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Study of the Insecticidal Activity of Essential Oils from *Erythrophleum guineense* and *Uvaria chamae* on the Peanut Weevil *Caryedon serratus* Ol. (Coleoptera, Bruchidae)

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Abstract

The objective of this research is to examine the toxicity of *Erythrophleum guineense* and *Uvaria chamae* essential oils on peanut weevils. Contact testing on peanut seeds was carried out on adult *C. serratus* for 144 hours at an ambient temperature of 30˚C in the laboratory. It has been shown that *C. serratus* weevils exhibited a toxic mortality rate of 5.65 ± 0.5%, at 0.2 µl, and of *Erythrophleum guineense*, at the same dose of 0.2 µl of *Uvaria chamae* exhibited a toxic mortality rate of 8.50 ± 0.55[a] (like average lifespan in days). However, he was observed during this work, that an increase in doses resulted in a decrease in the toxic effect. This can be probably due either: insects' adaptation or insect avoidance behavior at high doses of the extracts used. The essential oils cause 100% mortality when the highest dose is used, *i.e.* 0.8 µl after 2 days for *Erythrophleum guineense* and 0.8 µl after 4 days for *Uvaria chamae*. These substances have a protective effect on treated peanut seeds, as the weight losses observed are minimal at the highest doses and the germination capacity of the seeds remains intact. This study shows that the essential oils of *Erythrophleum guineense* and *Uvaria chamae* have insecticidal properties on adult *C. serratus*.

Keywords

C. serratus, *Erythrophleum guineense*, *Uvaria chamae*, Essential Oils and Peanut Seeds

1. Introduction

The peanut, also known as *Arachis hypogaea* L., is an oilseed and protein crop that contributes significantly to global food security, especially in developing countries [1]. In 2020, global production of peanuts in the shell averaged 53.6 million tonnes [2]. In the Republic of Guinea, peanut cultivation is considered one of the main economic and nutritional activities. It accounts for 16.41%, or 160,632 hectares of arable land [3]. This oilseed is rich in protein and lipids, containing 25% and 50% respectively. It is essential to understand the processes that regulate the preservation of global populations and to understand preservation techniques to ensure their survival [4]. However, these grains are often attacked by several insects, the most feared of which is *Caryedon serratus* Ol., responsible for quantitative losses of around 83% post-harvest [5]. These pests cause considerable damage to stored products. The use of synthetic insecticides for chemical control is the most effective method of protection, but it is costly and must be used judiciously.

Indeed, the misuse of pesticides or the use of uncertified products has significant repercussions for ecological health [6]. Over the past two years, a multitude of studies have sought to identify more effective food preservation techniques that would protect human health and the environment. The exploration of new product preservation techniques, based on ancestral skills and the use of phytopesticides made from essential oils derived from aromatic plants, represents a serious avenue of research [7]. For this reason, we analysed the insecticidal impact of essential oils from *Erythrophleum guineense* and *Uvaria chamae* against the peanut weevil *Caryedon serratus* Ol. (Coleoptera, Bruchidae), which destroys peanut reserves in Guinea under controlled conditions. We evaluated the activity of these products by contact based on peanut seed parameters.

2. Materials and Methods

2.1. Plant Material

The aerial parts of two plant species, *Erythrophleum guineense* and *Uvaria chamae*, were collected in the sub-prefecture of Tondon (prefecture of the district of Dubréka). The voucher specimen numbers and the name of the herbarium where the plant samples were deposited are: *Erythrophleum guineense* (ASS-01) HNG0002793, *Uvaria chamae* (ASS-02) HNG0002794 or: ASS (Aboubacar Safi Sylla), HNG (Herbier National de Guinée).

2.2. Animal Material

C. serratus is mass-bred in a plastic jar containing 300 g of peanut grain. This is carried out in the laboratory at a temperature ranging between 20˚C and 25˚C and with a relative humidity of between 10% and 13%.

