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Comparative efficacy of four biopesticides against *Oryctes monoceros* Olivier (Coleoptera: Dynastidae), a pest of oil palm in Côte d'Ivoire

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Abstract

The excessive use of synthetic insecticides in the phytosanitary protection of oil palm poses risks to public health and the environment. The aim of this study was to compare the efficacy of four (4) biopesticides against *Oryctes monoceros,* a pest responsible for delayed growth and, in some cases, the death of young oil palm plants. After obtaining larvae and adults from insect rearing, four biopesticides (A, B and C) at different concentrations (3.7×10^{-3} g/mL, 6.8×10^{-3} g/mL, and 1.2×10^{-2} g/mL), and biopesticide D (1.4×10^{-3} g/mL, 2.7×10^{-3} g/mL, and 4.8×10^{-3} g/mL) were first evaluated on *Oryctes monoceros* larvae. The larvae were exposed to the toxic effects of 100 mL of each prepared solution applied to 500 g of moistened wood sawdust. Among the four biopesticides tested, only biopesticide D, based on azadirachtin, showed high lethal efficacy, causing elevated larval mortality comparable to that of the reference insecticide. The respective lethal dose causing 10% mortality and lethal dose causing 50% mortality (LD50) values of $6.03\times10^{-4}\pm2.46\times10^{-1}$ g/mL and $2.38\times10^{-3}\pm9.16\times10^{-2}$ g/mL were lower, indicating higher efficacy. Compared to the reference synthetic insecticide cypermethrin, biopesticide D against adults showed an LD50 and a lethal dose causing 90% mortality (LD90) of $7.04\times10^{-3}\pm7.36\times10^{-2}$ g/mL and $2.34\times10^{-2}\pm2.11\times10^{-1}$ g/mL, respectively, while Cypermethrin yielded an LD50 and LD90 of $3.90\times10^{-6}\pm2.58\times10^{1}$ g/mL and $1.49\times10^{-4}\pm1.75\times10^{1}$ g/mL. These results demonstrate the significant insecticidal activity of the biopesticides tested, particularly biopesticide D, against both larvae and adults of *Oryctes monoceros*. This product could be used as an alternative to synthetic chemical pesticides in the management of this pest.

Key words: oil palm, biopesticide, lethal dose, Oryctes monoceros, Côte d'Ivoire.

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Introduction

The oil palm (*Elaeis guineensis* Jacq.) is a crop cultivated primarily for the high oil content of its fruits, which yield both palm oil and palm kernel oil (Ataga & Van der Vossen, 2007). In Côte d'Ivoire, oil palm cultivation is concentrated in three main production zones: the southeast, south-central, and southwest regions. This crop enables producers to diversify their income sources. However, like any cash crop, oil palm production is constrained by several factors, notably the impact of insect pests and diseases (Hala, 2020). Globally, yield losses in major crops due to pests and weeds are estimated at 35% before harvest, and in the absence of any control measures, these losses could reach up to 70% (Popp *et al*., 2013).

Ivorian oil palm plantations host a wide range of insect species from different orders, primarily Lepidoptera and Coleoptera. Among the latter is *Oryctes monoceros* Olivier, a beetle belonging to the family Dynastidae. This insect is a notorious pest of both oil palm and coconut plantations (Allou *et al*., 2006). *O. monoceros* typically inhabits old trunks of palm and coconut trees (Julia & Mariau, 1976). The most damaging stage is the adult, which bores galleries at the base of unopened leaves. These adults can reach the apical meristem, causing delayed development in young palms and, in severe cases, plant death (Mariau, 1981).

Given the spread of this pest, phytosanitary protection of oil palm plantations is imperative. Consequently, producers often resort to chemical pesticides. However, excessive use of these chemicals poses significant risks to human health and the environment (USDA, 2024).

In the context of plant protection and environmental preservation on the one hand, and sustainable agriculture on the other, alternative control methods such as biopesticides are promising options. These can reduce reliance on chemical products and help mitigate the risks of resistance development.

This study was therefore initiated to explore alternative control strategies for this pest. It aims to evaluate the efficacy of four biopesticides against *Oryctes monoceros* Olivier (Coleoptera: Dynastidae), a major pest of young oil palms.

