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Biological Activity of Total Extracts of Eight Plants on the Development of the Fruit Fly, *Bactrocera dorsalis* (Diptera: Tephritidae) from Egg to Emergence

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Abstract

Bactrocera dorsalis is one of the major constraints on the mango industry in Burkina Faso. To control these insect pests, a number of control methods have been used, including synthetic insecticides that are costly for producers. Overuse of these insecticides often leads to environmental pollution, food poisoning and resistance among the insects. A study of the biological efficacy of organic extracts from eight plant materials (*Capsicum annum*, *Cleome viscosa*, *Mytragina inermis*, *Strophantus hispidus*, *Ocimum basilicum*, *Cassia nigricans*, *Cassia occidentalis*) on *Bactrocera dorsalis* was carried out under laboratory conditions. In the laboratory, these plants were extracted using solvents of increasing polarity (n-hexane, ethyl acetate and methanol) according to the Nair method (Kambou *et al.,* 2008). The biological activity test on the development of *B. dorsalis* was carried out in a randomized Fisher block design with 25 treatments in 10 replicates. Hexane extracts of *C. annuum* and *S. hispidus* resulted in 100% inhibition of *B. dorsalis* development.

Keywords

Capsicum annuum, *Strophantus hispidus*, *Bactrocera dorsalis*, Eggs, Larva, Pupa

1. Introduction

The mango industry in Burkina Faso is faced with numerous insect pest attacks, including fruit flies. These fruit flies inflict enormous losses in quantity and quality on mango production. Indeed, the *Bactrocera dorsalis* species is the most damaging Tephritidae to fruit production in Burkina Faso. Its introduction in 2005 led to an increase in damage and economic losses. It can cause losses of up to 80% if no appropriate phytosanitary controls are put in place [1] (Vayssières *et al.*, 2010). The economic impact includes not only direct yield losses and high control costs, but also the loss of export markets due to high quarantine treatment costs imposed by importing countries [2] (Bokonon-Ganta *et al.*, 2010). In view of the extent of this damage, several strategies have been developed to combat fruit flies. The overuse of pesticides and the behavior of certain producers in Burkina Faso (who use cotton treatment pesticides such as Decis to control mango fruit flies) lead to pesticide residue deposits and cause the death of other insects, including beneficial insects. This gives this control method a negative environmental impact. Faced with this problem, other methods have been developed, such as chemical control using natural pesticides based on plant extracts. In this method, aqueous extracts of plants available locally in Burkina Faso are used to keep the pest population below the nuisance threshold. Biopesticide plants include *Cleome viscosa* L., *Capsicum annuum*, *Strophantus hispidus* DC, *Mytragina inermis* (Wild) kuntze, *Ocimum basilicum* L., *Cassia nigricans* (Vahl.), *Cassia occidentalis* L. and *Pseudocedrela kotchyi*. They contain allelochemicals with secondary metabolites with insecticidal or repellent, antiappetizing or toxic effects against phytophages due to the presence of alkaloid-capsaicinoid compounds, saponins and flavonoids ([3] Ehrlich *et al.*, 1964; [4] Meftah *et al.*, 2011; [5] Koleva *et al.*, 2013). These compounds can be exploited to reduce the incidence of pests on mango in Burkina Faso. The overall aim of this study is to assess the biological efficacy of total extracts of these eight plant species on the different developmental stages of *Bactrocera dorsalis*.

2. Materials and Methods

2.1. Test Plant Material

This consisted of the eight plant species *Capsicum annuum* L, *Cleome viscosa* L, *Mytragina inermis* (Wild) kuntze, *Strophantus hispidus* (A.CD), *Ocimum basilicum* L., *Cassia nigricans* (Vahl.), *Cassia occidentalis* L and *Pseudocedrela kotchyi*.

The choice of plant material was made on the basis of surveys carried out [6] (MAE, 1985) in previous years on plants with insecticidal properties and on the use of these plant substances in the control of other insects according to the literature (**Table 1**).

Table 1. Plant material selection criteria.

Sources	Plant material	Use
Ethnobotanical surveys on the use of natural substances with pesticidal properties by growers	*Strophantus hispidus, Cassia nigricans*	For the preservation of stored foodstuffs ([6] MAE, 1985)
	Cassia occidentalis Linn	For peanut, maize and millet conservation ([7] Aba Toumnou *et al.*, 2012)
	Ocimum basiculum Linn	For the conservation of cowpea, sorghum, fonio and rice ([7] Aba Toumnou *et al.*, 2012)

Continued

Revue de littérature	*Pseudocedrela kotschyi* et de *Strophantus hispidus*	[8] Kambou *et al.* (2008) showed the insecticidal activity of these extracts harvested in Burkina Faso was studied with mosquitoes (*Ochlerotatus triseriatus*), *Helicoverpa zea* and *Heliothis virescens* larvae and adult whitefly (*Bemisia tabaci*).
	Capsicum annuum et *Cassia nigricans*	Tested for insecticidal activity on *Bemisia tabaci* and *Helicoverpa armigera* ([9] Kambou *et al.*, 2015)). A study on its insecticidal activity carried out on bruchids ([10] Glitho, 2002) and its oil was tested on the three fruit flies *Ceratitis capitata* (Wiedemann), *Bactrocera dorsalis* (Hendel), and *Bactrocera cucurbitae* (Coquillett) ([11] Chang *et al.*, 2009).
	Ocimum basiculum	
	Capsicum annum L., *Cleome viscosa L.*, *Cassia nigricans*	[12] Kambou *et al.* (2019) tested the insecticidal activity of these extracts on armyworms (*Spodoptera frugiperda* J.E Smith) in maize crops and their effects on microorganisms in a ferruginous soil in Burkina Faso.
	Cleome viscosa (Linn.), *Mitragyna inermis* (Willd.) O. Kuntze	[13] Denou *et al.* (2016) have demonstrated the activity of these extracts in the traditional management of malaria in Mali and Togo.
	Cleome viscosa (Linn.)	The insecticidal activity of these extracts has been demonstrated on the lethality and repellency of brine shrimp insects by ([14] Rhimi *et al.*, 2017). [15] Sivaraman *et al.* (2014) on seed extracts of this extract against *Helicoverpa armigera* and demonstrated efficacy on *Helicoverpa armigera* larvae and nymphs.