2.3. Experimental Methods

2.3.1. Extraction of Essential Oils

The essential oils (**Figure 1**) are extracted by hydrodistillation using a Clevenger-type device. Yields are determined based on fresh matter. Hydrodistillation, also known as steam distillation, is an extraction method that uses water as a solvent. The idea is to boil a combination of water and plant material (some of which is very fine) in a flask, during which the plant cells open up and release their substance. The water vapour containing the essential oil passes through a water cooler to condense. Finally, the difference in density separates the water and the oil. After three hours of extraction, it was collected in a small bottle and covered with aluminium foil to protect it from light. It was then stored at a temperature of 4˚C. The yield of essential oil is defined as the ratio between the quantity of essential oil produced and the fresh quantity of plant material processed.

$$R\% = \frac{M1}{M2} \times 100$$

R: essential oil yield, expressed as a percentage. *M*1: mass of essential oils in grams; *M*2: sample volume in grams.

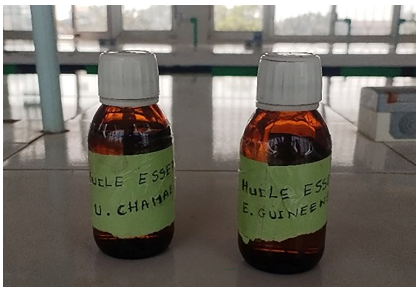

Figure 1. Extracts of essential oils from *Erythrophleum guinnense* and *Uvaria chamae*.

2.3.2. Insect Breeding (*Caryedon serratus* Ol.)

Large-scale breeding is carried out in one-litre glass jars. This involves interaction between adult weevils of indeterminate age and healthy peanut seeds.

The aim of this breeding programme is to obtain a sufficient quantity of adult *C. serratus* aged between 0 and 24 hours, which are essential for various experimental tests. The jars are kept in a dark place at a temperature of 27˚C and a relative humidity of 75%. We used an unspecified number of insects and peanut seeds that had already been contaminated (infested) to accelerate mass breeding (Figure 2).

Figure 2. Peanut seeds purchased, sorted, washed, dried and stored prior to insect rearing.

2.3.3. Contact Biocide Testing

Contact treatment is carried out for the two essential oils of *Erythrophleum guineense* and *Uvaria chamae* 20 g of peanuts for each treatment were placed in glass Petri dishes and then treated with according a volumetric approach which consisted of applying varying treatment volumes to each experiment. The volumes of extracts *Uvaria chamae* essential oil and *Erythrophleum guineense* applied to ensure homogeneous exposure were: 0.2 µL, 0.4 µL, 0.6 µL and 0.8 µL. These doses are distributed evenly and delicately in the Petri dishes. Each dish contains five *C. serratus*, which have a lifespan of less than 24 hours. Controls that have not received any treatment are processed. Three repetitions are performed for each dose and the control batch. All Petri dishes are placed in an incubator set to maintain a temperature of 27˚C and a relative humidity of 75%.

2.3.4. Calculation of the Mortality Rate of Adult *C. serratus* Ol.

This involves counting all adults that have died since the start of the tests for each dose until the patient has died completely. Every 24 hours over a period of 6 days, the dead bruches are counted. The mortalities observed during the tests (*Mo*) are converted into corrected mortality (*Mc*), taking into account the natural mortality (*Mt*) observed in the control group.

$$Mc = \frac{Mo - Mt}{100 - Mt} \times 100$$

Mo = mortality in treated batches, *Mt* = mortality in control batches, and *Mc* = corrected mortality.

2.3.5. Weight Loss Test

Following the last appearance of *C. serratus* Ol. individuals, the weight of the treated seeds and the control seeds is determined using a precision balance. This allows the weight loss of the seeds to be assessed using the following formula:

$$P_p\% = \frac{(P_1 - P_2)}{P_1} \times 100$$

P_P: weight loss.

P_1: initial weight.