Specifically, the objectives are: i) to assess the efficacy of the four biopesticides on *O. monoceros* larvae; ii) to compare the best biopesticide tested on larvae with a reference insecticide on *Oryctes monoceros* adults.

Materials and Methods

Experimental site

The study was conducted on oil palm at the entomology laboratory of the Mé research station (5°26'N, 3°50'W), part of the National Center for Agronomic Research. This station is located in the south-eastern region of Côte d'Ivoire. The area is characterized by two rainy seasons (March to July and November), alternating with two dry seasons (December to February and August to October) (Traoré & Mangara, 2009). The region receives an average annual rainfall of approximately 1500 mm, with an average temperature of 27°C. Bordered to the east by the Mé River (a tributary of the Comoé) and to the south by the Aghien Lagoon, the Mé research station is located 30 km northeast along the Abidjan-Alépé road (Traoré & Mangara, 2009). The trials were conducted from February 2023 to July 2024.

Preparation of various doses

Four biopesticides (A, B, C, and D) were used in these trials and compared with a reference chemical insecticide on both larvae and adults of *Oryctes monoceros*. The biopesticide A, product Neco 50 EC, is a biopesticide extracted from *Ocimum gratissimum*, containing thymol, gamma-terpinene, and eugenol. It is a systemic and contact product supplied at a concentration of 50 g/L. The biopesticide B, Proraly 50 EC, is a biological extract derived from *Cymbopogon winterianus* (lemongrass), containing thymol, eugenol, citronellal, and citronellol. The proraly concentration is 50 g/L. The biopesticide C, Astoun 50 EC, is a biological extract of essential oil from *Cymbopogon citratus*, with active ingredients including geranial, neral, and myrcene. Its concentration is 50 g/L. These three biopesticides, A, B, and C, were manufactured by the Biopesticide Production Unit (UPB) at Félix Houphouët-Boigny University in Abidjan, Côte d'Ivoire. The biopesticide D, Best-Wicido 200 SL, was manufactured by WishKrish Agrosciences in Chennai, Tamil Nadu, India. The biopesticide D is a biological insecticide extracted from *Azadirachta indica* (neem), with azadirachtin as the active ingredient at a concentration of 20 g/L. Cypercal 50 EC is a chemical insecticide containing Cypermethrin as the active ingredient, with a concentration of 50 g/L. Quantities of product were taken for dilution with distilled water to obtain the different concentrations of the formula tests [Eq. 1]:

$$Cf = Ci \times Vi / Vf \qquad \text{[Eq. 1]}$$

Where, Cf is the final concentration, Ci is the initial concentration, Vi is the initial volume, and Vf is the final volume.

For this study, three different volumes (8 mL, 16 mL, and 32 mL) of each product were taken and diluted in 100 mL of distilled water in a beaker. This allowed the preparation of three corresponding concentrations: 3.7×10^{-3} g/mL, 6.8×10^{-3} g/mL, and 1.2×10^{-2} g/mL, which were evaluated. For the biopesticide D (Azadirachtin), 8 mL, 16 mL, and 32 mL were also taken and diluted in 100 mL of distilled water. However, the latter dilutions yielded concentrations of 1.4×10^{-3} g/mL, 2.7×10^{-3} g/mL, and 4.8×10^{-3} g/mL, respectively, which were applied to larvae of stage 3.

Quantities of 16 mL, 32 mL, and 64 mL of biopesticide D (Azadirachtin) diluted in 100 mL of water yielded concentrations of 2.7×10^{-3} g/mL, 4.8×10^{-3} g/mL, and 7.8×10^{-3} g/mL, respectively, which were used for tests on adults. For these tests, two controls were used: the chemical insecticide Cypermethrin (positive control) at a concentration of 4.9×10^{-4} g/mL, and an untreated control (no exposure to the product). All prepared solutions were transferred into a hand sprayer for application.