2.2. Animal Material

One species of fruit fly was used in the study. This was *Bactrocera dorsalis*.

2.3. Methods

2.3.1. Laboratory Conditions

The study was conducted in the eco-toxicology laboratory of the former Plant Protection (PV) and in the biological control laboratory of the Centre National de Spécialisation en Fruits et Légume (CNS-FL) of the Institut de l'Environnement et de Recherche Agricole (INERA) Farako-Bâ in Bobo-Dioulasso. Fruit fly rearing conditions were: a temperature of 26℃ ± 1°C; a photoperiod of 12 h of light and 12h of darkness and a relative humidity of 70% ± 10.

2.3.2. Method for Obtaining Total Extracts

The method used for extracting total extracts is successive depletion by percolation with solvents of increasing polarity according to the total extract preparation diagram (Kambou *et al.*, 2008) (**Figure 1**).

2.3.3. Testing the Biological Efficacy of Total Extracts on *Bactrocera dorsalis*

1) Biological activity of total extracts on eggs, pupation and emergence of *Bactrocera dorsalis*

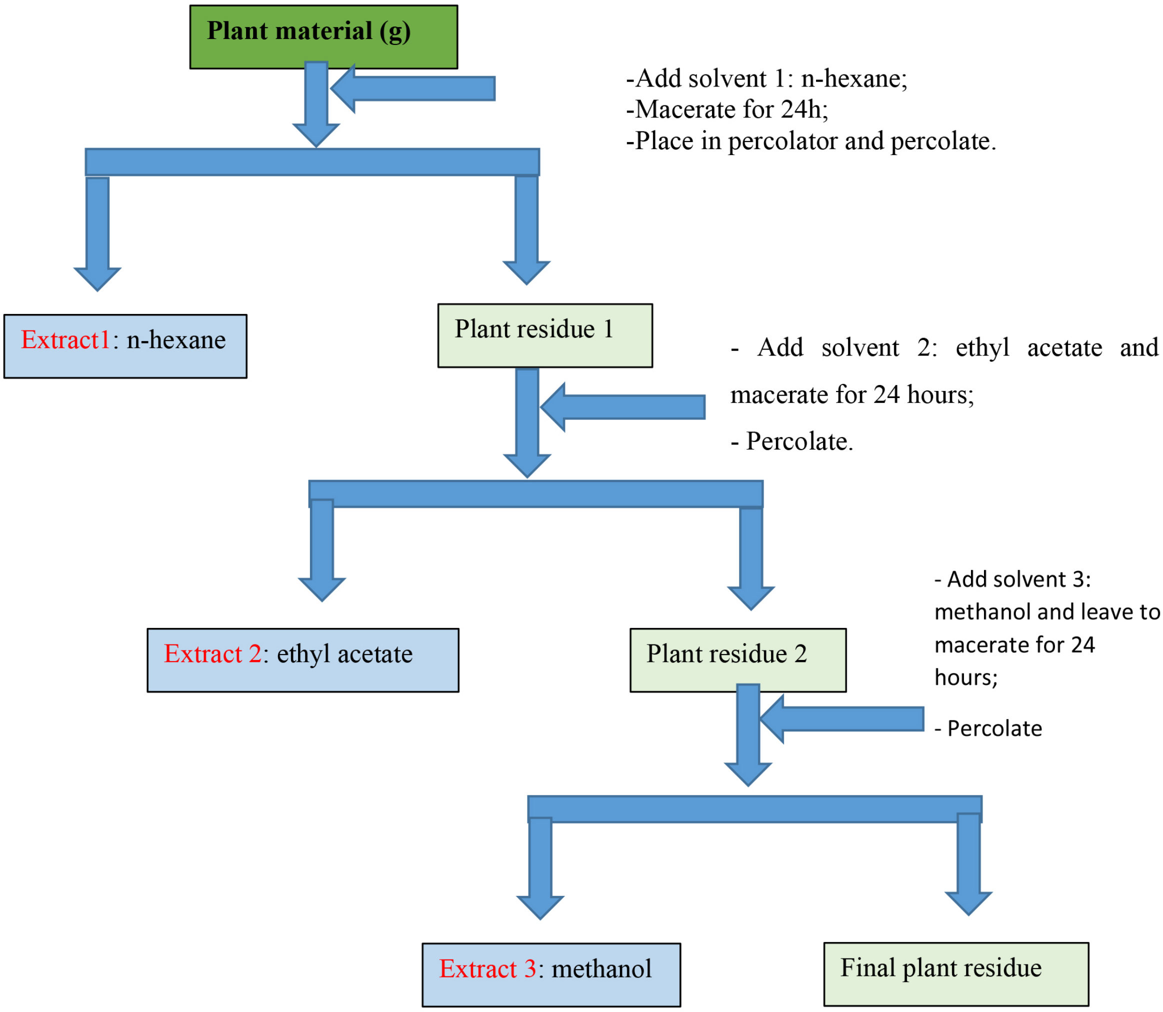

Figure 1. Diagram of total extract preparation for the study.

