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Evaluation of the Efficacy of Essential Oil Extracts in the Control of Termites (*Isoptera*: *Termitidae*) in Cashew Orchards in Badikaha (Côte d'Ivoire)

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Abstract

Cashew tree has gradually moved from a purely ecological aspect to a socio-economic one, due to the marketing of its nuts. But production per area, estimated at between 424 and 547 kg/ha, remains low, in contrast to India (2nd largest producer) and Vietnam (3rd largest producer), whose yields range from 1000 to 1500 and 2000 to 2500 kg/ha respectively. This low yield is due to a number of factors, among which insect pests are the most damaging. Among these insects, termites are considered to be one of the main pests of cashew trees. The general objective of this study is to contribute to termite management through the use of bioinsecticides, an alternative to the use of chemicals in cashew orchards. Five (5) biological products were tested: Limocide, Carapa oil, Neem oil, Kitana and Kaskara. Among them, two products proved effective, with a mortality rate of over 50%. These were Limocide, whose LC50 was obtained in 24 h at a dose of 3.6 g/ml and 3.1 g/ml , giving a mortality rate of 57.66% ± 4.04% and 51.33 ± 2.08 respectively , and Carapa, at a dose of 4.5 g/ml, with an estimated mortality rate of 52.33% ± 1.52%. Such results have demonstrated the potential application of Limocide and Carapa biopesticides to sustainably control termites in cashew orchards of Côte d'Ivoire.

Keywords

Termite, Pest, Organic Products, Cashew Tree, Côte d'Ivoire

1. Introduction

Cashew (*Anacardium occidentale* L.) originated in Brazil [1]. It is grown in over thirty-two (32) countries where agro-ecological conditions are favorable, particularly in America, Asia and Africa [2] [3]. The crop was introduced to Côte d'Ivoire in the early 1950s to combat deforestation and soil erosion [4]. Since then, the importance of the cashew tree has gradually moved from a purely ecological role to a majorly socio-economic one due to the marketing of its nuts in Côte d'Ivoire. It is against this background that since 2015, Côte d'Ivoire is the world's leading producer and exporter of raw cashew nuts, with annual national production estimated at 1,028,172 tonnes in 2022 [5] [6]. Despite the quantitative importance of Ivorian production, cashew nut yields from Ivorian orchards are relatively low, ranging from 424 to 547 kg/ha. In contrast, yields in India (2nd largest producer) and Vietnam (3rd largest producer) range from 1000 to 1500 and 2000 to 2500 kg/ha respectively [7]. This low cashew nut yield per hectare in Côte d'Ivoire is thought to be due to several factors, of which insect pests are the most damaging. Among these insects, termites are considered one of the main pests of cashew trees, with an attack rate of up to 44% in the absence of appropriate control methods [8]. The most serious damage caused by termites can lead to the decline and death of cashew trees [8]. To deal with the problem, growers mainly resort to chemical control. Abusive and uncontrolled use of these chemicals is detrimental to the environment and human health, through 1) accumulation of residues, soil and water pollution, 2) dangers to human health, or 3) destruction of biological communities (ecological imbalance) due mainly to the broad spectrum of action of synthetic compounds [9] [10]. These disadvantages of chemical control have led to the search for an ecological and sustainable control method, and therefore a biological control method aimed at reducing their use. However, recent research has focused on plants with insecticidal effects for crop protection. Several control trials using biopesticides have produced good results on numerous insect pests [11] [12]. For example, the biological efficacy of neem oil extract as an alternative to pyrethroids for the control of cotton pests has been demonstrated in Senegal [13]. The insecticidal properties of carapa oil have given good results against *Anopheles gambiae* and *Drosophila sp* in Burkina Faso [14]. The insecticidal and even antifungal effect of limocid oil was demonstrated by [15] in the Makouda region of Algeria. The choice to use neem, carapa, limocide, kaskara and kitana essential oils is based on the fact that studies have demonstrated their insecticidal properties in the fight against certain crop pests. However, there have been no studies of these five (5) products in termite control. Aside from these promising results in pest control, some authors have pointed out that biopesticides may show less stable efficacy beyond a given period. This is the case with Spinosad, a commercial biopesticide whose efficacy is less stable after 6 months [16]. The general aim of this study was to contribute to the sustainable management of termites through the use of biological products with an insecticidal effect, as an alternative to the use of chemical products in cashew orchards.

