Hindawi Publishing Corporation
Journal of Insects
Volume 2015, Article ID 319045, 6 pages
http://dx.doi.org/10.1155/2015/319045

Research Article

Chemical Composition and Insecticidal and Repellent Effect of Essential Oils of Two *Premna* Species against *Sitotroga cerealella*

Elvis Adjalian,[1,2] Philippe Sessou,[1] Théophile Odjo,[2] Gilles Figueredo,[3] Dansou Kossou,[2] Félicien Avlessi,[1] Chantal Menut,[4] and Dominique Sohounhloué[1]

[1] *Laboratoire d'Etude et de Recherche en Chimie Appliquée (LERCA), Ecole Polytechnique d'Abomey-Calavi/Université d'Abomey-Calavi, 01 BP 2009 Cotonou, Benin*
[2] *Laboratoire de Production Végétale, Faculté des Sciences Agronomiques/Université d'Abomey-Calavi, 01 BP 526 Cotonou, Benin*
[3] *Laboratoire d'Analyse des Extraits Végétaux et des Arômes (LEXVA Analytique), 460 rue du Montant, 63110 Beaumont, Benin*
[4] *Institut des Biomolécules Max Mousseron, Equipe "Glyco et Nanovecteurs pour le Ciblage Thérapeutique", Faculté de Pharmacie, 15 avenue Charles Flahault, BP 14491, 34093 Montpellier, France*

Correspondence should be addressed to Dominique Sohounhloué; ksohoun@bj.refer.org

Received 2 March 2015; Revised 26 June 2015; Accepted 8 July 2015

Academic Editor: Fedai Erler

This work aims to study for the first time the chemical composition and evaluate insecticidal and repellent effects of essential oils of *Premna angolensis* and *Premna quadrifolia* leaves, against *Sitotroga cerealella*, an insect pest of rice stocks as alternatives to synthetic pesticides. The GC-MS analysis showed that essential oil of *P. angolensis* contains 29 compounds representing 96.1% of the oil and 42 compounds corresponding to 91% for the essential oil of *P. quadrifolia*. The main constituents regardless of the species were β-caryophyllene (13.1%), (E)-β-caryophyllene (13.5%), octen-3-ol (3.2%–28%), phytol (3.7%–4.9%), β-elemene (1.4%–21%), globulol (11.2%), germacrene-D (8.9%), α-humulene (2.9%–6.4%), α-pinene (5%), sabinene (3.7%), δ-cadinene (0.4%–3.3%), and linalool (3.3%). The results of laboratory tests showed that both essential oils have insecticidal and repellent effects on *S. cerealella*. Presenting the results, the damage caused by the adults and larvae of *S. cerealella* was evaluated by calculating the percentage of grains attacked and weight loss thereof. The results suggest that volatile extracts of *P. angolensis* and *P. quadrifolia* can be used as alternatives to synthetic chemicals in paddy protection against *S. cerealella*.

1. Introduction

The genus *Premna* L. (Verbenaceae) contains about 200 species worldwide, which are distributed mainly in tropical and subtropical parts of Asia, Africa, Australia, and the Pacific Islands [1, 2]. Previous studies on chemical constituents of the genus *Premna* led to the isolation of triterpenes, diterpenes, and sesquiterpenes [3], some of them exhibiting significant antibacterial activities [4]. When antiparasitic activity of new Caledonian medicinal plants including *Premna serratifolia* L. was evaluated, it was observed that *P. serratifolia* was active against *Leishmania donovani* with IC_{50} values between 0.5 and 5 μg·mL^{-1} [5]. In addition, some preparations of plants of the genus *Premna* have been used in the treatment of liver disorders and antioxidant as well as for their immune modulatory effects [6] in the traditional Indian system of medicine. The *Premna* genus can be used in treating various ailments like rheumatism, asthma, dropsy, cough, fever, boils, and scrofulous disease. Traditionally in tropical Africa and Benin in particular, people with low purchasing power very often use odors produced by aromatic plants collected locally for the control of insects. This is the case of *Premna angolensis* Gürke and *Premna quadrifolia* Schum. & Thonn., leaves of which are burned and used by producers, as a fumigant in the attics of cereals against pests. In this study, extracts from leaves of both species *P. angolensis* and *P. quadrifolia* harvested in Benin were analyzed by gas chromatography-mass spectrometry (GC/MS) for the first time. The insecticidal and repellent activities were tested on the Angoumois grain moth *Sitotroga cerealella* (L.) (Lepidoptera: Gelechiidae) in rice storage.