Collection of *Bactrocera dorsalis* eggs

Bactrocera dorsalis eggs were obtained by introducing six egg-laying devices for 2 h into rearing cages containing *Bactrocera dorsalis* adults (200 males and 200 females) at least 15 days old. Using a graduated cylinder, 5,000 eggs were collected for the various tests at the biological control laboratory of the Institut de l'Environnement et de Recherche Agricole (INERA) in Farako-Bâ.

➢ **Preparation of modern brewing yeast waste**

Bactrocera dorsalis larval nutrient medium is required to perform the biological activity test of total extracts on *B. dorsalis* eggs and development.

The nutrient medium for *B. dorsalis* larvae was prepared as follows: brewer's yeast waste was heated to boiling, with a total heating time of 1 h 30 min, stirring frequently to prevent the yeast sticking to the bottom of the pot. After boiling, the resulting yeast was cooled completely for 24 hours. After cooling, 0.92 g of papain was added to 11.5 l of modern brewers' yeast waste (in the ratio of 8g of papain to 100 liters of yeast waste). The mixture was thoroughly mixed and transferred to a container, then placed in an incubator set at 65° C for 24 h. A quantity of 69 g potassium sorbate was added to the mixture at a rate of 6 g/l, to preserve the product, which was then packaged in canisters. The yeast waste preparation technique is summarized in Figure 2:

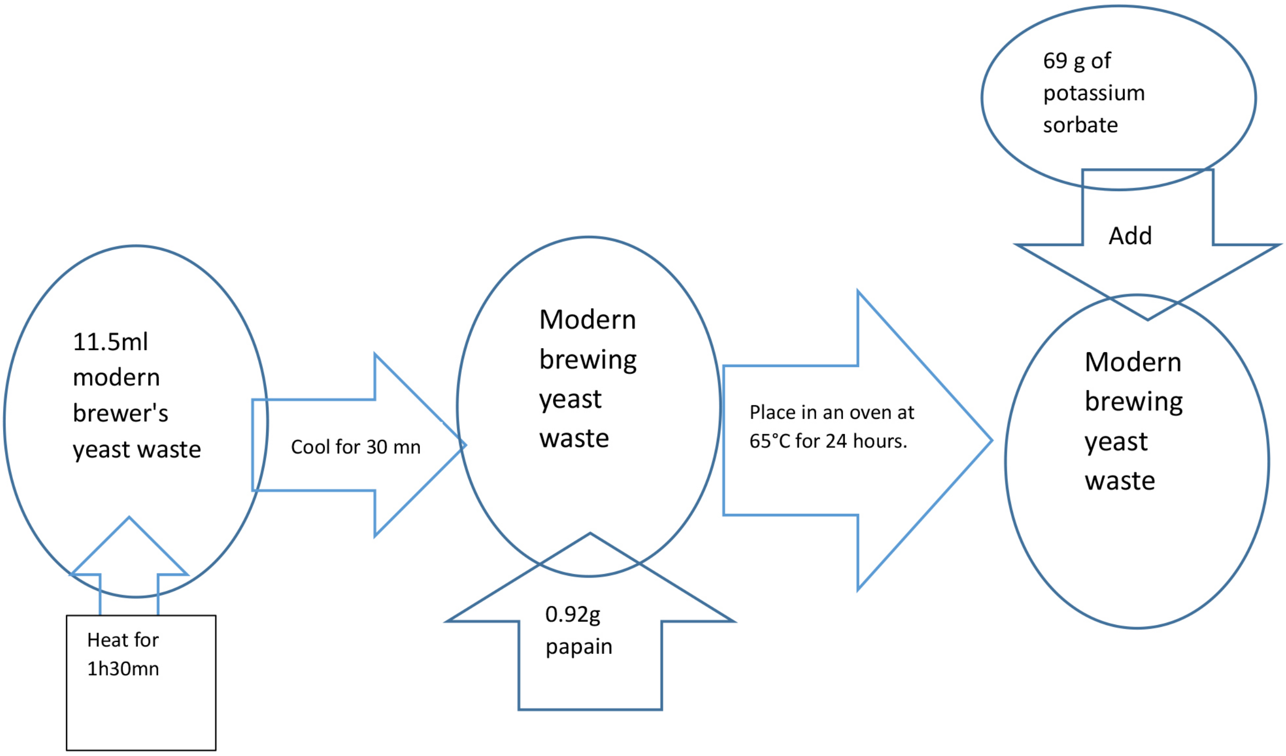

Figure 2. Preparation of modern brewer's yeast waste.

➢ **Preparation of larval nutrient medium**

A protein-rich nutrient medium was then prepared and used for the development of *Bactrocera dorsalis* larvae using the following technique. Preparation of 1kg of nutrient medium requires:

- Corn flour: 59 g;
- Soy flour: 112.10 g;
- Sugar: 108.17 g;
- Rice bran: 68.83 g;
- Rice fluff: 29.5 g;
- Nipagine: 0.98 g;
- Brewer's yeast waste: 295 ml;
- HCL: 2.95 mL;
- Distilled water: 295 mL.

To prepare (Figure 3), add 295 ml distilled water to the brewer's yeast waste, heat to boiling for 30 min and cool completely. Measure out the 295 ml of brewer's yeast waste, add it to the 295 ml of distilled water, then add the various quantities of the above nutrient medium components while stirring, in the following order: sugar, rice bran, rice litter, corn flour, soy flour, nipagine. Measure out 2.95 ml of HCL and add to the medium, then stir. Finally, package the medium in a plastic jar and store in the fridge for various tests on *B. dorsalis* eggs and development.