2. Material and Methods

2.1. Study Site

The study was carried out in Badikaha, located in north-central Côte d'Ivoire. Badikaha is a sub-prefecture belonging to the Department of Niakaramadougou, in the Hambol region. It lies between 9˚12'0"N latitude and 5˚10'00"W longitude. The climate is tropical Sudano-Guinean, with two main rainly seasons notably from May to October and a dry season from November to April with an annual rainfall of 800 mm. The vegetation of this region belongs to the southern part of the Sudanese domain characterized by sub-humid tropical climate and open forest [17].

2.2. Plant Materials

The plant materials used for this study consisted of cashew trees ranging in age from 29 to 37 years. These cashew trees consisted of all-nut trees. The targeted orchards did not undergo any phytosanitary treatments by the growers during the experimental period.

2.3. Animal Material

The animal material consists of termite species collected in cashew orchards.

2.4. Technical Equipment

The technical equipment consisted of collection trowels for excavating the litter, trays and entomological forceps for sorting the clods, and a hoe for the monoliths. Conservation and identification equipment consisted of pillboxes for termite conservation and a binocular magnifying glass (Motic SMZ-161) for termite species identification. The treatment materials consisted of four biological products: 1) Neem essential oil, 2) Carapa essential oil, 3) Limocide bio-insecticide, Kaskara bio-insecticide, 4) Kitana bio-insecticide. The reference product was a chemical called Sauveur 62 EC (**Table 1**).

2.5. Methodology

Experimental set-up

The experiment was carried out in the laboratory. A Fisher block with three

Table 1. Concentrations and active ingredients of products used.

Product trade name	Active ingredients	Concentrations
Neem oil	Azadirachtin	1 liter/ha
Carapa oil	Triterpene	1 liter/ha
Limocide	Sweet orange essences	1.5 liter/ha
Kaskara	*Bacillus thuringiensis* var kurtassi	1 kg/ha
Kitana,	Karanjin	1 liter/ha
Sauveur 62 EC	Acetamiprid 32 g/l + Lambdacyhalothrin 30 g/l	1 liter/ha

(3) replicates and six (6) treatments of Neem oil, Carapa oil, Limocide, Kitana, Kaskara and Sauveur 62 EC insecticide was set up. For each treatment, three different concentrations were formulated. The different concentrations prepared were each applied to a batch of 100 termites with 3 replicates, *i.e.* 300 termites treated per concentration. Live and dead termites were counted 24 h, 48 h and 72 h after treatment, and mortality rates were determined.

Termite sampling

Termite sampling was carried out using the standardized method recommended for harvesting termites in forests [18] [19]. It consists of delimiting 20 sections of 10 m^2 (5 m × 2 m) along a transect 100 m long and 2 m wide in cashew orchards at Badikaha. Each section is sampled as follows: 1) the litter and biogenic structures on the ground and above ground, up to 1.5 m high, are searched for termites; 2) twelve soil monoliths measuring 12 cm × 12 cm square and 10 cm thick are extracted per section and searched for termites; 3) the collected termites are taken alive to the laboratory for biopesticide efficacy testing.

Determining the amount of water required

Hand sprayer calibration

The 1-liter hand-held sprayer was calibrated to determine the volume of water required. A blank test was then carried out with water on the termites to determine the amount of spray required to treat the termites.

Determination of product concentrations

The different concentrations of the six (6) products used in the laboratory against termites were determined taking into account the recommended doses of the products. Thus, three concentrations per product were determined in order to find the Lethal concentrations.

Determination of lethal concentrations

The lethal concentration 50 or LC50 is the concentration that causes 50% of termites to die within 24 hours. It was determined for test products with mortality rates greater than or equal to 50% by the Finney method [20].

For each treatment, three different concentrations were formulated. The different concentrations prepared were each applied to a batch of 100 termites with 3 replicates, *i.e.* 300 termites treated per concentration. Live and dead termites

Table 2. Different doses of products used in the laboratory against termites.

Products	Concentrations (g/ml)		
	Concentration 1	Concentration 2	Concentration 3
Limocide	2.6	3.1	3.6
Carapa oil	3.5	4	4.5
Kitana	2.8	3.3	4.5
Neem oil	3.5	4	4.5
Kaskara	1	3	4.5
Sauveur		1.2	

were counted 24 h, 48 h and 72 h after treatment, and the mortality rate determined.