2. Material and Methods

2.1. Plant Material and Distillation of the Volatile Constituents. Leaves of *P. angolensis* and *P. quadrifolia* were collected from the municipality of Comé by the authors and certified at the National Herbarium of Abomey-Calavi University. The collected plant materials were stored in the laboratory between 18 and 20°C in the shade of the sunlight throughout the period of extraction. The essential oils were obtained by hydrodistillation of the leaves (450 g) for five hours using a Clevenger-type extractor according to British Pharmacopoeia method [7]. They were then dried over anhydrous sodium sulfate and analyzed by GC/MS.

2.2. Test Organisms. Individuals of *S. cerealella* used for mass rearing for this study come from the reserve WARDA (Benin). Rearing conditions were $T = 29 \pm 2^\circ$C, RH $= 70 \pm 10\%$.

2.3. Analysis of the Volatile Constituents

2.3.1. GC/MS. The essential oils were analysed on a Hewlett-Packard gas chromatograph Model 7890, coupled to a Hewlett-Packard MS Model 5875, equipped with a DB5 MS column (30 m × 0.25 mm; 0.25 μm), programming from 50°C (5 min) to 300°C at 5°C/min, 5 min hold. Helium was used as carrier gas (1.0 mL min^{-1}); injection was made in split mode (1 : 30); injector and detector of temperature were at 250 and 280°C, respectively. The MS working in electron impact mode was at 70 eV; electron multiplier was 2500 eV; ion source temperature was 180°C; mass spectra data were acquired in the scan mode in *m/z* range 33–450.

2.3.2. GC/FID. The essential oils were analyzed on a Hewlett-Packard gas chromatograph Model 6890, equipped with a DB5 MS column (30 m × 0.25 mm; 0.25 μm), programming from 50°C (5 min) to 300°C at 5°C/min, 5 min hold. Hydrogen was used as carrier gas (1.0 mL min^{-1}); injection was in split mode (1 : 60); injector and detector temperature were 280 and 300°C, respectively. The essential oil was diluted in hexane: 1/30. The compounds assayed by GC in the different essential oils were identified by comparing their retention indices with those of reference compounds in the literature and confirmed by GC-MS by comparison of their mass spectra with those of reference substances [8–10].

2.4. Test. All tests were performed at a temperature of 29±2°C and natural photoperiod with relative humidity 70 ± 10%.

2.5. Contact Toxicity Tests with Essential Oils. Bioassays were performed using the method described by Noudogbessi et al. [11]. The temperature of the test medium ranged from 25°C to 31°C and relative humidity was 80%. Five concentrations (0, 3, 5, 10, and 15 μL mL^{-1}) depending on the selected chemical profile of each essential oil in absolute ethanol solution were tested. The plant material, paddy rice grains of the variety "IR841," was treated with each essential oil. After 24 h, 5 males and 10 females of *S. cerealella*, aged 0 to 24 h, were deposited on the treated plant material. Overall, 5 doses × 3 repeats × 2 types of oil = 30 experimental units (containers) were implemented. The control sample treated only with ethanol was also infested by *S. cerealella*. Adult mortality was monitored 96 h after exposure to the essential oils. Then the insects were separated from the grains. The emergence of new insects was then observed at intervals of 24 h in the experimental units to the 50th day after infestation. Assessment concerned the rate of infested grains and weight loss of grains of rice.

To assess the *S. cerealella* damage on the rice seeds after treatment, the substrate grains were collected, counted, and weighed. The rate of weight loss of dry material of the grains was determined according to MCP (Method of Counting and Weighing) and MSVW (Method of Standard Volumetric Weight) [12]. Two criteria of assessment of the damage are commonly used: the percentage of attack of grains (A%) and percentage of weight loss (B%) [13], respectively, calculated by the equations:

$$A\% = \frac{\text{Na}}{\text{Na} + \text{Ns}} \times 100,$$
$$B\% = \frac{\text{PsNa} - \text{PaNs}}{\text{Ps}\,(\text{Na} + \text{Ns})} \times 100, \tag{1}$$

where Na is number of attacked grains, Ns is number of healthy grains, Pa is weight of damaged grains, and Ps is weight of healthy grains.