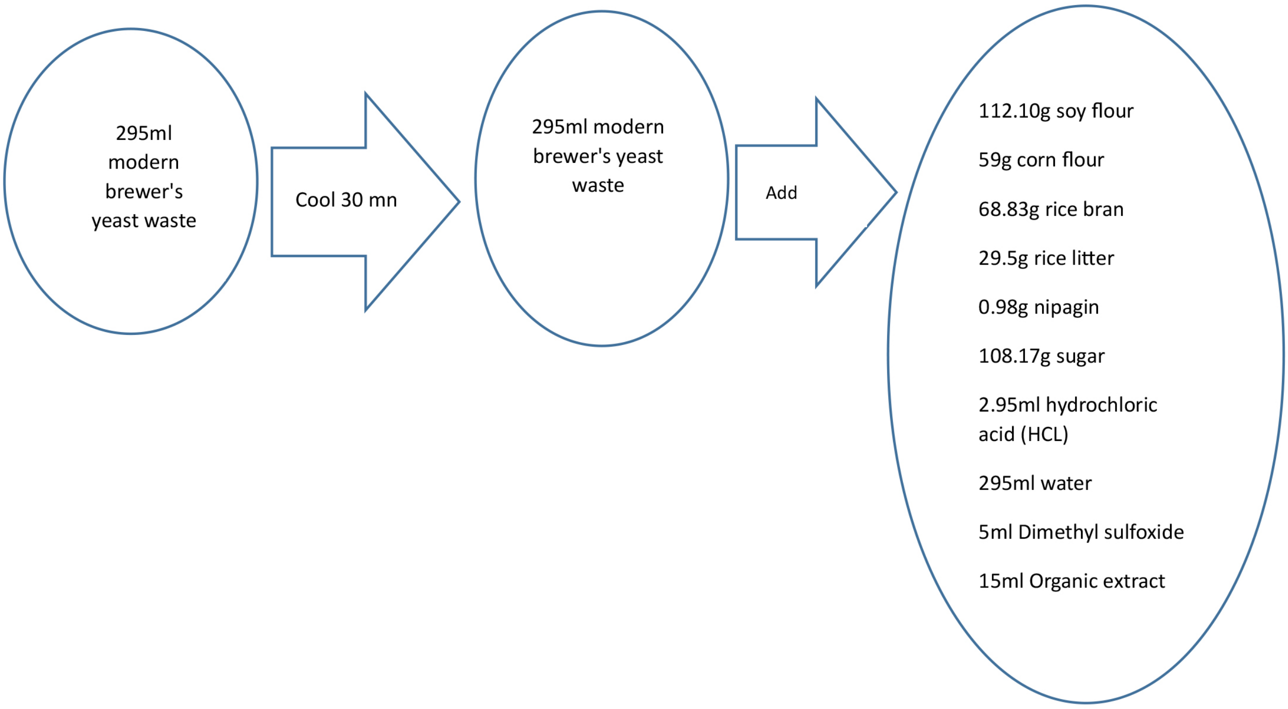

Figure 3. Preparation of larval nutrient medium.

➢ **Incorporation of protein-rich nutrient medium into the eight organic extracts of natural substances**

Once the protein-rich nutrient medium has been prepared, the procedure for incorporating it into each of the 8 organic extracts is as follows:

- 15 mg of each of the eight organic extracts of natural substances (*Capsicum annum* L, *Cleome viscosa* L, *Mytragina inermis* (Wild) kuntze, *Strophantus hispidus* A. DC, *Ocimum basilicum* L, *Cassia nigricans* Vahl, *Cassia occidentalis* L., *Pseudocedrela kotchyi*) was first collected and then dissolved in 1 ml DiMethyl SulfOxide (DMSO) in a microtube. The mixture was vortexed to ensure complete dissolution;

- Next, 29 g of the local nutrient medium was taken and added to 1 ml of organic extract of each natural substance. The untreated control received 29 g of nutrient medium to which 1 ml of DMSO was added (i.e. 0.517 mg/g concentration). The resulting mixture of each natural substance was placed in Petri dishes (25 dishes in all) containing a piece of lotus paper.

Testing the biological activity of total extracts from eight plants on *B. dorsalis* eggs and development.

20 eggs were placed in each dish. This set-up was repeated 10 times for each of the eight extracts, for a total of 250 Petri dishes used in the experiment. Daily observations were made and the number of eggs hatched was counted every 24 h, 48 h, 72 h and 96 h. The experiment was monitored until the 25th day of the

Bactrocera dorsalis cycle. This made it possible to determine the rates of egg hatching, pupation and fly emergence. In this test, we did not look separately at larval mortality, as Stage 1 larvae do not sink into the nutrient medium to feed, and are therefore not visible under a magnifying glass once dead.

These rates were calculated on the basis of the formulas.

$$\text{Hatching rate} = \frac{\text{Number of eggs hatched}}{\text{Total number of eggs}} * 100$$

$$\text{Pupaison rate} = \frac{\text{Number of pupae recorded}}{\text{Number of eggs incubated}} * 100$$

$$\text{Emergence rate} = \frac{\text{Number of pupae emerged}}{\text{Number of pupae put in emergence}} * 100$$

Breeding *Bactrocera dorsalis* and *Ceratitis cosyra* in the laboratory

The *B. dorsalis* adults used in this test represented the 60th and 40th generation of flies reared in the laboratory, respectively. Cotton soaked in water and a mixture of sugar and a protein source were placed in the cages for fly nutrition.

2.3.4. Phytochemical Composition of Total Active Extracts

Phytochemical screening of the total active extracts was carried out using the chemical tube characterization test method described by [16] Ciulei (1982) and adapted by the chemistry laboratory of the Institut de Recherche en Sciences de la Santé (IRSS). These are tests of general and/or specific chemical reactions, coloration or complexation in a liquid medium. The characterization tests are listed in **Table 2**.

