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Effect of aqueous extracts of *Azadirachta indica* A. Juss, *Jatropha curcas* L. and *Moringa oleifera* Lam. on coffee berry borer (*Hypothenemus hampei* F.; Coleoptera: Scolytidae) in laboratory

Ehouman Jean Brice OHOUEU[1*], Alphonse BOUET[1], Amoa Jésus AMOA[1], Djiha Isabelle BEUGRE[1], Drolet Jean-Marc SERY[1], Hyacinthe LEGNATE et Eboua Narcisse WANDAN[2]

[1]National Center for Agricultural Research, Man Research Station, B.P 440 ManMan, Côte d'Ivoire.
[2]National Polytechnic Institute Felix Houphouet Boigny of Yamoussoukro, ESA, Côte d'Ivoire.
[*]Corresponding author, E-mail: ohoueubrice@gmail.com, Phone number: (+225) 0140471277; Tel./ Fax (+225) 2733792279

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ABSTRACT

The coffee berry borer (*Hypothenemus hampei*) is the major pest of coffee crop. This beetle develops resistance against a wide range of insecticides. The aim of this study was to evaluate the effect of aqueous extracts of three plants (*Moringa oleifera*, *Jatropha curcas* and *Azadirachta indica*) on *H. hampei* compared to the chemical insecticide Cypercal 50 EC (cypermethrin). Aqueous extracts of leaves and barks of these plants were applied at three concentrations (400 mg/ml, 200 mg/ml, 100 mg/ml) on coffee berry borer grown in laboratory, according to a randomized block with five repetitions. The results showed that all aqueous extracts of *Moringa oleifera* leaves and bark exhibit insecticidal effects on berry borer. Mortality rates of 80% and 60% of berry borer were recorded after application of aqueous extracts of *Moringa oleifera* leaves and bark, at 400 mg/ml respectively. All three concentrations (400 mg/ml, 200 mg/ml and 100 mg/ml) of aqueous leaf extracts and the 400 mg/ml concentration of *Jatropha curcas* bark caused 50% coffee berry borer mortality. As for *Azadirachta indica*, only the concentration of 400 mg/ml of its barks and leaves aqueous extract caused 50% coffee berry borer mortality. These aqueous extracts obtained from natural plants in Côte d'Ivoire could be a sustainable alternative to chemical insecticides which have become ineffective against the coffee berry borer.

Keywords: Insectarium, cypermethrin, breeding, pesticide and Côte d'Ivoire.

INTRODUCTION

Coffee crop is exposed to several pests that limit its yield. The major insect pest regularly encountered in coffee farms is the berry borer (*Hypothenemus hampei*) (Mbang et al., 2012). The beetle causes damage at all stages of coffee fruiting. The fall of young infested coffee berry is sometimes significant and can reach

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30% of berries appeared (Ohoueu et al., 2021). Furthermore, coffee berry borer entry galleries in cherries favor infestation by bacteria (*Erwinia* sp) and fungi (*Aspergillus* sp., *Fusarium* sp., *Penicillium* sp.) which can be harmful to human health. The presence of mycotoxins in particular is frequent (Ohoueu et al., 2021). *H. hampei* larvae continue to evolve in harvested cherries as long as living conditions are favourable (Mawussi, 2008). Thus, breakage of the fragile perforate coffee seeds during shelling is a source of product loss. Production losses can reach 60% (Wegbe et al., 2003). Several insecticides that have already been tried out have shown their limits in farming environments. In addition, the use of chemical insecticides is increasingly discouraged to avoid its harmful effects on the entomofauna of the natural enemies of *H. hampei*, and to preserve the health of consumers of the finished products. However, organic pesticides based on plant species with negligible impact on the environment are being developed. Thus, the effect of aqueous extracts of local plants, in particular of *Jatropha curcas, Azadirachta indica* and *Moringa oleifera,* which respectively seem to contain pesticidal properties (Van der Vossen and Kamilo, 2007), could be tested on coffee berry borer. The objective of this study was to evaluate the efficacy of plant extracts with an insecticidal effect in the control of coffee berry borer (*Hypothenemus hampei*).

MATERIALS AND METHODS

Study area

The study was carried out in the insectarium of research station of the National Centre for Agronomic Research (CNRA) in Divo. This station is located at 17 km from Divo (Côte d'Ivoire), between 5°.8373900 North latitude and – 5°.3572300 West longitude. The climatic conditions in the insectarium were close to ambient condition of temperature (24 to 28°C). The average relative humidity recorded during the study ranged from 60 to 70%.

Materials

The vegetal material used was constituted from leaves and barks of *Jatropha curcas, Azadirachta indica* and *Moringa oleifera* plants. Red Robusta coffee cherries were used for coffee berry borer breeding. In addition, coffee berry borer breeded in the insectarium were available for the different tests. Added to this biological material is Cypercal 50 EC (cypermethrin), an insecticide from the pyrethroid family, efficacious against coleoptera pests of cherries (Ndoutoumou, 2015).