2.6. Repellency Tests. The repellent action of the plants was tested in an olfactometer (Figure 1), consisting of a 75 cm glass tube of 4 cm in diameter, with a 29 mm hole in the middle. At either end of the tube, a small jar was placed containing either 10.0 g containing paddy rice treated with only ethanol or 10.0 g of paddy rice seeds mixed with a solution of essential oil at concentrations 0.1%, 0.5%, and 1%. The hole in the middle was covered with gauze, whereas the ends of the tube were closed by putting a plastic petri dish against them. Air was gently (ca I mls) sucked away from the centre of the tube to prevent the accumulation of plant odor in the tube.

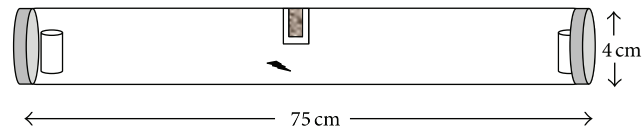

Figure 1: Olfactometer set-up. An individual female Angoumois grain moth was introduced in the center of the tube. Her position was recorded after 15 min since introduction. Treated and control paddy rice were positioned at either end of the tube.

Ten female *S. cerealella* aged 24 h to 48 h were released one after the other in the middle of the tube through the hole. Insect behavior was observed and the position was recorded for 15 min. Both volatile extracts were tested once before the second round. Insects were considered to have made a choice when entered in one of the jars containing rice grains or those who have reached the last twenty-five centimeters of the tube. For those who chose the middle of the tube, they have finally made a choice. The percentage of insects rejected was calculated using the following formula:

$$\text{Percentage Repellency (\%)} = \frac{A - B}{A + B} \times 100, \qquad (2)$$

where A is average number of insects present in the untreated portion (insects repelled) and B is average number of insects in the treated (not repelled insects) part.

The average percentage of repulsion for the essential oil was calculated and assigned according to previous ranking [14] to one of several repulsive classes ranging from 0 to V: class 0 (Percentage Repellency (PR) < 0,1%), class I (PR = 0,1–20%), class II (PR = 20,1–40%), class III (PR = 40,1–60%), class IV (PR = 60,1–80%), and class V (PR = 80,1–100%).

2.7. Statistical Analysis. The results from the observations were statistically processed by Analysis of Variance (ANOVA) using SAS (Statistical Analysis System) Version 9.1. Finally, an average of the percentages of the three results of the test was made. The results of statistical tests were considered significantly different if the probability of the hypothesis was less than or equal to 5%.

3. Results

Chromatographic analysis of the essential oil extracted from leaves of *P. angolensis* detected 29 compounds representing 96.1% of the weight of the essential oil (Table 1). However sesquiterpenes hydrogenated (26.6%) and oxygen (20%) were predominant. As for *P. quadrifolia*, 43 compounds were identified representing 91% of the essential oil. It was dominated by the hydrocarbon sesquiterpenes (65.5%) (Table 1). The predominant compounds of the two essential oils, regardless of species and their origin, were β-caryophyllene (13.1%), (E)-β-caryophyllene (13.5%), octen-3-ol (3.2%–28%), phytol (3.7%–4.9%), β-elemene (1.4%–21%), globulol (11.2%), germacrene-D (8.9%), α-humulene (2.9%–6.4%), α-pinene (5%), sabinene (3.7%), δ-cadinene (0.4%–3.3%), and Linalool (3.3%).