Application of different doses

A quantity of 100 mL of each prepared solution was measured using a syringe for each dose and poured onto 500 g of wood sawdust to ensure adequate moistening. Using a soft entomological forceps, 10 larvae or 10 adults of *Oryctes monoceros* were released into each box. After the application of the doses and the insect release, the boxes were transferred to a greenhouse. For each of the three concentrations of each product, three replicates were performed. A total of 570 larvae and 210 adults were used in the trial. Mortality rates were assessed daily for 5 days following the product application. Observations included counting the number of dead, moribund (barely moving), and active individuals. If mortality in the control group was equal to or greater than 10%, the test was invalidated. However, when a few dead or moribund insects were observed among the controls (mortality less than 10%), mortality rates were then corrected using Abbott's (1925) formula [Eq. 2]:

$$\mathbf{CM}\ (\%) = \frac{OM(\%) - MT(\%)}{100 - MT(\%)} \qquad \text{[Eq. 2]}$$

Where, CM is the corrected mortality, OM is the observed mortality, and MT is the mortality in the control group.

Statistical analyses

Mean separation was conducted using the least significant difference test at a 5% significance level using SAS, version 9.4 (SAS Institute Inc., Cary, NC, USA) to compare the effects of different biopesticides. Using WinDL 32.0 software (CIRAD, Montpellier, version 1998), the lethal dose (LD_{50}) (the dose causing 50% mortality of the test insect population) was determined for each bio-insecticide 48 hours after exposure of larvae or adults to the pesticide. This allowed the determination of threshold or remarkable lethal doses LD_{10}, LD_{50}, and LD_{90}, corresponding respectively to mortality rates of 10%, 50%, and 90% within the population. The product with the lowest LD_{50} or LD_{90} values was considered the most effective (Tchoumbougnang *et al*., 2009).

Results

Effect of biopesticides on *Oryctes monoceros* larvae

The untreated control recorded no mortality over 5 days. Application of biopesticide A on larvae at a concentration of 3.7×10^{-3} g/mL induced mortality rates of up to 16.67±5.8% for the 4th and 5th days post-treatment. The 6.8×10^{-3} g/mL dose induced mortality rates of 20.00±10.0%; 23.33±5.8% and 26.67±5.8 were recorded on the 3rd, 4th, and 5th days, respectively. The highest dose of 1.2×10^{-2} g/mL resulted in mortality rates of 23.33±15.3%, 26.67±15.3%, 26.67±15.3 %, and 30.00±20.0% from the 2nd to the 5th day of observation, respectively. The chemical control (Cypermethrin) induced mortality rates ranging from 73.33±20.8% to 100±0% over the course of the experiment. Statistical analysis indicated a significant difference in mortality rates for each observation day ($p<0.05$) (Table 1).

The untreated control showed no mortality throughout the trial period. The biopesticide B only induced larval mortality from the second day onward, regardless of the dose. At the lowest concentration, 3.7×10^{-3} g/mL, a mortality rate of 20% was recorded only on the 5th day. At the intermediate dose 6.8×10^{-3} g/mL, high mortality rates of 20.00±0.00% were recorded on the 4th and 5th days, respectively. In contrast, the highest dose 1.2×10^{-2} g/mL induced mortality rates of 3.33±5.8%; 10.00±0.00%; 20.00±11.5% and 23.33±15.3%, respectively, from the 2nd to the 5th day. The chemical control (Cypercal) caused mortality rates ranging from 73.33±20.8% to 100±0% during the trial. These results also showed statistically significant differences in mortality rates between each observation day ($p<0.05$) (Table 2).

The untreated control recorded no mortality for the duration of the trial. The dose of 3.7×10^{-3} g/mL of the biopesticide C induced a mortality rate of 20±15.3% on the 5th day after application. The intermediate dose of 6.8×10^{-3} g/mL caused mortality rates of 26.67±5.8% on the 4th day and 36.67±5.8% on the 5th day. As for the highest dose of 1.2×10^{-2} g/mL. The observed mortality rates were 20±5.8%, 33.33±11.5%, and 40±15.3% on the 3rd, 4th, and 5th days of observation, respectively. Moreover, the chemical control (Cypermethrin) caused mortality rates exceeding 70 % on each day of observation. Statistical analysis revealed a significant difference in mortality rates across observation periods ($p<0.05$) (Table 3).