Methods

Coffee berry borer breeding

Two (02) kilograms of perforated coffee cherries (red, green or dried), harvested from plantations at CNRA (National Centre for Agricultural Research) station in Divo were dissected with a scalpel to extract adult coffee berry borer.

Then, forty (40) healthy red-colored cherries were put in 1,440 cm^3 (L (15 cm) × W (12 cm) × H (8 cm)) clear, colorless plastic pots and 40 coffee berry borers extracted from cherries were deposited there. After a period of 28 days of breeding, which corresponds to the complete biological development cycle of *H. hampei* Ferrari under natural conditions (Ndoutoumou et al., 2015), the 40 cherries were dissected to remove adults coffee berry borers which were used for pesticidal plants test.

Preparation of aqueous extracts of the leaves and barks of A. indica, J. curcas and M. oleifera

The leaves and barks of A. *indica, J. curcas* and *M. oleifera* were harvested in the morning, packed in resealable plastic bags and transferred to laboratory. The leaves were washed in tap water to remove dust and dried at ambient temperature (29°C) for one week. After drying, 400 g of each organ per plant were weighed separately on a precision balance. Then, these organs were ground with a blender and dissolved separately in one liter of distilled water. The homogenate obtained was stored in the shade at ambient temperature (29°C) for one week and then filtered.

Referring to the method of Stoll (Ndoutoumou et al., 2015), 5% of the total maceration volume was recovered (20 ml). From the raw aqueous extract obtained, two (02) other concentrations were prepared for

each organ of vegetal material used: 400 mg/ml, 200 mg/ml and 100 mg/ml. These concentrations were defined according to the method of double dilution of geometric bond of ratio ½ (Zirihi et al., 2003; Ahon et al., 2011).

For the reference control (Cypercal), the concentration of 0.12 mg/ml of cypermethrin was prepared. This concentration was obtained from a commercial preparation of 2.5 ml diluted in 1 liter of distilled water.

Experimental design

A completely randomized design with 05 repetitions, with as factor studied, "insecticidal substance" at 20 levels (water, cypermethrin, EAFMO100, EAFMO200, EAFMO400, EAECMO100, EAECMO200, EAECMO400, EAFJC100, EAFJC200, EAFJC400, EAECJC100, EAECJC200, EAECJC400, EAFAI100, EAFAI200, EAFAI400, EAECAI100, EAECAI200, EAECAI400) indicated in Table 1. The elementary plot is represented by a petri dish comprising 20 unperforated ripe cherries and 20 adults of coffee berry borers. There were a total 100 petri dishes treated.

Application of insecticide substances

The method of Ndoutoumou et al. (2015) was adopted to apply the different aqueous plant extracts to the coffee berry borer. A volume of 2 ml of different concentrations of aqueous extracts of leaves and bark of *A. indica*, *J. curcas* and *M. oleifera* and the reference insecticide (CypermethrinC) were sprayed on 20 bark beetles and 20 unpunched cherries contained in each of 100 Petri dishes, using a hand sprayer. Petri dish treated with water was used as an absolute control. The one treated with Cypercal 50 EC represented the reference control. The treatments were done only once before coffee berry borer perfored cherries as indicated by Wegbe et al. (2003) who showed that in the wild, the coffee berry borer emerges from the fruits between 2 p.m. and 4 p.m. to acclimatize and be fertilized before returning. After treatments, the Petri dishes were closed and placed on shelves for daily observations of mortalities during 10 days.

Data Collection

24 hours after treatments, the number of dead bark beetles is counted in each petri dishes and noted each day during 10 days, because it is on the 10^{th} day of the treatment that the last bark beetles still alive penetrated the cherries. The cherries perforated by the bark beetles were dissected 28 days after the treatments to check the state of the bark beetles (dead or alive) that entered the fruit and of their reproductions (larva, nymph or adult). Cherry dissection was done on day 28 after treatment because the fruit borer reproductive cycle is 28 days.

Estimation of coffee berry borer mortality rate

The mortality rate was calculated according to the formula of Masaaki et al. (2019) recommended by FAO and WHO in insecticide tests. The formula looks like this:

$$\mathrm{Mc} = \frac{Mo-Me}{100-\mathrm{Me}} X\ 100$$

where Mc: Corrected mortality (%),

Mo: Mortality observed in treated lots (%)

Me: Mean of mortalities from distilled water controls

Lethal concentration and lethal time 50% (LC_{50} and LT_{50})

During the test, the number of dead insects is counted each day to determine the concentration of aqueous extract that kills 50% of the insects as a function of time for 10 days.