The results of the estimation of the influence of different concentrations (0 to 15 μL mL^{-1}) of the two essential oils on adult mortality of *S. cerealella*, the emergence of young insects, the rate of grains attacked, and loss corresponding weights are shown in Tables 2 and 3. Mortality rates of insects in Table 2 were obtained 4 days after treatment of the grains of paddy rice which ranged between 0 and concentrations 15 μL mL^{-1}. At a concentration of 3 μL·mL^{-1} *P. angolensis* essential oil showed over 90% mortality through its contact activity on the adults of *S. cerealella*. The number of grains damaged and the loss of the weight of rice decrease when the dose of essential oil increases. The insecticidal effect of *P. quadrifolia* essential oil was less noticed compared to the essential oil of *P. angolensis*, with significant difference ($P < 0.001$). In the controls sample, we noticed that the number of adults of *S. cerealella* increased rapidly and reached the rate of 89.62 ± 0.01 with *P. quadrifolia* and 85.71 ± 0.03 with *P. angolensis*.

Repellent Effect of Essential Oils Tested. The percentages of repulsion for the different doses of the essential oil of the leaves of *P. quadrifolia* and *P. angolensis* are summarized in Table 4. The different doses of essential oils (0.1%, 0.5%, and 1%) caused 67.11% to 96.84% repellency for *P. angolensis* and 65.55% to 91.55% for *P. quadrifolia*. This clearly shows that the percentage of repulsion increases with the dose.

4. Discussion

The output value of the essential oil from the leaves of *P. quadrifolia* was relatively better (0.102% ± 0.005) than that of *P. angolensis* (0.056% ± 0.004). No data have been reported in the literature on the essential oils of those two species. Essential oils *P. quadrifolia* and *P. angolensis* showed different chemical compositions. They were potentially rich in sesquiterpenoid compounds. During this study, insecticidal and repellent activity of both oils against *S. cerealella* was valued according to the treatment and the dose of applied oil. Previous studies on other species of *Premna* showed that their chemical compositions were rich in caryophyllene, β-cadinene, α-selinene, and phytol [15, 16]. The insecticide nature of essential oils of *P. angolensis* and *P. quadrifolia* manifested by contact adult insects *S. cerealella* may be linked to the main volatile compounds extracted reportedly acting alone or in synergy with other minor constituents. In fact, the essential oil of the leaves of *P. angolensis* contains monoterpenes and oxygenated hydrocarbon such as α-pinene and Oct-1-en-3-ol and Linalool which insecticidal properties have been demonstrated against *Tribolium confusum*, *Tribolium castaneum*, *Sitophilus zeamais*, *Callosobruchus maculatus*, and *Rhyzopertha dominica* [11, 17].

The repulsion rates evaluated of *P. angolensis* essential oil showed a greater repellent activity against adults of Angoumois grain moth than *P. quadrifolia* essential oil belonging, respectively, to the repulsive V and IV class, according to MC-Donald and Guyr [14] ranking. This can be explained by the strong offensive odor of both oil and confirm the use of the leaves by farmers in protecting their grain in some parts of Benin. Insect repellent effect of the extract of *P. angolensis* volatile proved more interesting than that of *P. quadrifolia* despite having a very low yield of essential oil.

The use of essential oils in the preservation of cereals is increasingly recognized [18]. Essential oils are nowadays known as neurotoxins acutely interfering with octopaminergic transmitters in Arthropods [19]. Different doses of oils caused highly significant mortality ($P < 0.001$) in comparison with the mortality rates in the controls. Paddy rice is the most common form of conservation; only *S. cerealella* species is likely to multiply in the paddy rice which confirms the results of previous work [20]. Increasing doses of oil also reduced significantly the emergence of adults 50 days after infestation rates. Such a reduction in emergence rates results from the manifestation of ovicidal or larvicidal volatile extracts, which have destroyed the development of some eggs

Table 1: Yield and chemical composition of essential oil of *P. angolensis* and *P. quadrifolia* leaves.