The untreated control recorded no mortality throughout the trial. The different doses of the biopesticide D induced varying mortality rates. The dose of 1.4×10^{-3} g/mL caused a mortality rate of 20±0% after 1 day. Mortality rates recorded after 2, 3, 4, and 5 days were 40±10%, 46.67±11.5%, 53.33%±23.1%, and 63.33±23.1%, respectively. As for the 2.7×10^{-3} g/mL dose, mortal-

Table 1. Effect of biopesticide A on *Oryctes monoceros* larvae according to observation periods.

Concentrations	Mortality rate (%) (mean±standard deviation)				
	1 day	2 days	3 days	4 days	5 days
TNT	0.00±0.00[b]	0.00±0.00[b]	0.00±0.00[d]	0.00±0.00[c]	0.00±0.00[c]
3.7×10^{-3} g/mL	0.00±0.00[b]	6.67±5.8[b]	10.00±0.00[cd]	16.67±5.8[b]	16.67±5.8[bc]
6.8×10^{-3} g/mL	6.67±11.5[b]	16.67±11.5[b]	20.00±10.0[bc]	23.33±5.8[b]	26.67±5.8[b]
1.2×10^{-2} g/mL	16.67±5.8[b]	23.33±15.3[b]	26.67±15.3[b]	26.67±15.3[b]	30.00±20.0[b]
Cypermethrin	73.33±20.8[a]	86.66±2.31[a]	100±0[a]	100±0[a]	100±0[a]
Pr>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

TNT, untreated control; Pr, probability; F, Fisher value. Values followed by the same letter within a column are not significantly different (least significant difference test α=5%).

Table 2. Effect of biopesticide B on *Oryctes monoceros* larvae according to observation periods.

Concentrations	Mortality rate (%) (mean±standard deviation)				
	1 day	2 days	3 days	4 days	5 days
TNT	0±0[b]	0.00±0.00[b]	0.00±0.00[d]	0.00±0.00[c]	0.00±0.00[c]
3.7×10^{-3}g/mL	0±0[b]	3.33±5.8[b]	3.33±5.8[cd]	16.67±5.8[b]	20.00±0.00[bc]
6.8×10^{-3}g/mL	0±0[b]	3.33±5.8[b]	6.67±11.5[bc]	20.00±0.00[b]	20.00±10.0[b]
1.2×10^{-2}g/mL	0±0[b]	3.33±5.8[b]	10.00±0.00[b]	20.00±11.5[b]	23.33±15.3[b]
Cypermethrin	73.33±20.8[a]	86.66±23.1[a]	100±0[a]	100±0[a]	100±0[a]
Pr>F	0.0753	0.0586	0.0477	0.0294	0.0003

TNT, untreated control; Pr, probability; F, Fisher value. Values followed by the same letter within a column are not significantly different (least significant difference test α=5%).

Table 3. Effect of biopesticide C on *Oryctes monoceros* larvae across observation periods.

Concentrations	Mortality rate (%) (mean±standard deviation)				
	1 day	2 days	3 days	4 days	5 days
TNT	0±0[b]	0±0[b]	0±0[c]	0±0[c]	0±0[c]
3.7×10^{-3}g/mL	0±0[b]	3.33±5.8[b]	6.67±11.5[c]	16.67±11.5[c]	20±15.3[c]
6.8×10^{-3}g/mL	0±0[b]	10±0[b]	16.67±5.8[b]	26.67±5.8[b]	36.67±5.8[b]
1.2×10^{-2}g/mL	3.33±5.8[b]	10±0[b]	20±5.8[b]	33.33±11.5[b]	40±15.3[b]
Cypermethrin	73.33±20.8[a]	86.66±23.1[a]	100±0[a]	100±0[a]	100±0[a]
Pr>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

TNT, untreated control; Pr, probability; F, Fisher value. Values followed by the same letter within a column are not significantly different (least significant difference test α=5%).

ity rates from one to three were 23.33±5.8%, 53.33±15.3%, and 66.67±5.8%, respectively. On the 4th and 5th days, the mortality rates reached 73.33±11.5% and 76.67±15.3%, respectively. The dose of 4.8×10^{-3} g/mL induced a 40±10% mortality rate after 1st day. On the 2nd through the 5th day, the mortality rates were 70±10%, 76.67±5.8%, and 83.33±5.8%, respectively. The chemical control (Cypercal) induced mortality rates of 73.33±20.8% and 86.66±23.1% after the 1st and 2nd day, respectively. From the 3rd to the 5th day, the chemical control caused 100±0% mortality. Statistical analysis showed a significant difference in mortality rates for each observation period ($p<0.05$) (Table 4).