For each concentration, the mortality rate (*M*) was calculated according to the formula below:

$$M = \frac{\text{Number of died individuals}}{\text{Total number of individuals}} \times 100 \quad (1)$$

The mortality rates obtained were then corrected using [21] formula.

$$M_c = \frac{M_o - M_t}{100 - M_t} \times 100 \quad (2)$$

M_c: Corrected mortality; M_o: Mortality rate recorded in the trial; M_t: Mortality rate recorded in the control.

2.6. Statistical Analysis

The data collected were processed using Microsoft Office Excel version 2010 and analyzed using the ade4 package of R studio software version 4.1.1. Prior to statistical analysis, the Shapiro and Wilk test was used to verify normality between variables. Thus, when a significant difference was observed at the 5% threshold, the Newman-Keuls test was used to classify and compare the attack rate and mortality rate. The results of the dose-response test were then subjected to probit analysis according to the method of [20], using XLSTAT version 2015 software to calculate the LC50.

3. Results and Discussion

3.1. Relative Abundance of Species

Figure 1 shows the relative abundance of species in cashew tree orchards. In total, two trophic groups of termites were identified in the cashew orchards. These were the mushroom group, comprising three species (*Pseudacanthotermes militaris, Odontotermes* sp and *Ancistrotermes guineensis*) and the forage group, comprising a single species (*Trinervitermes geminatus*). *Pseucanthotermes militaris* was the most abundant species (35%). It was followed by *Trinervitermes geminatus* (30%), *Odontotermes* sp (19%) and *Ancistrotermes guineensis* (16%).

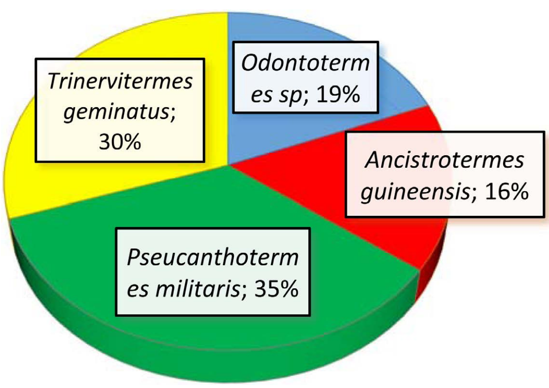

Figure 1. Relative abundance of termites in cashew orchards.

However, the proportion test showed an uneven distribution of species in the environments (p = 0.0048).

3.2. Product Efficacy after Application

Principal component analysis (PCA) (**Figure 2**) shows that the first two axes (F1 and F2) explain 98.92% of the variability in the data (**Figure 2(a)**). The correlation circle (**Figure 2(b)**) and the study of variable contributions to the formation of the two axes show that the F1 and F2 axes oppose two (2) groups of products (**Figure 2(c)**). The first group on the positive side of the F1 axis, made up of Témoin, Neem, Kitana and Kaskara, contrasts with the second group on the negative side of the F1 axis, which includes Carapa, Limocide and Sauveur. Mortality rates of the reference product Sauveur and the bioinsecticides Limocide and Carapa at 24 h, 48 h and 72 h were higher than those of the other bioinsecticides Neem, Kaskara and Kitana. The ascending hierarchical classification of products (**Figure 3**) based on termite mortality rates indicates three (3) product groups. Groups II and III are made up of products which are effective against termites. This group includes the reference product Sauveur, Carapa and Limocide. Group I is made up of products that are less effective against termites. These include Neem oil, Kaskara and Kitana.

3.3. Product Efficacy

Statistical analyses (**Table 2** and **Table 3**) show that mortality rates varied significantly according to treatment concentration and duration (Anova 1, $p < 0.05$). Indeed, the reference insecticide, Acetamiprid 32 g/l + Lambdacyhalothrin 30 g/l, at a dose of 1.2 g/ml recorded mortality rates of 56% of termites in 24 h, and mortality rates of 100% of termites in 48 h and 72h. As for bio-insecticides, Limocide, at doses of 3.1 g/ml and 3.6 g/ml, caused the death of over 50% of termites in 24 h and over 60% in 48 h and 72 h. This was followed by Carapa, at a dose of 4.5 g/ml, which caused the death of over 50% of termites in 24 h, and over 60% in 48 h and 72 h. For Kitana, Neem and Kaskara, termite mortality rates were below 50% at all concentrations.