N°	Name of the compound	RI	*Premna angolensis* (%)	*Premna quadrifolia* (%)
1	(Z)-3-Hexen-1-ol	850	1.0	—
2	α-Pinene	933	5.0	—
3	Sabinene	965	—	3.7
4	β-Pinene	970	—	0.6
5	Octen-3-ol	973	28.0	3.2
7	Octan-3-one	977	2.7	—
8	Myrcene	987	0.3	—
9	Octan-3-ol	991	1.4	—
10	α-Phellandrene	996	—	1.0
11	Limonene	1022	—	1.9
12	β-Phellandrene	1023	—	0.6
13	p-Cymene	1024	0.5	0.8
14	Eucalyptol	1025	—	t
15	Limonene	1027	1.4	—
16	(E)-β-Ocimene	1039	—	0.1
17	γ-Terpinene	1051	—	0.1
18	(Z)-Sabinene hydrate	1064	—	0.1
19	Linalool	1096	3.3	—
20	Triacetonamine	1108	—	2.8
21	Terpinen-4-ol	1174	2.5	0.5
22	Naphthalene	1178	—	0.9
23	α-Terpineol	1188	—	0.1
24	Methyl salicylate	1194	2.2	—
25	Nerol	1221	t	—
26	Ethyl salicylate	1266	t	—
27	α-Cubebene	1339	—	0.2
28	α-Ylangene	1362	—	0.1
29	α-Copaene	1369	—	1.7
30	β-Elemene	1374	1.4	21
31	(E)-β-Damascenone	1384	1.2	—
32	α-Gurjunene	1400	—	2.0
33	β-Caryophyllene	1414	—	13.1
34	γ-Elemene	1421	—	1.1
35	(E)-β-Caryophyllene	1424	13.5	—
36	(E)-α-Bergamotene	1424	—	0.8
37	Aromadendrene	1443	0.6	—
38	(Z)-β-Farnesene	1443	—	0.2
39	Alloaromadendrene	1454	—	0.4
40	α-Humulene	1458	6.4	2.9
41	Selina-4,11-diene	1466	—	1.1
42	Germacrene-D	1475	—	8.9
43	β-Selinene	1486	0.6	1.6
44	γ-Patchoulene	1490	2.8	—
45	α-Bulnesene	1490	—	1.8
46	α-Farnesene	1494	—	0.8
47	δ-cadinene	1499	0.9	—
48	β-Bisabolene	1499	—	1.9
49	Germacrene A	1501	—	0.2

Table 1: Continued.

N°	Name of the compound	RI	*Premna angolensis* (%)	*Premna quadrifolia* (%)
50	γ-Cadinene	1506	—	0.9
51	(Z)-Calamenene	1512	—	0.4
52	δ-Cadinene	1525	0.4	3.3
53	Germacrene B	1553	—	1.1
54	(E)-Nerolidol	1562	0.7	—
55	Epiglobulol	1565	2.2	—
56	Spathulenol	1571	—	0.2
57	Caryophyllene oxide	1577	—	1.3
58	Globulol	1590	11.2	—
59	Humulene epoxide II	1616	0.9	—
60	Epi-α-muurolol	1649	—	1.2
61	Selin-11-en-4-α-ol	1653	—	1.5
62	α-Cadinol	1658	1.0	—
63	Intermedeol	1673	0.3	—
64	Phytol	2048	3.7	4.9
	Total (%)		**96.1**	**91%**
	Yield (%)		**0.056**	**0.102**
	Hydrogenated monoterpenes (%)		**8.6**	**8.9**
	Oxygenated monoterpenes (%)		**9.2**	**4.3**
	Hydrogenated sesquiterpenes (%)		**26.6**	**65.5**
	Oxygenated sesquiterpenes (%)		**20**	**9.1**
	Oxygenated aliphatic compounds (%)		**31.7**	**3.2**

t (traces) = 0.1%; RI: retention index.

Table 2: Rate of *S. cerealella* death, of emergence, of number of rice attacked (A), and of weight loss (B) provoked by *P. angolensis* essential oil in contact method.

Dose (μL mL^{-1})	Mortality	Emerged	A (%)	B (%)
0	18.78 ± 0.07^{b}	85.71 ± 0.03^{a}	25.19 ± 2.41^{b}	22.726 ± 1.955^{b}
3	90.12 ± 0.30^{a}	1.07 ± 0.06^{b}	0.37 ± 0.01^{c}	0.003 ± 0.048^{c}
5	94.26 ± 0.17^{a}	0.40 ± 0.11^{c}	0.32 ± 0.020^{c}	0.046 ± 0.028^{c}
10	100 ± 0.00^{a}	0.33 ± 0.05^{cd}	0.26 ± 0.02^{c}	0.003 ± 0.024^{c}
15	100 ± 0.00^{a}	0.13 ± 0.10^{d}	0.15 ± 0.02^{c}	0.000 ± 0.020^{c}
Probability	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$
CV (%)	13.75	10.58	18.76	16.85

0: ethanol treatment (control); ***very highly significant difference (0.1%).
The averages followed by the same letter were not significantly different at the beginning of 5%.