Table 2. Chemical characterization compounds and reactions.

Searched substances	Chemical reagents used
Tannins	2% FeCl3 alcoholic solution (ferric chloride test)
Saponosides, steroidal and triterpenic glycosides	5% alcoholic sulfuric acid solution (Lieberman-Burchard reagent)
Carotenoids	Solution of antimony chloride in CHCL3 (Carr Price reagent)
Alkaloid salts	Dragendorff and Mayer reagents)
Reducing compounds	(Fehling reagent (I + II)
Flavonoids	Shibata reaction or cyanidin test
Anthracenosides	25% ammonia solution (Bornsträger reagent)
Anthocyanosides (pigments)	HCL 12N solution (Bat-Smith reagent)
Coumarins and derivatives	(10% ammonia solution (Feigl's reagent)

2.3.5. Data Processing and Analysis

The collected data were entered and grouped using Microsoft Excel 2010. The database was then imported into R software version 3.6.0 for various statistical analyses. The data were first tested for normality using the Shapiro-Wilk test.

This was followed by a comparison of means test at the 5% threshold (effects of total extracts from eight plants on eggs, pupation and emergence of *Bactrocera dorsalis* in the laboratory).

3. Results and Discussion

3.1. Yields and Chemical Composition of Total Extracts

3.1.1. Yield of Total Extracts

Table 3 shows the test samples, mass and yield of the various organic extracts. A 400 g test portion of each sample was successively macerated for 24 h with 1500 ml of n-hexane, ethyl acetate and a methanol-water mixture (80:20, v/v). Yields of apolar extracts (hexane) ranged from around 0.66 to 5.76%. The *Mytragina inermis* sample gave the highest yield (5.76%) of aqueous macerated extracts, while the lowest yield (0.66%) was observed with the *Ocimum basilicum* sample. The mass of apolar lipophilic extracts (n-hexane) varied from 2.49 g to 21.71 g. The *Mytragina inermis* sample gave the highest mass of lipophilic extracts, and the *Ocimum basilicum* sample the lowest. The proportion of medium-polar extracts (ethyl acetate) ranged from 1.64% to 5.91%. The highest level of medium-polar extracts was found in the *Ocimum basilicum* sample, and the lowest in the *Cassia occidentalis* sample. The level of polar extracts (hydromethanolic) varied from 1.45% to 18.13%. The highest content was obtained with the *M. inermis* sample, and the lowest with the *Cassia occidentalis* sample (Table 3).

Table 3. Test sample, total extract mass and extraction yield.

Natural substances	Test plug (g)	n-Hexan		Ethyl acetate		Methanol	
		Extracted mass (g)	Yield (%)	Extracted mass (g)	Yield (%)	Extracted mass (g)	Yield (%)
C. viscosa	400	3.54	0.93	8.91	2.35	17.51	4.63
C. annuum	400	18.92	5.23	7.48	2.07	34.16	9.44
P. kotschyi	400	15.55	4.08	20	5.25	57.6	15.11
C. nigricans	400	3.61	0.93	18.83	4.87	22.94	5.93
C.occidentalis	400	10.48	2.73	6.31	1.64	5.56	1.45
S. hispidus	400	6.27	1.64	8.72	2.29	11.69	3.07
O. basilicum	400	2.49	0.66	22.47	5.91	11.28	2.97
M. inermis	400	21.71	5.76	13.11	3.48	68.37	18.13

3.1.2. Chemical Composition of Total Active Extracts

Biological activity tests on the 8 total extracts enabled us to select Cleome viscosa hexane (with high insecticidal activity on *B. dorsalis* adults), *Capsicum annuum* (with hexane and ethyl acetate) and *Strophantus hispidus* (with methanol), which showed high insecticidal activity on *B. dorsalis* eggs and development. Chemical characterization tests in solution in test tubes revealed groups of potentially bioactive phytochemical compounds in total active extracts of *Cleome viscosa* (in hexane), *Capsicum annuum* (in hexane and ethyl acetate) and *Strophantus hispidus* (in methanol). The results of phytochemical characterization tests on *C. viscosa* are given in Table 4, as are those on *C. annuum* and *S. hispidus*. Analysis of hexanic *C. viscosa* revealed the presence of sterols, terpenes and carotenoids. Analysis of *C. annuum* and *S. hispidus* also revealed groups of potentially bioactive chemical compounds: sterols and triterpenes, coumarins and derivatives, anthraquinones, alkaloids, flavonoids, tannins and cardenolides. The presence of the various constituents in the plant is revealed by extractions using different solvents, which indicate a greater or lesser number of compounds depending on their solvent affinity.

Table 4. Results of phytochemical characterization tests on ethyl acetate n-hexane and methanol extracts of *Cleome viscosa*, *Capsicum annuum Strophantus hispidus*.

Chemical groups	n-hexane			Ethyl acetate			Methanol		
	C. viscosa	*C. annuum*	*S. hispidus*	*C. viscosa*	*C. annuum*	*S. hispidus*	*C. viscosa*	*C. annuum*	*S. hispidus*
Sterols/triterpenes	+	+	+	+	+	+	+	+	+
Anthraquinones	(-)	+/-	(-)	+	+/-	+	+	+	+
Coumarins and derivatives	(-)	+	(-)	(-)	+/-	+/-	(-)	+	+
Carotenoids	+	+	+	(-)	+/-	+/-	(-)	(-)	(-)
Cardenolides	(-)	+/-	+	(-)	+/-	+	(-)	+/-	+
Alcaloids	(-)	+/-	+/-	+	+	+	+	+	+
Tannins	(-)	(-)	(-)	+	(-)	+	+	(-)	+
Flavonoids	(-)	+	(-)	(-)	+	+	+	+	+
Saponosides	(-)	(-)	(-)	(-)	(-)	(-)	+	+/-	+
Anthocyanosids	+	(-)	(-)	+	+/-	+	+	+	+
Reducing compounds	(-)	(-)	(-)	+	(-)	+/-	+	+	+

Legend: += present; (-) = absent; ± = traces.