4. Discussion

In total, two trophic groups of termites were identified in cashew orchards. These were the mushroom group, comprising three species (*Pseudacanthotermes militaris*, *Odontotermes* sp and *Ancistrotermes guineensis*) and the forager group, comprising a single species (*Trinervitermes geminatus*). Species belonging to the mushroom group were strongly represented in cashew orchards. Most of these species had already been identified in cashew orchards in northern Côte d'Ivoire [19]. The high abundance of mushroom termites compared to foragers is due to the fact that tree branches are left on the ground for a long time after pruning. These branches, left on the ground for long periods of time, would be breeding grounds for termites, particularly mushroom termites.

Our results are similar to those of [19] [22], which showed that mushroom termites are most abundant in cashew orchards. According to [19], these termites

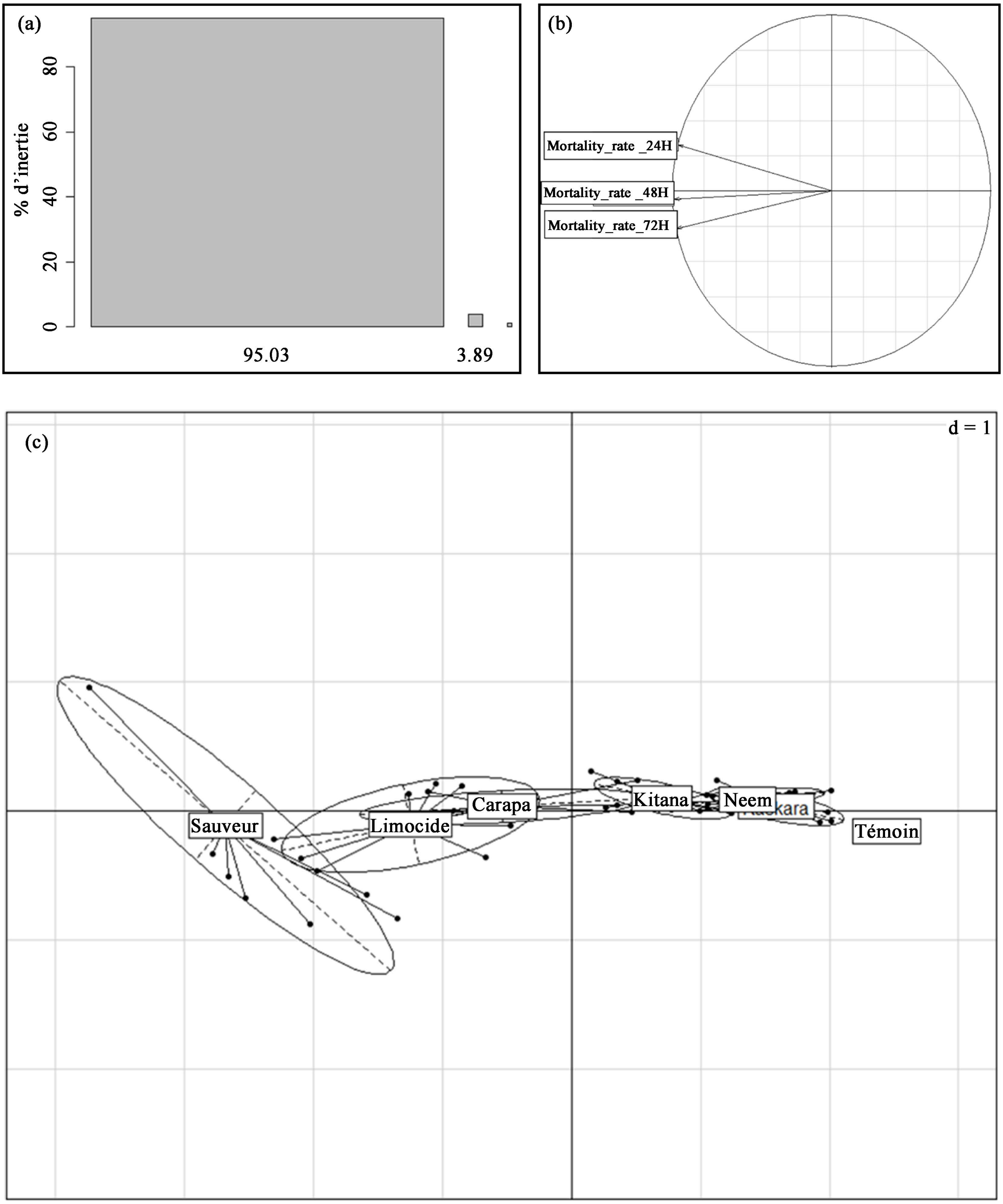

Figure 2. Principal component analysis showing product efficacy as a function of time. (a) Contribution of variables, (b) Correlation circle and (c) Factor maps.