P_2: final weight.

2.3.6. Germination Test

After performing the contact test, the germination test is carried out (**Figure 3**). This involves extracting 25 seeds from each box and placing them in Petri dishes covered with cotton wool and filled with water. These are kept in a laboratory climate for 4 to 5 days. The germination rate is determined using the formula below.

$$G\% = \frac{NGE}{NTG} \times 100$$

G: germination percentage.

NGE: number of germinated seeds.

NTG: total number of seeds.

Figure 3. The germination of infected peanut seeds after treatment with aqueous extracts from the leaves of both plants.

3. Results

Examination of the insecticidal capacity of essential oils against *C. serratus* Ol.

3.1. Insecticidal Effects of *Erythrophleum guineense* and *Uvaria chamae* Essential Oils on the Longevity of *C. serratus* Ol. Adults

The values are given as mean ± standard deviation, with the mean indicating the average number of days of insect immortality for each treatment observed. The standard deviation (±) shows the variability in insect immortality times around this mean. The exponents (a, b, c, d) indicate the statistical differences between treatments. Exposure of insects to extracts of *Erythrophleum guineense* and *Uvaria chamae* significantly reduced the average lifespan of insects compared to the control group. With *Erythrophleum guineense*, the average lifespan of the control group decreased from 11.56 ± 0.53 days to 5.65 ± 0.50 days at a dose of 0.2 µl. However, a gradual decrease was observed with increasing doses, reaching 1.75 ± 0.50 days at a dose of 0.8 µl. Similarly, treatments with *Uvaria chamae* showed a considerable and dose-dependent decrease in average longevity, from 8.50 ± 0.55 days with a dose of (0.2 µl) to 2.50 ± 0.56^{d} days at (0.8 µl) (Table 1). The differences observed between doses were statistically significant at: ($p < 0.05$).

Table 1. Test results of the effect of *Erythrophleum guineense* and *Uvaria chamae* essential oils treated by contact on the longevity of *C. serratus* Ol. adults.

The leaves	Treatment	Dosages (µl)	Average lifespan in days
Erythrophleum guineense	T1	0.2	5.65 ± 0.50^{b}
	T2	0.4	3.00 ± 0.00^{c}
	T3	0.6	2.00 ± 0.00^{d}
	T4	0.8	1.75 ± 0.50^{d}
Control	T0	0	11.56 ± 0.53^{a}

Continued

Uvaria chamae	T1	0.2	8.50 ± 0.55^{a}
	T2	0.4	6.50 ± 0.56^{b}
	T3	0.6	4.25 ± 0.95^{c}
	T4	0.8	2.50 ± 0.56^{d}

T1, T2, T3, T4 = different treatments, T0 = Control.

The results in **Table 2** obtained highlight an increasing insecticidal activity of leaf extracts from *Erythrophleum guineense* and *Uvaria chamae* depending on the dose applied and the duration of exposure.

Table 2. Test results of the dose effect of *Erythrophleum guineense* and *Uvaria chamae* ta essential oil on the corrected mortality of *C. serratus* Ol. adults.

The leaves	Dosages	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days
Erythrophleum guineense	0.2	5.5	21.3	43.5	59	81.46	87.45
	0.4	19.78	47.5	75.43	100	100	100
	0.6	33	75.06	100	100	100	100
	0.8	70.11	100	100	100	100	100
Uvaria chamae	0.2	9.2	22.35	40.35	52.33	56.12	45.19
	0.4	4.7	12.79	33.65	43.23	55.95	52.11
	0.6	21	32.80	55.12	75.89	100	100
	0.8	24.6	59.10	69	100	100	100

3.2. Insecticidal Effects of Essential Oils from *Erythrophleum guineense* and *Uvaria chamae* on Weight Loss in Peanut Seeds Infested with *C. serratus* Ol.