3.2. Effects of Total Extracts of Eight Plants on Eggs, Pupation and Emergence of *Bactrocera dorsalis* in the Laboratory

3.2.1. Effects of Total Extracts on *Bactrocera dorsalis* Eggs after 24 h of Observation

No hatching of *B. dorsalis* eggs was observed after 24 h of observation.

3.2.2. Effect of Total Extracts on *Bactrocera dorsalis* Eggs after 48 h of Observation

Figure 4 shows the effect of organic extracts on *Bactrocera dorsalis* egg hatchability after 48h of observation. Statistical analysis shows a highly significant difference. Among the organic extracts of natural substances tested, the hexanic extract of *O. basilicum* produced the lowest rate of egg hatching (57.37%), down 30.42% on the untreated control. In contrast, methanolic extracts of *S. hispidus* produced a higher hatching rate of 99%, an increase of 20.07% on the untreated control. This was followed by the methanolic and ethyl acetate extracts of *M. inermis* (87.42%, an increase of 18.25%), the methanol extracts of *C. viscosa* (97%, an increase of 17.65%) and *C. nigricans* (96%, an increase of 16.43%).

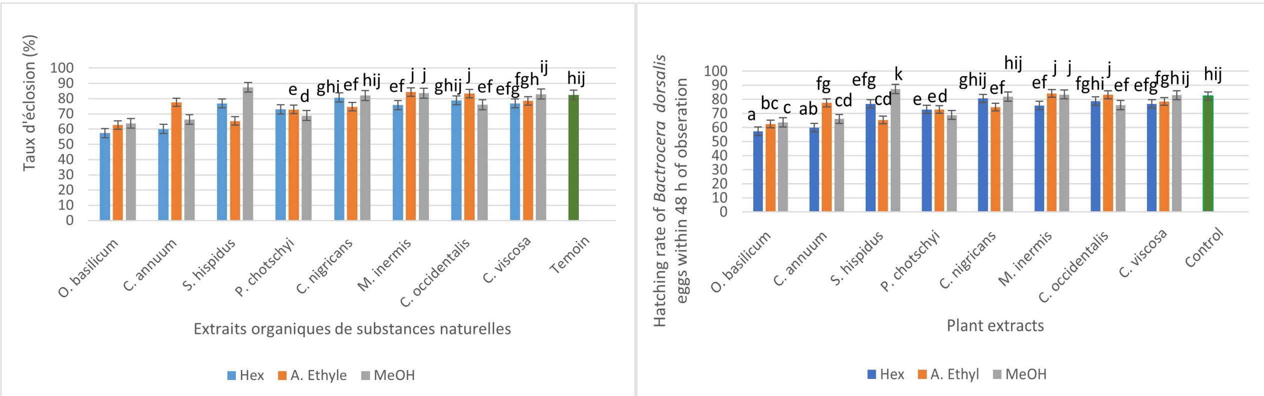

Figure 4. Effects of organic extracts on *Bactrocera dorsalis* eggs after 48 hours of observation.

3.2.3. Effects on Eggs after 72 h

Statistical analysis shows a highly significant difference (**Figure 5**). The lowest hatching rate was obtained with the methanol extract of *O. basilicum* (86.5%), a reduction of 11.29% compared with the untreated control. On the other hand, the hexane, ethyl acetate and methanol extracts of *C. annuum* and the methanol extract of *S. hispidus* resulted in a higher hatching rate of 100% after 72 h, i.e. an increase in hatchability of 2.56% compared with the untreated control. A similar hatching rate was obtained in the presence of ethyl acetate extract of *M. inermis* (99.5%), hexanolic and methanol extracts of *C. nigricans* (99%) and hexanolic extract of *C. viscosa* (99%).

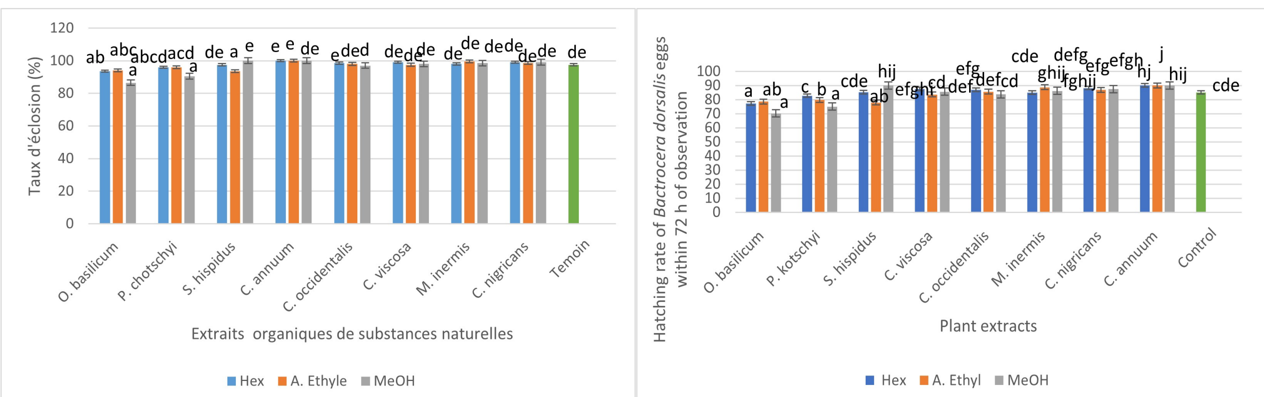

Figure 5. Effects of organic extracts on *Bactrocera dorsalis* eggs after 72 hours of observation.