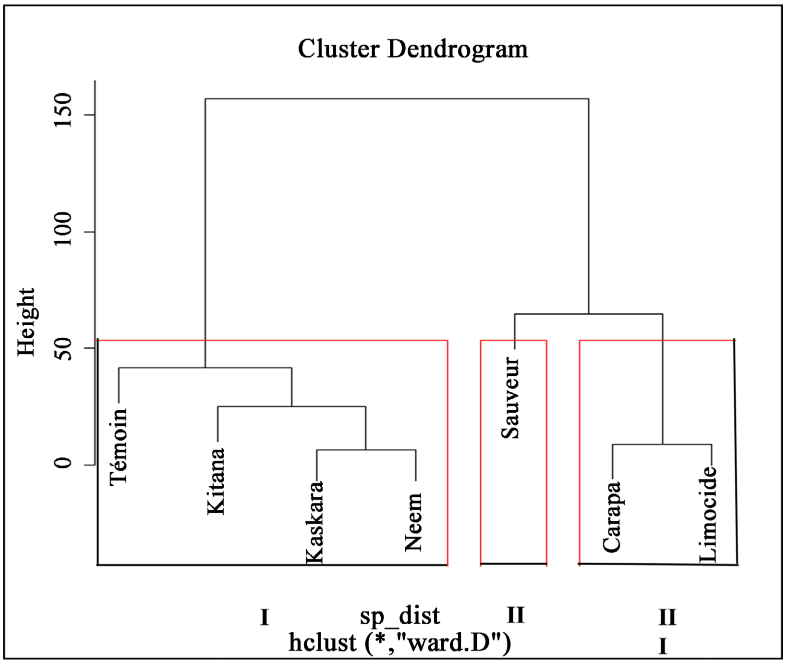

Figure 3. Similarity dendrogram showing product efficacy as a function of time.

Table 3. Comparison of product efficacy as a function of time.

Products	Concentrations (g/ml)	Mortality rate (%) (Mean ± S.E.).		
		24 hours	48 hours	72 hours
Limocide	2.6	40.33 ± 3.05[ab]	52.66 ± 4.04[ab]	67.66 ± 4.04[ab]
	3.1	51.33 ± 2.08[a]	61.66 ± 4.04[ab]	68.33 ± 3.51[ab]
	3.6	57.66 ± 4.04[a]	74.05 ± 3.05[a]	100 ± 0[a]
Carapa	3.5	30.66 ± 1.52[b]	37.33 ± 1.52[b]	45.66 ± 3.21[b]
	4	44,33 ± 2.51[ab]	57.66 ± 4.04[ab]	67.33 ± 4.04[ab]
	4.5	52.33 ± 1.52[a]	63.33 ± 2.51[ab]	76.66 ± 4.04[a]
Kitana	2.8	21 ± 4.35[b]	28.66 ± 2.5[b]	35.66 ± 1.52[bc]
	3.3	25.33 ± 3.51[b]	31.33 ± 2.08[b]	40.66 ± 2.51[b]
	4.5	34.33 ± 3.51[b]	41.33 ± 2.08[b]	46 ± 2[b]
Neem	3.5	12.66 ± 2.08[bc]	15.66 ± 1.52[c]	20.33 ± 3.05[c]
	4	20.33 ± 2.08[c]	26.66 ± 4.04[b]	31.66 ± 3.21[bc]
	4.5	22.33 ± 1.52[c]	31.33 ± 4.04[b]	35.33 ± 2.08[bc]
Kaskara	1	8.66 ± 0.57[c]	11.66 ± 1.15[c]	23.66 ± 1.52[c]
	3	14.33 ± 2.08[bc]	19.33 ± 1.52[bc]	25.66 ± 2.51[c]
	5	21.66 ± 2.5[b]	26.33 ± 2.08[b]	33.66 ± 2.08[bc]
Sauveur	1.2	56.66 ± 2.21[a]	100 ± 0[a]	100 ± 0[a]
Control		0 ± 0[c]	8.33 ± 2.23[c]	15 ± 1.52[c]
F		10.82	7.81	11.88
p		0.008	0.003	0.006