Statistical analysis

The ANOVAs were carried out with the data on the number of dead coffee berry borer after different treatments. The Least Significant Difference (LSD) was realised with STATISTICA 7.1 software. Excel spreadsheet was used to produce the graphs of the recorded variables (bark beetle mortality rate as a function of time).

Table 1: Treatment of aqueous plant extracts.

Treatment	**Applied product**	**Concentration (mg/ml)**
Absolute control (TA)	Distilled water	0
Reference control (TR)	Cypercal 50 EC (cypermethrin)	0,12
EAFJC400	Aqueous leaf extract of *J. curcas*	400
EAFJC200	Aqueous leaf extract of *J. curcas*	200
EAFJC100	Aqueous leaf extract of *J. curcas*	100
EAECJC400	Aqueous bark extract of *J. curcas*	400
EAECJ200	Aqueous bark extract of *J. curcas*	200
EAECJC100	Aqueous bark extract of *J. curcas*	100
EAFAI400	Aqueous leaf extract of *A. indica*	400
EAFAI200	Aqueous leaf extract of *A. indica*	200
EAFAI100	Aqueous leaf extract of *A. indica*	100
EAECAI400	Aqueous bark extract of *A. indica*	400
EAECAI200	Aqueous bark extract of *A. indica*	200
EAECAI100	Aqueous bark extract of *A. indica*	100
EAFMO400	Aqueous leaf extract of *M. oleifera*	400
EAFMO200	Aqueous leaf extract of *M. oleifera*	200
EAFMO100	Aqueous leaf extract of *M. oleifera*	100
EAECMO400	Aqueous bark extract of *M. oleifera*	400
EAECMO200	Aqueous bark extract of *M. oleifera*	200
EAECMO100	Aqueous bark extract of *M. oleifera*	100

RESULTS

Mean of coffee berry borer mortality 2 days after treatment with aqueous leaf and bark extracts

The results obtained on the mortality rate of coffee berry borer outside the cherry after phytosanitary treatments are presented in Table 2. The reference insecticide (Cypermethrin) caused in an average death of 100 coffee berry borer. The raw concentration of *Moringa oleifera* leaves (400 mg/ml) and that obtained after the first dilution (200 mg/ml) caused in an average mortality of 83 beetles. The third concentration of *Moringa oleifera* leaf extract, 100 mg/ml obtained after the second dilution causedin an average mortality of 70 coffee berry borer.

Statistical analysis did not show any significant difference ($p = 0,23 > 0.05$) between the efficacy of the reference insecticide (Cypermethrin) and those of the aqueous extracts of *Moringa oleifera* leaves at concentrations of 400 mg/ ml and 200 mg/ml.

The three different concentrations (400 mg/ml, 200 mg/ml and 100 mg/ml) of aqueous leaf extract and the raw concentration (400 mg/ml) of aqueous bark extract of *Jatropha curcas* resulted in a mortality of 50 coffee berry borers on average.

Statistical analysis showed a significant difference ($p = 0,023 < 0.05$) between the efficacy of the reference insecticide (Cypermethrin) between the concentrations of *Jatropha curcas* leaf and bark extract. Raw concentrations (400 mg/ml) of aqueous extract from the bark and leaf of *Azadirachta indica* caused an average mortality of 50 coffee berry borers. However, the concentrations of 200 mg/ml and 100 mg/ml respectively caused a mortality of 30 and 20 coffee berry borers on average.

Statistical analysis showed a significant difference ($p = 0,023 < 0.05$) between the efficacy of the reference insecticide (Cypermethrin) between the concentrations of leaf and bark extract of *Azadirachta indica*.

Evaluation of insecticide activity of aqueous leaf extracts at 400 mg/ml according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). During this period, aqueous extract of *Moringa oleifera* leaf caused 80% mortalitywhile aqueous extracts of *Azadirachta Indica* and *Jatropha curcas* leaves each caused 50% mortality of coffee berry borer 2 days after treatment. This mortality rate remained constant for 9 days before reaching 60% mortality on the 10th day. As for *Jatropha curcas*, mortality was 60% on the 4th day before reaching 80% on the 9th day of treatment.

Treatment with distilled water (Absolute control) caused 10% mortality on Day 10 (Figure 1).

Evaluation of insecticide activity of aqueous leaf extracts at 200 mg/ml according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). *Moringa oleifera* leaf extract at 200 mg/ml caused 80% mortality one day after treatment. 2 days after treatment, aqueous extract of *Jatropha curcas* leaves at 200 mg/ml caused 50% mortality of coffee berry borer and the rate remained constant for 10 days. Moreover, the 200 mg/ml concentration of *Azadirachta Indica* resulted in 30% mortality of coffee berry borers during the 10 days (Figure 2).

Treatment with distilled water (Absolute control) caused 10% mortality on the 10th day.