3.2.4. Effects on Eggs after 96 h

Statistical analysis shows a highly significant difference (**Figure 6**). The hexane, ethyl acetate and methanol extracts of *C. annuum* and the methanol extracts of *S. hispidus*, *C. nigricans*, *C. occidentalis*, *M. inermis* and the hexane, ethyl acetate extracts of *C. viscosa*, *P. kotschyi*, and the hexane extract of *O. basilicum* showed a total hatching rate of 100%. In contrast, the ethyl acetate and methanol extracts of *O. basilicum* (99.5%) and the methanolic extract of *P. kotschyi* (99.5%) were identical. The methanol extract of *C. viscosa* showed an egg hatching rate of 99%, the lowest of all extracts.

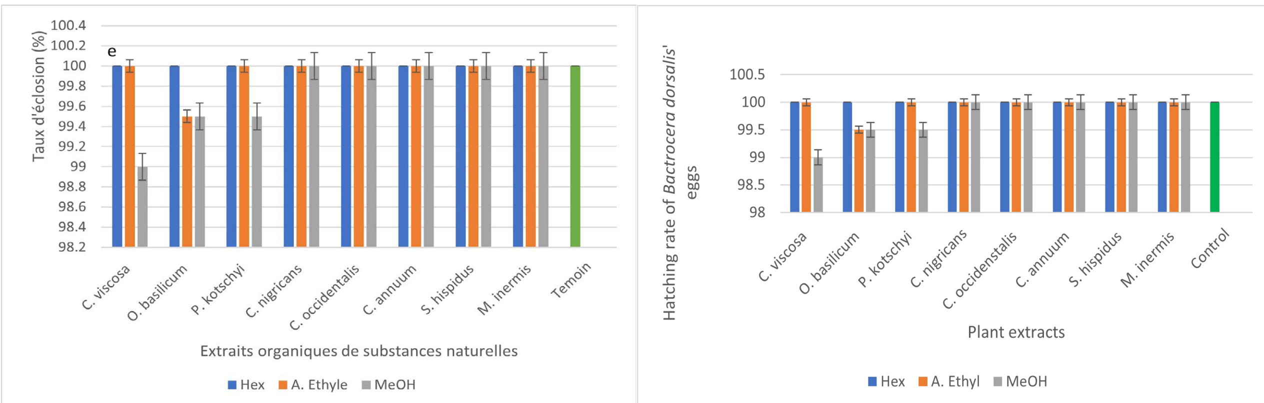

Figure 6. Effects of organic extracts on *Bactrocera dorsalis* eggs after 96 h of observation.

3.2.5. Effects on Pupation

Statistical analysis shows a highly significant difference (**Figure 7**). The hexane extract of *C. annuum* obtained the lowest pupation rate (5.7%), i.e. a reduction of 90.42% compared with the untreated control, followed by the ethyl acetate extract (7%), i.e. a reduction of 88.23%, and the methanol extract of *C. annuum* (10.8%). Next came the hexane extract of *C. nigricans* at 16.4%, a reduction of 75.44%, and the methanol extract of *Strophantus hispidus* at 17%, a reduction of 71.43%. The least effective extracts were those of *Cleome viscosa*, particularly the methanol extract, which facilitated pupation of *Bactrocera dorsalis* at 36.9%, i.e. a reduction of 37.8% compared with the untreated control.

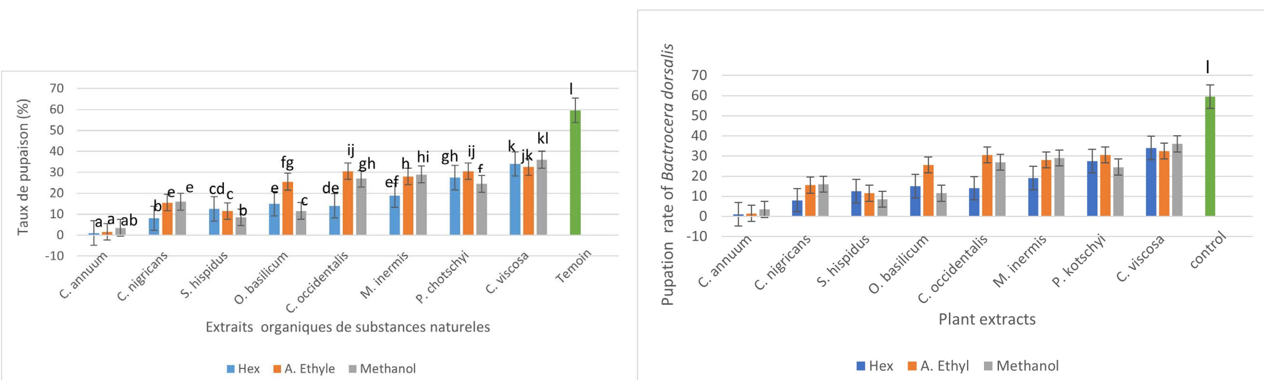

Figure 7. Effects of organic extracts on pupation of *Bactrocera dorsalis*.