Means followed by the same letters are not significantly different (Newman-Keuls test, $p < 0.05$); P: Approximate test probability; F: Fischer constancy; S.E.: Standard error.

live in symbiosis with superior fungi that facilitate food degradation. These fungi degrade wood fragments, making them easy for the termites to digest. Furthermore, the low abundance of foraging termites may be due to the presence of a few forage plants in cashew orchards. According to [23], forage termites build up large reserves of grass culms. In view of the widespread damage caused by termites in cashew orchards, methods of reducing the rate of attack to a reasonable ecological level have been tested. Among these, biological control, which poses less of a threat to man and his environment, was evaluated in the present study. The results showed that after treatment, the reference insecticide Sauveur 62 EC and biopesticides such as Limocide and Carapa oil significantly reduced the termite population. The efficacy of Sauveur 62 EC at 1.2 g/ml resulted in mortality rates of over 55%. This efficacy was due to the presence of two active molecules belonging to the Pyrethroid and Neonicotinoid families. Recent work in Côte d'Ivoire has shown that chemical treatments by ground spraying and seed treatment have significantly reduced termite attacks on rice and maize [8] [22]. The biopesticides recorded mortality rates in excess of 50% at doses of 3.6 g/ml and 3.1 g/ml of Limocide and 4.5 g/ml of Carapa, over 24 hours. These results show that the different doses used were more effective than the dose of the reference insecticide against termite pests. The insecticidal properties of essential oils in the fight against insect attacks of various kinds have already been reported by several authors, both in Côte d'Ivoire and elsewhere [16] [20]. According to [24], *Calotropis procera* extracts reduced termite attacks in mango nurseries in northern Côte d'Ivoire than did aqueous extracts of Terminalia mantaly and *Strychnos spinosa*, which showed no effectiveness against termites. In addition, studies conducted by [24] on effectiveness of botanical biopesticides with different concentrations of termite mortality showed that papaya leaves at a dose of 1500 grams caused the fastest mortality rate of termites than soursop leaf and lemongrass leaf. Neem oil, Kitana and Kaskara induced mortality rates of less than 50%. These results could be explained by the fact that the various biopesticides used were ineffective against termites or that the various doses used have not proved effective against termites. Indeed, Kitana, Kaskara and Neem oil are said to have insecticidal properties that do not affect termites, but rather other insects. These results are similar to those of [19], who showed that neem oil at doses of 50 g/l and 70 g/l was effective against armyworm larvae. Also, work carried out by [25], showed that neem oil at a dose of 1.6 kg extract per hectare gave satisfactory results in termite control in oil palm cultivation.

5. Conclusions

This study revealed that two trophic groups of termites are predominant in cashew orchards of Côte d'Ivoire. These were the mushroom group, comprising three species (*Pseudacanthotermes militaris*, *Odontotermes sp* and *Ancistrotermes guineensis*) and the forager group, comprising a single species (*Trinervitermes geminatus*). Species belonging to the mushroom group are the most dominant among the two groups identified in cashew orchards. The study evaluating the efficacy of essential oil extracts in a controlled environment for termite control in cashew orchards showed that biological control can be an alternative to chemical control for protecting cashew orchards against termites.

Of the five biological insecticides evaluated, Limocide and Carapa oil proved effective at doses of 3.6 g/ml and 4.5 g/ml respectively in controlling termites, with mortality rates (LC 50) of over 50% in 24 h. The biopesticides Kitana, Kaskara and neem oil were less effective. The results obtained through mortality rates and lethal concentrations show that Limocide and Carapa could be used against termites in cashew orchards in Côte d'Ivoire instead of chemical products.