These treatments resulted in a reduction in average weight loss compared to the control group (**Table 3**). In the *Erythrophleum guineense* sample, the value decreased from 30.81 ± 0.35^{a} in the control group to 9.57 ± 2.54^{b} at a dose of (0.2 µl) in terms of weight loss. There was then a gradual decrease with increasing dose, reaching zero at (0.6 µl) and (0.8 µl) (**Table 3**). At the same time, *Uvaria chamae* extracts caused a dose-dependent decrease in average weight loss from 13.93 ± 3.25^{a} at (0.2 µl) to 4.76 ± 1.76^{cd} at (0.8 µl). This represents a difference between treatments of ($p < 0.05$).

Table 3. Results of the dose effect test of *Erythrophleum guineense* and *Uvaria chamae* essential oil treated by contact on seed weight loss.

The leaves	Treatment	Dosages	Average lossen poids (%)
Erythrophleum guineense	T1	0.2 µl	9.00 ± 1.43^{b}
	T2	0.4 µl	5.00 ± 0.82^{c}
	T3	0.6 µl	0.00 ± 0.00^{d}
	T4	0.8 µl	0.00 ± 0.00^{d}

Continued

Control	T0	0 µl	30.81 ± 0.35[a]
	T1	0.2 µl	13.93 ± 3.25[a]
Uvaria chamae	T2	0.4 µl	9.57 ± 2.54[b]
	T3	0.6 µl	6.37 ± 1.56[c]
	T4	0.8 µl	4.76 ± 1.76[cd]

T1, T2, T3, T4 = different treatments, T0 = Control.

3.3. Effects of Essential Oils from *Erythrophleum guineense* and *Uvaria chamae* on the Germination Capacity of Peanut Seeds

Extracts of *Erythrophleum guineense* show a significant increase in the average germination rate compared to the control (Table 4). This rate increased from 11.69 ± 1.41[e] (control) to 78.60 ± 3.40[d] after the first dose of (0.2 µl). This was followed by a gradual increase to 94.25 ± 1.70[a] at (0.8 µl). Similarly, in *Uvaria chamae*, a significant and dose-dependent increase in mean germination rates was observed, increasing from 52.50 ± 2.64[d] à (0.2 µl) à 77.50 ± 2.08[a] à (0.8 µl).

Table 4. Results of dose effect testing of essential oils from *Erythrophleum guineense* and *Uvaria chamae* treated by contact on peanut seed germination.

The leaves	Treatment	Dosages	Germination Averages
	T1	0.2 µl	78.60 ± 3.40[d]
Erythrophleum guineense	T2	0.4 µl	85.35 ± 4.57[c]
	T3	0.6 µl	93.55 ± 1.75[b]
	T4	0.8 µl	94.25 ± 1.70[a]
Control	T0	0 µl	11.69 ± 1.41[e]
	T1	0.2 µl	52.50 ± 2.64[d]
Uvaria chamae	T2	0.4 µl	65.50 ± 2.64[c]
	T3	0.6 µl	70.00 ± 2.94[b]
	T4	0.8 µl	77.50 ± 2.08[a]

3.4. Statistical Analyses (R)

The data were recorded in Microsoft Excel spreadsheets as a database for analysis. Statistical analyses of the measured variables were performed using R software. The resulting data were subjected to a non-parametric (sum of ranks) Wilcoxon and Kruskal-Wallis test. The first test was used to determine the significant difference between the calculated means of two samples. The second test was used to test for significant differences between the calculated means of samples. The difference between two values is considered significant when the p-value is less than 5% ($p < 0.05$).