Evaluation of insecticide activity of aqueous leaf extracts at 100 mg/ml according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). The *Moringa oleifera* leaf extract at 100 mg/ml resulted in 60% mortality after one day of treatment then 70% on the 2nd day until the

10th day. The aqueous extract of *Jatropha curcas* leaves at 100 mg/ml caused 50% mortality of coffee berry borer 2 days after treatment then 60% on the 3rd day and remained constant until the 10th day. The concentration of 200 mg/ml of *Azadirachta Indica* caused only 30% mortality of coffee berry borer from the 7th day to the 10th day (Figure 3).

Treatment with distilled water (Absolute control) caused 10% mortality on the 10th day.

Evaluation of insecticide activity of aqueous bark extracts at 400 mg/ml concentration according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). *Moringa oleifera* bark extract at 400 mg/ml caused 60% mortality one day after treatment. Aqueous bark extracts of *Azadirachta Indica* and *Jatropha curcas* with a concentration of 400mg/mL each resulted in 50% mortality of bark beetles 2 days after treatment. This mortality rate remained constant until the 10th day after treatment with *Jatropha curcas* bark extract. *Azadirachta Indica* caused 60% mortality from the 3rd to the 10th day (Figure 4). Treatment with distilled water (Absolute control) caused 10% mortality on the 10th day.

Evaluation of insecticide activity of aqueous bark extracts at 200 mg/ml according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). *Moringa oleifera* bark extract at 200 mg/ml concentration resulted in 60% mortality from the 1st to the 10th day after treatment. the concentration of 200 mg/ml of *Azadirachta Indica* caused 60% mortality of coffee berry borer 5 days after treatment. The aqueous extract of *Jatropha curcas* bark at a concentration of 200 mg/ml caused 40% mortality of coffee berry borer from the 2nd day of treatment (Figure 5).

Treatment with distilled water (Absolute control) caused 10% mortality on the 10th day.

Evaluation of insecticide activity of aqueous bark extracts at 100 mg/ml according to time

One day after treatment with the reference insecticide, total mortality was observed (100% of coffee berry borer). *Moringa oleifera* bark extract at a concentration of 100 mg/ml caused 70% mortality from the 1st to the 10th day after treatment. the concentration of 100 mg/ml of *Azadirachta Indica* and *Jatropha curcas* resulted respectively 30% and 40% mortality of coffee berry borers (Figure 6). Treatment with distilled water (Absolute control) caused 10% mortality on the 10th day.

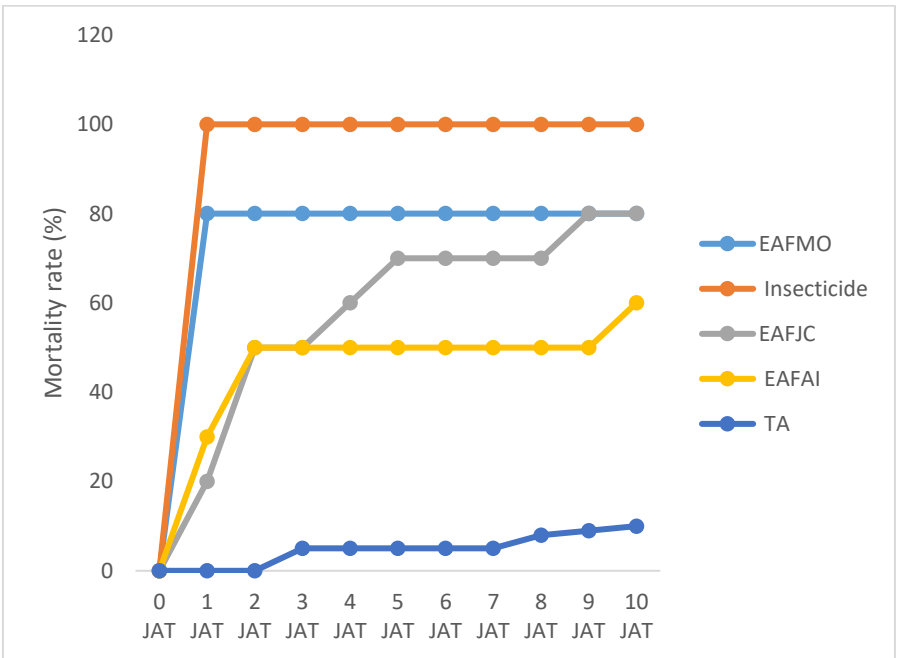
Mortality of coffee berry borer 28 days after treatments

After cherries perforated by coffee berry borer dissection 28 days after treatment, coffee berry borers sprayed with *M. oleifera* extracts (EAFMO100, EAFMO200, EAFMO400, EAECMO100, EAECMO200, EAECMO400) were all dead inside the cherries and did not reproduce. However, coffee berry borer sprayed with extracts of *A. indica* (EAFAI100, EAFAI200, EAFAI400, EAECAI100, EAECAI200, EAECAI400) and *J. curcas* (EAFJC100, EAFJC200, EAFJC400, EAECJC100, EAECJC200 and EAECJC400) were able to reproduce inside the cherries. Larvae, nymphs and new adults of coffee berry borer were observed.

