Ivoire, which fully funded this work through the fellowship agreement 1674/FIRCA/UPGC/FADCI-FCIAD/2017, the Centre National de Floristique (CNF) for Loranthaceae species identification and Technicians (Kacou Williams Harries and Zie Bamba) of shea breeding program of Côte d'Ivoire for help then data collection in field.

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