Comparison of the efficacy of different biopesticides on *Oryctes monoceros* larvae

Lethal doses causing 10% mortality (LD_{10}) in *Oryctes monoceros* larvae with biopesticide D were $6.03\times10^{-4}\pm2.46\times10^{-1}$ g/mL, for biopesticide A, $4.96\times10^{-3}\pm1.95\times10^{-1}$ g/mL, biopesticide C, $9.50\times10^{-3}\pm1.37\times10^{-1}$ g/mL, and for biopesticide B, $3.10\times10^{-2}\pm6.26\times10^{-1}$ g/mL. For lethal doses resulting in 50% larval mortality (LD_{50}), biopesticide D exhibited an LD_{50} of $2.38\times10^{-3}\pm9.16\times10^{-2}$ g/mL. The LD_{50} for biopesticide A, biopesticide C, and biopesticide B were $3.08\times10^{-2}\pm7.68\times10^{-3}$ g/mL, $6.08\times10^{-2}\pm4.30\times10^{-1}$ g/mL, and $6.76\times10^{-1}\pm1.66$ g/mL, respectively (Table 5).

Comparison of the efficacy of the biopesticide D (Azadirachtin) and the synthetic chemical insecticide Cypermethrin on adult *Oryctes monoceros*

Mortality rate of adult Oryctes monoceros

Different doses of biopesticide D (Azadirachtin) induced variable mortality rates in adults. The dose of 2.7×10^{-3} g/mL caused mortality rates ranging from 10±0% to 40±0% across observation periods. The 4.8×10^{-3} g/mL dose induced mortalities of 43.33±5.8%, 46.67±11.5%, 50±10%, and 50±5.8% between day 2 and day 5. The 7.8×10^{-3} g/mL dose induced mortality of 43.33±5.8%, 50±0%, 60±5.8% and 60±0% between day 2 and day 5. The chemical control (Cypermethrin) induced mortality rates of 83.33±10% and 96.67±5.8%, respectively, on the 1st and 2nd day after treatment. From days 3 to 5, the chemical control induced 100±0% mortality. The untreated control induced no mortality throughout the trial. Statistical analysis showed a significant difference in mortality rates across observation periods ($p<0.05$) (Table 6).

Table 4. Effect of biopesticide D on *Oryctes monoceros* larvae across observation periods.

Concentrations	Mortality rate (%) (mean±standard deviation)				
	1 day	2 days	3 days	4 days	5 days
TNT	0 ± 0^{c}	0 ± 0^{d}	0 ± 0^{d}	0 ± 0^{d}	0 ± 0^{c}
1.4×10^{-3} g/mL	20 ± 0^{b}	40 ± 10^{c}	46.67 ± 11.5^{c}	53.33 ± 23.1^{c}	63.33 ± 23.1^{b}
2.7×10^{-3} g/mL	23.33 ± 5.8^{b}	53.33 ± 15.3^{bc}	66.67 ± 5.8^{b}	73.33 ± 11.5^{bc}	76.67 ± 15.3^{ab}
4.8×10^{-3} g/mL	40 ± 10^{b}	70 ± 10^{ab}	76.67 ± 5.8^{b}	83.33 ± 5.8^{ab}	83.33 ± 5.8^{ab}
Cypermethrin	73.33 ± 20.8^{a}	86.66 ± 23.1^{a}	100 ± 0^{a}	100 ± 0^{a}	100 ± 0^{a}
Pr>F	<0.0001	0.0002	<0.0001	<0.0001	<0.0001

TNT, untreated control; Pr, probability; F, Fisher value. Values followed by the same letter within a column are not significantly different (least significant difference test α=5%).

Table 5. Lethal dose 10% and lethal dose 50% of biopesticides on *Oryctes monoceros* larvae.