Table 2: Mean of coffee berry borer mortality 2 days after treatment with aqueous leaf and bark extracts.

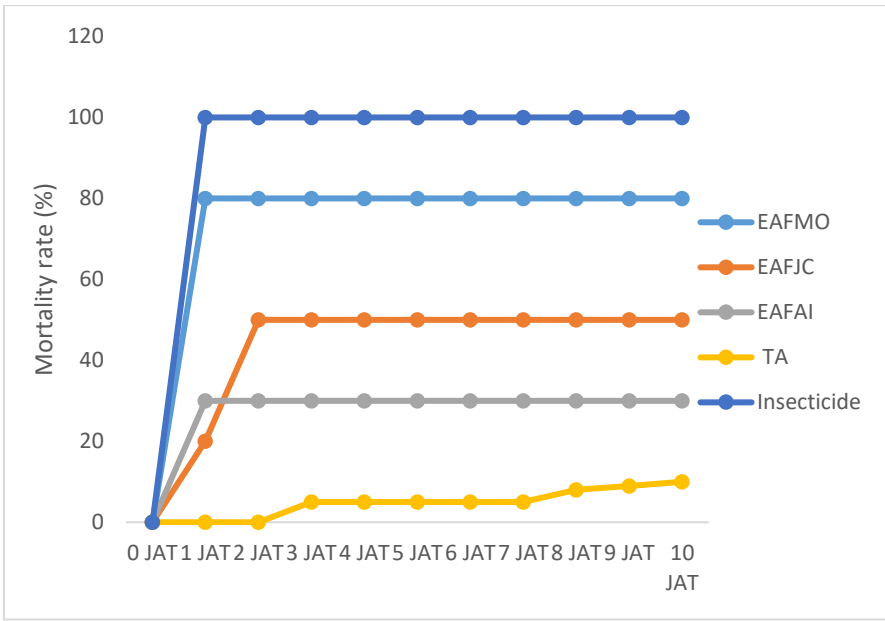
Treatment		**Average mortality of coffee berry borer per plant according concentration of extract sprayed**		
Organs	Concentration (mg/ml)	*Moringa Oleifera*	*Jatropha curcas*	*Azadirachta indica*
Leaves	400	83a (EAFMO400)	50b (EAFJC400)	50b (EAFAI400)
	200	83a (EAFMO200)	50b (EAFJC200)	30c (EAFAI200)
	100	70b (EAFMO100)	50b (EAFJC100)	20c (EAFAI100)
Barks	400	60b (EAECMO400)	50b (EAECJC400)	50b(EAECAI400)
	200	60b (EAECMO200)	40c (EAECJC200)	40c (EAECAI200)
	100	70b (EAECMO100)	30c (EAECJC100)	30c (EAECAI100)
Insecticide (Pyrethroid)	0,12	100a (TR)		
Absolute control (distilled water)	0	0 (TA)		

The means of the same column with a similar letter are not significantly different ($p>0.05$), while the means with different letters are significantly different ($p<0.05$).



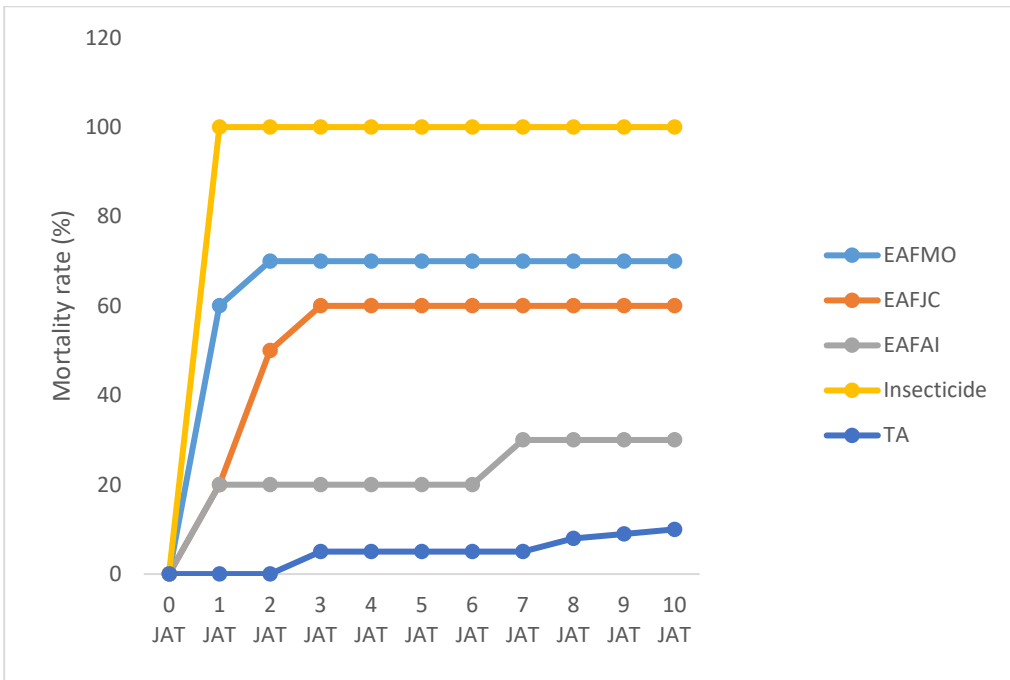
Aqueous leaf extract of *M. oleifera* (EAFMO), Aqueous leaf extract of *Jatropha curcas* (EAFJC), Aqueous leaf extract of *Azadirachta indica* (EAFAI), Absolute control (TA).