The application of limocide and carapa to control termites in cashew orchards would be a promising alternative to chemical insecticides, which are a threat to the environment and people's health, and would also play an important role in integrated pest management to control termites in cashew orchards in Côte d'Ivoire. Further studies are needed to determine the persistence levels and cost effectiveness of adopting these essential oil extracts in management of termites in cashew nut.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Delgado, C. and Couturier, G. (2014) Principaux insectes nuisibles à l'anacardier en Amazonie péruvienne. *Données Préliminaires*, **69**, 293-302. https://doi.org/10.1051/fruits/2014018

[2] Bezerra, M.A., Lacerda, C.F., Filho, E.G., De Abreu, C.E.B. and Prisco, J.T. (2017) Physiology of Cashew Plants Grown under Adverse Conditions. *Brazilian Journal of Plant Physiology*, **19**, 449-461. https://doi.org/10.1590/S1677-04202007000400012

[3] Agboton, C., Onzo, A., Ouessou, F.I., Goergen, G., Vidal, S. and Tamo, M. (2014) Insect Fauna Associated with *Anacardium occidentale* (Sapindales: Anacardiaceae) in Benin, West Africa. *Journal of Insect Science*, **14**, 229. https://doi.org/10.1093/jisesa/ieu091

[4] Kra, K.D., Kwadjo, K.E., Douan, G.E., Kouamé, K.L., Ouattara, K.V. and Doumbia, M. (2017) Évaluation des dégâts de *Analeptes trifasciata* (Coleoptera: Cerambycidae) sur les anacardiers dans les régions du Béré et de l'Iffou (Côte d'Ivoire). *Journal of Applied Biosciences*, **112**, 10969-10977. https://doi.org/10.4314/jab.v112i1.1

[5] Kouassi, A.M., Kouamé, K.F., Koffi, Y.B., Djè, K.B., Paturel, J.E. and Oulare, S. (2010) Analyse de la variabilité climatique et de ses influences sur les régimes pluviométriques saisonniers en Afrique de l'Ouest: Cas du bassin versant du N'zi (Bandama) en Côte d'Ivoire. *Cybergeo*: *European Journal of Geography*, **513**, Document 513. https://doi.org/10.4000/cybergeo.23388

[6] CCA (2022) Bilan du Conseil Coton Anacarde. https://www.conseilcotonanacarde.ci/wp-content/uploads/2022/02/Exportateurs-agr%C3%A9es-2022.pdf

[7] Ricau, P. (2019) Connaitre et comprendre le marché international de l'anacarde.

RONGEAD, 49 p.

[8] Sane, C.A.B., Rouland-Lefevre, C., Grechi, I., Rey, J.Y., Vayssieres, J.F., Diame, L. and Diarra, K. (2016) Diversité, nuisances et modes de gestion des termites (*Isoptera*) dans les agrosystèmes sénégalais. *International Journal of Biological and Chemical Sciences*, **10**, 134-154. https://doi.org/10.4314/ijbcs.v10i1.10

[9] Rasmussen, J.J., Wilberg-Larsen, P., Baattrup-Pederson, A., Cedergreen, N., Mcknight, U., Kreuger, J., Jacobsen, D., Kristensen, E.A. and Friberg, N. (2015) The Legacy of Pesticide Pollution: An Overlooked Factor in Current Risk Assessments of Freshwater Systems. *Water Research*, **84**, 25-32. https://doi.org/10.1016/j.watres.2015.07.021

[10] Togola, A., Meseka, S., Menkir, A., Ujjan, A.A., Khanzada, M. and Shahzad, S. (2018) Insecticide and Papaya Leaf Extract Toxicity to Mustard Aphid (*Lipaphis erysimi* Kal.). *Journal of Agricole Food and Applied Sciences*, **2**, 45-48.

[11] Glitho, I.A., Ketoh, K.G. and Koumaglo, H.K. (1997) Effets de quelques huiles essentielles sur l'activité reproductrice de *Callosobruchus maculatus* Fab. *Annales de l' Université de Ouagadougou*, **5**, 174-185.

[12] Fondio, D. (2022) Entomofaune de la culture du concombre (*Cucumis sativus* Linné 1753, Cucurbitaceae), bioécologie et lutte à base d'extraits aqueux de plantes locales contre *Leptoglossus membranaceus* Fabricius, 1781 (Coreidae), principal ravageur du concombre à Daloa, Côte d'Ivoire. Thèse de Doctorat, UFR Agroforesterie,Université Jean Lorougnon Guédé de Daloa, Daloa, 140 p.