Table 3: Rate of *S. cerealella* death, of emergence, of number of rice attacked (A), and of weight loss (B) provoked by *P. quadrifolia* essential oil in contact method.

Dose (μL mL^{-1})	Mortality	Emerged	A (%)	B (%)
0	10.82 ± 0.17^{d}	89.62 ± 0.01^{a}	25.44 ± 0.93^{b}	24.31 ± 0.28^{b}
3	57.96 ± 0.05^{c}	2.10 ± 0.04^{b}	0.61 ± 0.05^{c}	0.01 ± 0.00^{c}
5	70.38 ± 0.00^{bc}	1.62 ± 0.08^{b}	0.48 ± 0.05^{c}	0.05 ± 0.02^{c}
10	76.75 ± 0.12^{ab}	1.28 ± 0.05^{b}	0.35 ± 0.04^{c}	0.04 ± 0.03^{c}
15	88.85 ± 0.17^{a}	0.13 ± 0.10^{c}	0.07 ± 0.01^{c}	0.04 ± 0.01^{c}
Probability	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$	$<0.001^{***}$
CV (%)	14.21	7.51	7.90	6.02

0: ethanol treatment (control); ***very highly significant difference (0.1%).
The averages followed by the same letter were not significantly different at the beginning of 5%.

Table 4: Percentage (%) of the repellence with olfactometer of the essential oil of the leaves of *P. angolensis* and *P. quadrifolia* on adult *Sitotroga cerealella*.

Dose (%)	Repellency rate (%) (±SD)	
	P. angolensis	*P. quadrifolia*
0.1	67.11 ± 10.95	65.55 ± 12.86
0.5	88 ± 10.95	83.55 ± 9.24
1	96 ± 8.94	91.55 ± 11.58
Mean (±SD)	**83.70 ± 1.16**	**80.22 ± 13.31**
Repellence class	**V**	**IV**

or larvae probably due to sesquiterpenoid compounds or oxygenated aliphatic and synergy with minor compounds.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

The authors are grateful to Polytechnic School of Abomey-Calavi (Benin) for financial support. They are also thankful to Professor Aristide ADOMOU from National Herbarium of Benin for plants identification. The authors thank Dr. Noudogbessi that made the chemical analysis of essential oils in the laboratory of Professor Chantal Menut in France (may he rest in peace).

References

[1] J. W. Kadareit, "Flowering plants-dicotyledons," in *The Families and Genera of Vascular Plants*, K. Kubitzki, Ed., vol. 7, p. 449, Springer, 2004.

[2] J. Lovett and G. P. Clarke, "*Premna schliebenii*," in *IUCN. 2006 Red List of Threatened Species*, 1998.

[3] A. Hymavathi, K. S. Babu, V. G. M. Naidu, S. R. Krishna, P. V. Diwan, and J. M. Rao, "Bioactivity-guided isolation of cytotoxic constituents from stem-bark of *Premna tomentosa*," *Bioorganic and Medicinal Chemistry Letters*, vol. 19, no. 19, pp. 5727–5731, 2009.

[4] H. Sudo, T. Ide, H. Otsuka, E. Hirata, A. T. TakushiShinzato, and Y. Takeda, "Megastigmane, benzyl and phenethyl alcohol glycosides, and 4, $4'$-dimethoxy-β-truxinic acid catalpol diester from the leaves of Premna subscandens MERR," *Chemical and Pharmaceutical Bulletin*, vol. 48, no. 4, pp. 542–546, 2000.

[5] J. Desrivot, J. Waikedre, P. Cabalion et al., "Antiparasitic activity of some new caledonian medicinal plants," *Journal of Ethnopharmacology*, vol. 112, no. 1, pp. 7–12, 2007.