Figure 1: Mortality rate of coffee berry borer after aqueous leaf extracts (*M. oleifera, J. curcas* and *A. indica*) treatment with 400 mg/ml concentration.



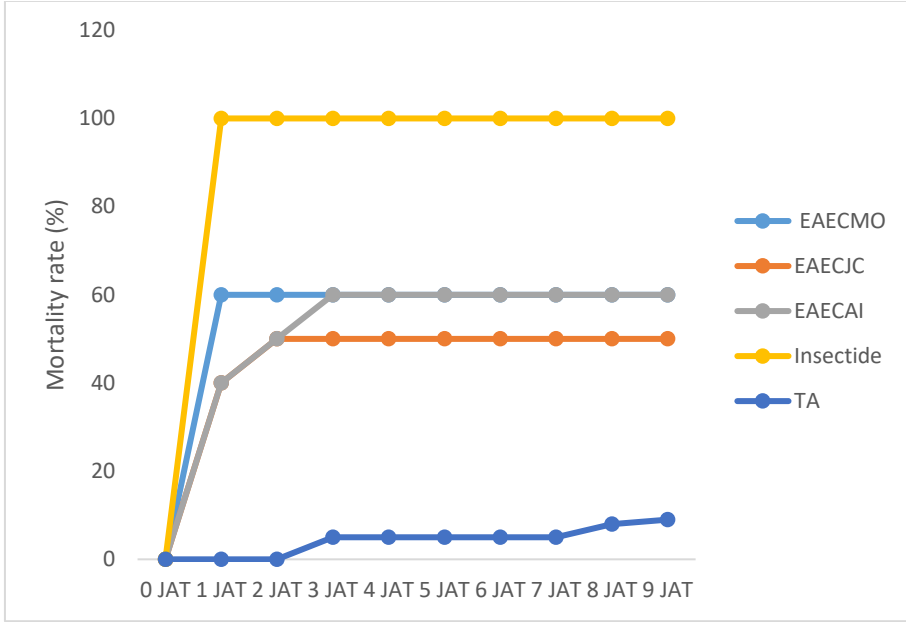
Aqueous leaf extract of *M. oleifera* (EAFMO), Aqueous leaf extract of *Jatropha curcas* (EAFJC), Aqueous leaf extract of *Azadirachta indica* (EAFAI), Absolute control (TA).

Figure 2: Mortality rate of coffee berry borer after aqueous leaf extracts (*M. oleifera*, *J. curcas* and *A. indica*) treatment with 200 mg/ml concentration.



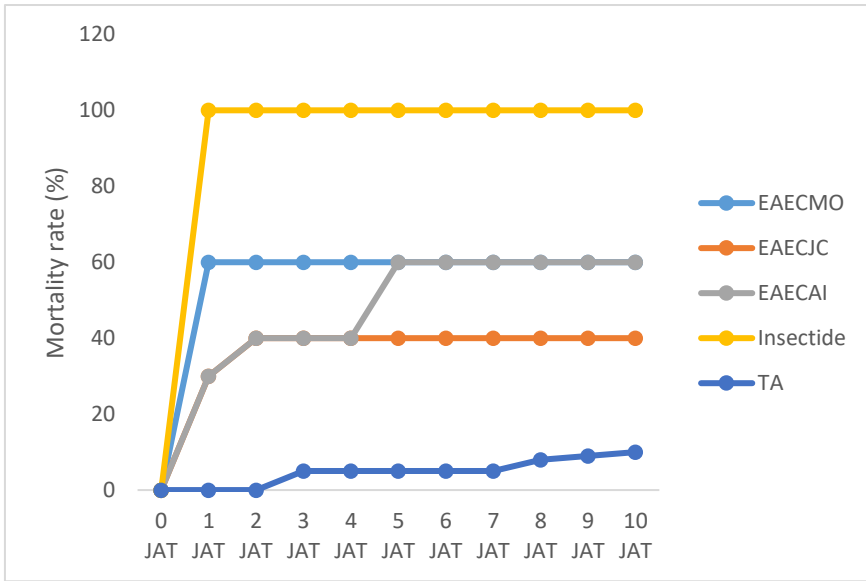
Aqueous leaf extract of *M. oleifera* (EAFMO), Aqueous leaf extract of *Jatropha curcas* (EAFJC), Aqueous leaf extract of *Azadirachta indica* (EAFAI), Absolute control (TA).