Products	n	CI (95%)	LD_{10}±SD (g/mL) (LD_{10})	CI (95%)	LD_{50}±SD (g/mL) (LD_{50})
Biopesticide B	90	1.84×10^{-3}–5.25×10^{-1}	$3.10\times10^{-2}\pm6.26\times10^{-1}$	3.73×10^{-4}–1.22×10^{3}	$6.76\times10^{-1}\pm1.66$
Biopesticide C	90	5.22×10^{-3}–1×10^{-1}	$9.50\times10^{-3}\pm1.37\times10^{-1}$	$2.06.10^{-2}$–$3.04.10^{4}$	$6.08\times10^{-2}\pm4.30\times10^{-1}$
Biopesticide A	90	2.05×10^{-3}–1.19×10^{-2}	$4.96\times10^{-3}\pm1.95\times10^{-1}$	7.68×10^{-3}–1.42×10^{-1}	$3.08\times10^{-2}\pm7.68\times10^{-3}$
Biopesticide D	90	3.83×10^{-5}–1.23×10^{-3}	$6.03\times10^{-4}\pm2.46\times10^{-1}$	$1.09.10^{-3}$–$3.38.10^{-3}$	$2.38\times10^{-3}\pm9.16\times10^{-2}$
Cypermethrin	90	1×10^{-38}–1×10^{38}	$2.87\times10^{-6}\pm3.47\times10^{1}$	1×10^{-38}–5.47×10^{30}	$1.78\times10^{-3}\pm3.6\times10^{-2}$

N, number of larvae tested; CI, confidence interval; LD_{10}, lethal dose for 10% mortality; LD_{50}, lethal dose for 50% mortality; SD, standard deviation.

Table 6. Effect of biopesticide D (Azadirachtin) on *Oryctes monoceros* adults.

		Mortality rate (%) (mean±standard deviation)				
	Doses	1 day	2 days	3 days	4 days	5 days
TNT		0 ± 0^{c}	0 ± 0^{d}	0 ± 0^{d}	0 ± 0^{d}	3.33 ± 5.8^{d}
Biopesticide D	2.7×10^{-3} g/mL	10 ± 0^{bc}	23.33 ± 5.8^{cd}	33.33 ± 5.8^{c}	40 ± 15.3^{c}	40 ± 0^{c}
	4.8×10^{-3} g/mL	23.33 ± 5.8^{b}	43.33 ± 5.8^{bc}	46.67 ± 11.5^{b}	50 ± 10^{b}	50 ± 5.8^{b}
	7.8×10^{-3} g/mL	26.67 ± 5.8^{b}	43.33 ± 5.8^{b}	50 ± 0^{b}	60 ± 5.8^{b}	60 ± 0^{b0}
Cypermethrin	4.9×10^{-4} g/mL	83.33 ± 10^{a}	96.67 ± 5.8^{a}	100 ± 0^{a}	100 ± 0^{a}	100 ± 0^{a}
Pr>F		0.0024	0.0010	0.0209	0.001	0.0002

TNT, untreated control; Pr, probability; F, Fisher value. Values with the same letter in the same column are not significantly different (least significant difference test α=5%).

Table 7. Lethal dose of biopesticide D (Azadirachtin) on *Oryctes monoceros* adults in 48 hours.

Products	n	CI (95%)	LD_{50}±SD (g/mL) (LD_{50})	CI (95%)	LD_{90}±SD (g/mL) (LD_{90})
Biopesticide D	90	5.33×10^{-3}–1.32×10^{-2}	7.04×10^{-3}±7.36×10^{-2}	1.27×10^{-2}–$2.48.10^{-1}$	2.34×10^{-2}±2.11×10^{-1}
Cypermethrin	90	1×10^{-38}–1×10^{38}	3.90×10^{-6}±2.58×10^{1}	1×10^{-38}–4.05×10^{30}	1.49×10^{-4}±1.75×10^{1}

N, number of larvae tested; CI, confidence interval; LD_{50}, lethal dose for 50% mortality; LD_{90}, lethal dose for 90% mortality; SD, standard deviation.