[13] Sané, B., Badiane, D., Gueye, M.T. and Faye, O. (2018) Evaluation de l'efficacité biologique d'extrait de neem (*Azadirachta indica* Juss.) comme alternatif aux pyréthrinoïdes pour le contrôle des principaux ravageurs du cotonnier (*Gossypium hirsutum* L.) au Sénégal. *International Journal of Biological and Chemical Sciences*, **12**, 157-167. https://doi.org/10.1016/j.watres.2015.07.021

[14] Sombie, A., Bazongo, P., Wangrawa, D.W., Ilboudo, M.E., Ilboudo, Z., Yameogo, F., Romba, R., Ouilly, J.T., Sanon, A. and Badolo, A. (2020) Propriétés insecticides de l'huile fixe et des extraits terpeniques des amandes de *Carapa procera* DC contre *Anopheles gambiae* S. L. et Drosophila SP. *Annales de l' Université Joseph KI-ZERBO, Série C*, **16**, 13-25.

[15] Tirakmet, S. (2015) Etude comparative entre l'activité insecticide des huiles essentielles extraites à partir de deux espèces de la famille des Astéracées récoltées dans la région de Makouda et l'activité insecticide d'un pesticide organique de synthèse sur le ravageur secondaire du blé tendre stocké *Tribolium castaneum* (Coleoptera: Tenebriodae). Université Mouloud Mammeri, Tizi-Ouzou.

[16] Cissokho, P.S., Gueye, M.T., Sow, E.H. and Diarra, K. (2015) Substances inertes et plantes à effet insecticide utilisées dans la lutte contre les insectes ravageurs des céréales et légumineuses au Sénégal et en Afrique de l'Ouest. *International Journal of Biological and Chemical Sciences*, **9**, 1644-1653. https://doi.org/10.4314/ijbcs.v9i3.43

[17] Sory, E.H. (2018) Suivi de l'évolution des caractéristiques agros-morphologiques des clones d'anacardier du parc à bois de Badikaha. Mémoire de fin de cycle pour l'obtention du diplôme d'ingénieur en biotechnologie. ISTOM Ecole Supérieure d'Agro-Développement International, Abidjan, 86 p.

[18] Jones, D.T. and Eggleton, P. (2000) Sampling Termite Assemblages in Tropical Forests: Testing a Rapid Biodiversity Assessment Protocol. *Journal of Applied Ecology*, **37**, 191-203. https://doi.org/10.1046/j.1365-2664.2000.00464.x

[19] Tra, B.C.S., Yeboue, L., Kpassou, A.D.S., Konate, S., Kouassi, K.P., Soro, S. and Tano, Y. (2020) Structure des assemblages de termites (Insecta: Blattodea) le long

d'un gradient d'âge d'anacardiers (*Anacardium occidentale* L.) dans la région de Ferké (Côte d'Ivoire). *Entomologie Faunistique*, **73**, 36-49.

[20] Finney, D.J. (2001) Probit Analysis. 3rd Edition, Cambridge University Press, Cambridge, 33 p.

[21] Abbott, W.S. (1925) A Method of Computing the Effectiveness of an Insecticide. *Journal of Economic Entomology*, **18**, 265-267. https://doi.org/10.1093/jee/18.2.265a

[22] Brune, A. (2011) Microbial Symbioses in the Digestive Tract of Lower Termites. In: Rosenberg, E. and Gophna, U., Eds., *Beneficial Microorganisms in Multicellular Life Forms*, Springer Verlag, Berlin, 3-25. https://doi.org/10.1007/978-3-642-21680-0_1

[23] Coulibaly, T., Akpesse, A.A.M., Yapi, A., Zirihi, G. and Kouassi, K.P. (2014) Dégâts des termites dans les pépinières de manguiers du Nord de la Côte d'Ivoire (Korhogo) et essai d'extraits aqueux de plantes. *Journal of Animal and Plant Sciences*, **22**, 3455-3468.

[24] Wattimena, C.M.A. and Latumahina, F.S. (2021) Effectiveness of Botanical Biopesticides with Different Concentrations of Termite Mortality. *Journal Belantera*, **4**, 66-74. https://doi.org/10.29303/jbl.v4i1.630

[25] Tahiri, A., Amissa, A., Adima, F. and Adje, N. (2011) Effet pesticide et screening des extraits de *Azadirachta indica* (A.) Juss. sur le termite *Macroternes bellicosus* Rambu. *Bois et Fôrets des Tropiques*, **310**, 79-88. https://doi.org/10.19182/bft2011.310.a20461