4. Discussion

These results corroborate those reported by several authors who have highlighted the impact of essential oils on the viability and longevity of stored product pests. According to Goucem-Khalfane [8], bergamot, thyme and peppermint essential oils, tested at doses of 0.25 to 2 µl, significantly reduced the lifespan of insects, reaching 0 ± 0, 1.75 ± 0.95 and 3.5 ± 0.57 days, respectively, at the maximum dose of 2 µl. Similarly, Chebari *et al.* [9] observed complete inhibition of adult emergence when Lantana camara essential oil was applied topically to *Ephestia kuehniella* pupae. The evaluation of Pinus pinaster essential oil also revealed increasing mortality of *Callosobruchus maculatus* adults depending on the dose and exposure time, reaching 100% mortality after 24 hours at doses of 12 µl and 18 µl. Furthermore, Koroghli (2018) [10] showed that both peppermint (Mentha piperita L.) and rosemary (*Rosmarinus officinalis* L.) essential oils have a highly significant toxic effect on *R. dominica* adults as the dose and exposure time increase; this toxic effect is significantly greater for pennyroyal essential oil than for sage essential oil.

The weight loss of peanut seeds is directly related to the number of adults that emerged. In the control batches, an average loss of 30.81% ± 0.35% was recorded. *Erythrophleum guineense* essential oil reduced this loss to 9% at a dose of 0.2 µl and completely eliminated it at 0.6 µl. For *Uvaria chamae* essential oil, weight loss decreased from 13.93% at 0.2 µl to 4.76% at 0.8 µl. These observations are consistent with those of Hedjal-Chebheb [11], who showed that increasing concentrations of essential oils from *Eucalyptus lehmannii*, *E. astringens*, *E. maidenii* and *E. cinerea* preserve the initial weight of *Vigna unguiculata* seeds, unlike the control batches, which suffered a 50% decrease. No significant weight loss was recorded for batches treated with *Pinus halepensis* essential oil at a dose of 50 µl/50 g. The work of Aryal *et al.* [12] is consistent with this: after 60 days of storage, maize grains treated with essential oils showed significantly reduced weight loss and damage compared to untreated controls, in which losses reached 24.78% ± 0.58% and damage 59.38% ± 2.09%. In general, the mortality rates observed in our study increase with concentration and duration of exposure for both oils tested. These results confirm those of Chabni and Belabbas [13], who reported 100% mortality in *Callosobruchus chinensis* individuals after two days of exposure to peppermint essential oil (2 µl) and after five days for sage essential oil. Furthermore, peppermint provided total protection of the seeds, with no weight loss, due to the absence of adult emergence from 1.5 µl, while sage produced similar effects from 2.5 µl. In addition, the essential oils tested promoted the preservation of the seeds' germination capacity. The results of Aryal *et al.* [12] indicate maximum germination of 95% ± 2.9% at 10% essential oil, followed by 87.5% ± 2.50% at 5% and 85% ± 2.89% at 2.5%, while untreated seeds only reached 30% ± 4.08%. In our study, healthy seeds had an average germination capacity of 94.25% ± 1.70%, compared to only 11.69% for the control batches. This shows that the essential oils of *Erythrophleum guineense* and *Uvaria chamae* not only help protect seeds from infestation, but also maintain their physiological viability. These findings are consistent with those of Taleb-Toudert [14], who demonstrated that the essential oils of *Eu-*

calyptus radiata and *E. globulus* completely preserve the germination capacity of Vigna unguiculata seeds treated with 8 µl.

5. Conclusion

As part of our research, we sought to examine the bio-efficacy of two essential oils: *Erythrophleum guineense* and *Uvaria chamae*, in relation to adult *C. serratus* Ol. The activity of these products was evaluated through direct contact. The study showed that the lifespan of adults decreases as the doses of insecticides tested increase. The most striking effect was observed with a dose of 0.8 µl of *Erythrophleum guineense* essential oil over two days. Furthermore, these bio-insecticides have a protective effect rather than destroying the germination quality of peanut seeds, regardless of the dose used. However, untreated seeds showed a low germination rate. Thus, the two essential oils obtained in this study, specifically *Erythrophleum guineense*, show a toxic effect on adult *C. serratus* Ol. Consequently, they can be used as substitutes for conventional insecticides.

Conflicts of Interest

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

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