Figure 3: Mortality rate of coffee berry borer after aqueous leaf extracts (*M. oleifera*, *J. curcas* and *A. indica*) treatment with 100 mg/ml concentration.



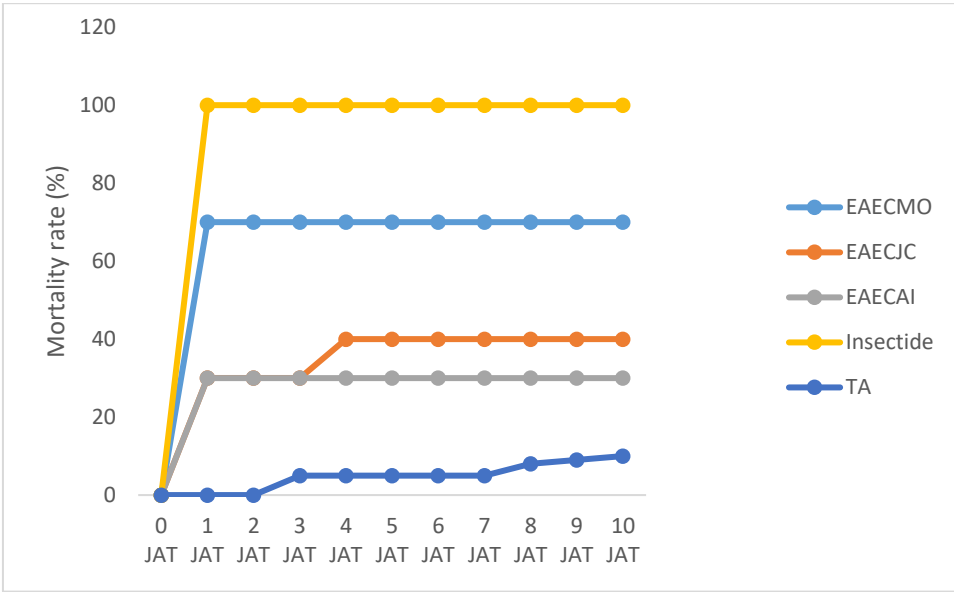
Aqueous bark extract of *M. oleifera* (EAECMO), Aqueous bark extract of *Jatropha curcas* (EAECJC), Aqueous bark extract of *Azadirachta indica* (EAECAI), Absolute control (TA).

Figure 4: Mortality rate of coffee berry borer after aqueous bark extracts (*M. oleifera*, *J. curcas* and *A. indica*) treatment with 400 mg/ml concentration.



Aqueous bark extract of *M. oleifera* (EAECMO), Aqueous bark extract of *Jatropha curcas* (EAECJC), Aqueous bark extract of *Azadirachta indica* (EAECAI), Absolute control (TA).

Figure 5: Mortality rate of coffee berry borer after aqueous bark extracts (*M. oleifera*, *J. curcas* and *A. indica*) treatment with 200 mg/ml concentration.



Aqueous bark extract of *M. oleifera* (EAECMO), Aqueous bark extract of *Jatropha curcas* (EAECJC), Aqueous bark extract of *Azadirachta indica* (EAECAI), Absolute control (TA).

Figure 6: Mortality rate of coffee berry borer after aqueous bark extracts (*M. oleifera*, *J. curcas* and *A. indica*) treatment with 100 mg/ml concentration.

DISCUSSION

The efficacy of aqueous extracts of leaves and bark of *Moringa oleifera*, *Jatropha curcas* and *Azadirachta indica* varied according to the concentrations of these extracts and according to time. The reference insecticide (Cypercal) induced a total mortality of 100% of coffee berry borer, followed by the aqueous extracts of *Moringa oleifera*, which caused 80% mortality of coffee berry borer after one day of treatment with the raw concentration of 400 mg/ml and the diluted concentration (200 mg/ml). The second dilution of the concentration to 100 mg/ml resulted in 60% mortality after one day of treatment. The three different concentrations of *Jatropha curcas* (400 mg/ml; 200 mg/ml and 100 mg/ml) were trained 50% mortality of coffee berry borer.