[6] K. P. Devi, M. S. Ram, M. Sreepriya, G. Ilavazhagan, and T. Devak, "Immunomodulatory effects of *Premna tomentosa* extract against Cr (VI) induced toxicity in splenic lymphocytes—an in vitro study," *Biomedicine & Pharmacotherapy*, vol. 57, no. 2, pp. 105–108, 2003.

[7] British Pharmacopoeia, 11. P. A. HMSO, London, UK, 1980.

[8] R. P. Adams, *Identification of Essential Oil by Ion Trap Mass Spectrometry*, Academy Press, New-York, NY, USA, 1989.

[9] P. Rösch, J. Popp, and W. Kiefer, "Raman and surface enhanced Raman spectroscopic investigation on *Lamiaceae* plants," *Journal of Molecular Structure*, vol. 480-481, pp. 121–124, 1999.

[10] A. A. Swigar and R. M. Silverstein, *Monoterpenes, Infrared, Mass, NMR Spectra and Kovats Indices*, Aldrich Chem, Milwaukee, Wis, USA, 1981.

[11] J. P. Noudogbessi, M. Keke, F. Avlessi, D. Kossou, and D. C. K. Sohounhloue, "Evaluation of the insecticidal, larvicidal and ovicidal effects on *Callosobruchus maculatus* of essential oils of *Cymbopogon giganteus* and of *Xylopia aethiopica*," *Scientific Study & Research*, vol. 10, no. 4, pp. 337–338, 2009.

[12] C. U. Panthenius, "Etat des pertes dans les systèmes de stockages du maïs au niveau des petits paysans dans la région maritime au Togo," Fiche technique 83, GTZ, 1988.

[13] Centre d'Etude et d'Expérimentation du Machinisme Agricole et Tropical (CEEMAT), *Conservation des Grains en Régions Chaudes: Techniques Rurales en Afrique*, Centre d'Etude et d'Expérimentation du Machinisme Agricole et Tropical (CEEMAT), Paris, France, 1988.

[14] L. MC-Donald and H. D. Guyr, "Preliminary evaluation of new candidate materials as toxicants, repellents and attractants against stored product insects," Marketing Research Report 882, Agricultural Research Service, United State Department of Agriculture, Washington, DC, USA, 1970.

[15] P. K. Renjana and J. E. Thoppil, "Larvicidal activities of the leaf extracts and essential oil of *Premna latifolia* roxb. (verbenaceae) against *Aedes albopictus* Skuse (Diptera: Culicidae)," *Journal of Applied Pharmaceutical Science*, vol. 3, no. 6, pp. 101–105, 2013.

[16] C. T. Sadashiva, P. Sharanappa, Y. Naidoo, and I. Balachandran, "Chemical composition of essential oil from the leaves of *Premna coriacea* Clarke," *African Journal of Biotechnology*, vol. 12, no. 20, pp. 2914–2916, 2013.

[17] G. K. Ketoh, H. K. Koumaglo, and I. A. Glitho, "Inhibition of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) development with essential oil extracted from *Cymbopogon schoenanthus* L. Spreng. (Poaceae) and the wasp *Dinarmus basalis* Rondani (Hymenoptera: Pteromalidae)," *Journal of Stored Products Research*, vol. 41, pp. 363–371, 2006.

[18] A. Smith-Palmer, J. Stewart, and L. Fyfe, "The potential application of plant essential oils as natural food preservatives in soft cheese," *Food Microbiology*, vol. 18, no. 4, pp. 463–470, 2001.

[19] N. L. Tatsadjieu, P. M. J. Dongmo, M. B. Ngassoum, F.-X. Etoa, and C. M. F. Mbofung, "Investigations on the essential oil of *Lippia rugosa* from Cameroon for its potential use as antifungal agent against *Aspergillus flavus* Link ex. Fries," *Food Control*, vol. 20, no. 2, pp. 161–166, 2009.

[20] A. Togola, P. A. Seek, I. A. Glitho et al., "Economic losses from insect pest infestation on rice stored on-farm in Benin," *Journal of Applied Sciences*, vol. 13, no. 2, pp. 278–285, 2013.