Determination of lethal dose 50% and lethal dose 90% values

The lethal dose values for the biopesticide D (Azadirachtin) were 7.04×10^{-3}±7.36×10^{-2} g/mL for LD_{50} and 2.34×10^{-2}±2.11×10^{-1} g/mL for LD_{90}. In comparison, the reference chemical insecticide Cypercal showed significantly lower lethal doses of LD_{50}: 3.90×10^{-6}±2.58×10^{1} g/m L and LD_{90}: 1.49×10^{-4}±1.75 $\times10^{1}$ g/mL (Table 7).

Discussion

Analysis of larval and adult mortality of *Oryctes monoceros* over the 5-day period showed a significant increase in mortality rate in response to increasing doses of the four biopesticides tested (ranging from 0 to 83.33±0.58 %). In contrast, no mortality was observed in the untreated control groups. The contact lethal doses (LD_{10}, LD_{50}, and LD_{90}) highlighted their biocidal effect and showed that insect mortality was strongly dependent on the dose of products applied, as mentioned by Yéboué *et al*. (2022) and Akessé *et al*. (2020). This first observation confirms the insecticidal properties of these products in addition to their fungicidal effects previously documented by Fofana *et al*. (2020) and Kassi *et al*. (2014). In effect, these compounds act on the insect nervous system.

Based on LD_{50} values, the biopesticide D was the most effective of the four tested on *Oryctes monoceros* larvae, and showed a lethal effect on adults. This effectiveness is linked to its active ingredient, azadirachtin. This molecule has antiappetant, sterilizing, and development-regulating effects (Aribi *et al*., 2020). Various studies have highlighted the bio-insecticidal effect of this molecule (Traoré *et al*., 2019; Yao *et al*., 2021; Guessan-bi *et al*., 2024). The work of Hajjar *et al*. (2021) also highlighted the integration of the repellent effect of the neem-based insecticide and Bio-Trap pheromone with *Beauveria bassiana* (Hypocreales: Cordycipitaceae) to control *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae). Their results showed that the repellent effect of the neem-based insecticide (azadirachtin) on adult *Rhynchophorus ferrugineus.* Apart from biopesticide D (azadirachtin), biopesticides (A, B, and C) also had lethal effects on *Oryctes monoceros* larvae, but the respective LD_{50} determined with these biopesticides were below 2.10^{-2} g/mL. The insecticidal potential of these biological products is explained by the active molecules they contain. Biopesticide A contains active molecules such as Thymol and γ-Terpinene, which are present in the essential oil of *Ocimum gratissimum* and would be responsible for the insecticidal effect (Kobenan *et al*., 2018; Kassi *et al*., 2014). The efficacy of biopesticide A was demonstrated by Akessé *et al.* (2020) against the beetle *Diastocera trifasciata,* a cashew branch borer in Côte d'Ivoire. As for biopesticide C, its efficacy has been further proven as a biofungicide (Fofana *et al*, 2020). However, its active ingredients include major compounds such as geranial, neral, and myrcene, found in the essential oil of *Cymbopogon citratus*, which are thought to contribute to its insecticidal effect. Regarding biopesticide B, despite its combination of several active compounds, including thymol, eugenol, citronellal, and citronellol, its insecticidal action proved limited. Nonetheless, this systemic and contact biopesticide with a broad spectrum is recommended for controlling black and yellow cercospora diseases in banana and various other plant diseases.

Conclusions

At the end of this study, the evaluation of the efficacy of the four biopesticides (A, B, C, and D), tested on third-instar larvae, revealed that biopesticide D, based on azadirachtin, demonstrated significant efficacy. Although this biopesticide demonstrated insecticidal properties on *Oryctes monoceros* larvae, its lethal effect did not surpass that of the reference chemical insecticide, Cypercal, based on Cypermethrin on adults. These results underscore the importance of further exploring and optimizing the use of biopesticides for the management of *Oryctes monoceros*. For example, azadirachtin, although effective, could benefit from improved formulations or combinations with other active ingredients to increase its efficacy. The integration of Azadirachtin into pest management programs for oil palm, especially against *Oryctes monoceros*, could offer a more sustainable and environmentally friendly alternative to synthetic pesticides.

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