There is no significant difference ($p=0.23>0.05$) between the efficacy of the insecticide (Cypercal 50 EC) and those of the aqueous extracts of *Moringa oleifera* leaves at a concentration of 400 mg/ml and 200 mg /ml. Thus, to remedy the problems resulting from the use of synthetic pesticides, plants with insecticidal effect such as *Moringa oleifera*, *Jatropha curcas* and *Azadirachta indica* present themselves as a promising alternative in the fight against coffee pests. These results corroborate the work of Okwor et al. (2020) who showed the effectiveness of aqueous extracts of *Moringa oleifera* leaves at different concentrations (100; 200; 300 and 400 mg/ml) on beetle pests of cowpea and rice stocks in the laboratory. Coelho et al. (2009) showed the insecticidal effect of *Moringa oleifera* leaves on aphids in cereal fields in Pakistan.

Furthermore, Ndoutoumou et al. (2015) showed in Gabon that *Jatropha curcas* leaf extracts are toxic to the coffee berry borer. The insecticidal effect of these aqueous leaf extracts could be explained by the presence of active ingredients toxic to pests. These are lectin for *Moringa oleifera*, azadirachtin for *Azadirachta indica* and curcin for *Jatropha*

curcas (Boateng and Kusi, 2008; Senthil-Nathan, 2013; Diabaté and Tano, 2014). Unlike these biodegradable active ingredients that are not very harmful to humans and the environment, various authors have highlighted contamination of phytosanitary products in surface waters and watersheds (Coulibaly et al., 2012 and Traoré et al., 2015). Furthermore, a series of epidemiological studies carried out since 2000 have concluded that exposure to pesticides can affect spermatogenesis, reducing male fertility (Roeleveld and Bretveld, 2008). In addition, residence near agricultural areas has been cited as an explanatory factor for developmental abnormalities in several studies (low birth weight, fetal death, childhood cancers, cryptorchidism, hypospadias) (Carbone et al., 2006).

The raw concentration (400 mg/ml) and the first dilution (200 mg/ml) of aqueous extracts of *Moringa oleifera* bark each caused 60% mortality of bark beetles. While the second dilution of 100 mg/ml of aqueous extracts of *Moringa oleifera* bark caused 70% mortality of coffee berry borer.

The analysis of variance showed that there is no significant difference between the three concentrations (400, 200, 100 mg/ml) of aqueous extract of *Moringa oleifera* bark on the mortality of coffee berry borer. On the other hand, there is a significant difference between the efficacy of aqueous leaf extracts and aqueous bark extracts of *Moringa oleifera* (Coelho et al., 2009). This difference could be explained by the high amount of lectin in the leaves of *Moringa oleifera* compared to the barks. These results corroborate the work of Okwor et al. (2020) who showed the effectiveness of aqueous extracts of *Moringa oleifera* leaves compared to aqueous bark extracts.

At the level of the other two plants, only the raw concentrations (400 mg/ml) of aqueous extracts of bark caused 50% mortality of coffee berry borer.

The ineffectiveness of the diluted concentrations of these bark extracts could be explained by the fact that the more these aqueous extracts are diluted, the more their concentration in active ingredients decreases as well as their toxicity. According to Bouchelta et al. (2005), the saponins contained in the aqueous extracts of *Jatropha curcas* are bitter and have toxic effects on insects. The dilution of this substance would be a source of reduction in the bitter taste, hence their ineffectiveness at these concentrations (200 mg/ml and 100 mg/ml).

Conclusion

The objective of this study was to evaluate the effectiveness of plant extracts with insecticidal effect in the control of coffee berry borer (*Hypothenemus hampei*) in laboratory. It appears from this study that the aqueous extracts of *Moringa oleifera* leaf with a raw concentration of 400 mg/ml and the diluted one of 200 mg/ml are as effective on coffee berry borer as the insecticide Cypercal. The three different concentrations of *Jatropha curcas* (400 mg/ml, 200 mg/ml and 100 mg/ml) caused 50% mortality of coffee berry borer. Only raw concentrations (400 mg/ml) of aqueous leaf extracts of *Azadirachta indica* caused 50% mortality of coffee berry borer. Regarding plant bark extracts, the second dilution of 100 mg/ml concentration is the most effective of the extracts with 70% mortality. Only raw concentrations (400 mg/ml) of aqueous extracts of *Azadirachta indica* and *Jatropha curcas* bark caused 50% of coffee berry borer. The use of these aqueous extracts on coffee berry borer parasitoids would make it possible to know their effects on non-target insects to avoid possible damage in the field application of biopesticides.

COMPETING INTERESTS

The authors declare no competing interests.

AUTHORS' CONTRIBUTIONS

EJBO and AB conceived and designed the study. EJBO, DIB and DJMS conducted the study. AJA and HL analysed and interpreted the data. EJBO wrote the first draft. ENW and AJA revised the manuscript. All authors read and approved the final version of the manuscript.

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