3.2.6. Effects on Emergence

Statistical analysis shows a highly significant difference (**Figure 8**). Only the hexane and methanol extracts of *Capsicum annuum* and *Strophantus hispidus* inhibited the emergence of *Bactrocera dorsalis*. The methanol extract of *Pseudocedrela kotschyi* also inhibited the emergence of *B. dorsalis* at 100%, i.e. zero *B. dorsalis* emerged, statistically indistinguishable from the two extracts of *C. annuum* and *S. hispidus* mentioned above. The other treatments stimulated *B. dorsalis* emergence to a greater or lesser extent than the untreated control.

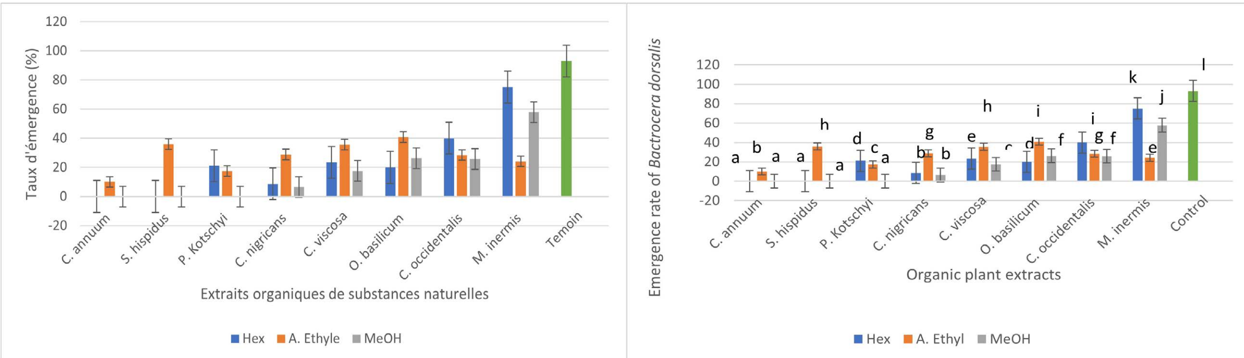

Figure 8. Effects of organic extracts on the emergence of *Bactrocera dorsalis.*

Table 5. Summary of the effects of total extracts on the different stages of *B. dorsalis.*

Plants	solvants	Egg stage	Larval stage	Adults
	n-hexan	-	+++++	+++++
Capsicum annuum	Ethyl acetate	-	++++	++++
	Methanol	-	+++	+++++
	n-hexane	-	-	-
Cleome viscosa	Ethyl acetate	-	-	-
	Methanol	-	-	-
	n-hexan	-	++	++
Cassia nigricans	Ethyl acetate	-	-	-
	Methanol	-	-	-
	n-hexan	-	-	-
Cassia occidentalis	Ethyl acetate	-	-	-
	Methanol	-	-	-
	n-hexan	-	-	-
Ocimum basilicum	Ethyl acetate	-	-	-
	Methanol	-	-	-
	n-hexan	-	-	-
Mytragina inermis	Ethyl acetate	-	-	-
	Methanol	-	-	-

Continued

	n-hexan	-	-	-
Pseudocedrela kotschyi	Ethyl acetate	-	-	-
	Methanol	-	+	+++++
	n-hexan	-	-	-
Strophantus hispidus	Ethyl acetate	-	-	-
	Methanol	-	+++	+++++

Legend: - = no effect; +++++ = total effect; +++ = moderate effect; ++ = low effect.

All the results obtained on the development of *B. dorsaslis* are summarized in Table 5. Based on these results, *C. annuum* and *S. hispidus* were selected for further work.

Chemical composition of total extracts

Phytochemical analysis of the three active extracts of *C. viscosa*, *C. annuum* and *S. hispidus* was carried out in the course of this study. This analysis revealed the presence of triterpenes, carotenoids, coumarins, anthocyanosides, alkaloids, flavonoids, saponosides and cardelonides in these organic extracts, with the exception of tannins, which are absent in *C. annuum* and present in *C. viscosa* and *S. hispidus*. These results are similar to those of [17] Ahouansinkpo *et al.* (2016), [5] Liljana *et al.* (2013) and [18] Gurnani *et al.* (2016) who also revealed the presence of these same constituents in the fruits of *C. annuum* and the leaves of *C. viscosa* and *S. hispidus*.

Biological activity of total extracts on *B. dorsalis* eggs and development

The 8 total plant extracts had no inhibitory effect on *B. dorsalis* egg hatching. This could be explained by the fact that the egg wall was not permeable to the penetration of the total extracts. Hence the high hatching rate of *B. dorsalis* eggs after 72 hours of observation. This means that the presence of chemical compounds with insecticidal properties in the various plant extracts had no effect on the hatching of *B. dorsalis* eggs. This result is in line with that obtained by [19] Boutchelta *et al.* (2005) who showed that the presence of compounds such as flavonoids in Capsicum frutescens extract had a weak effect on the hatching of *Bemisia tabaci* eggs.

Once the *B. dorsalis* eggs had hatched, the stage 1 larvae were unable to feed on the nutrient medium containing certain total extracts in order to continue their development. This means that some of the 8 extracts had an effect on the development of *B. dorsalis* larvae. The hexane extract of *C. annuum* was the most inhibitory, followed by the extract of *Strophantus hispidus*. This result could be explained by the presence of phytochemical compounds that had anti-appetant effects on the subsequent development of *B. dorsalis*. These effects prevented their evolution into the adult stage. As pointed out by [20] Koul (2008), alkaloids, terpenoids and phenols have anti-appetent properties on the larvae of certain insect species. The toxicity of alkaloids by contact and/or ingestion on *B. tabaci* larvae was demonstrated by [19] Bouchelta *et al.* (2005). This could explain the similar results obtained in this experiment.

Also, the presence of tannins and saponins in nutrient media from total *C. annuum* and *S. hispidus* extracts could be toxic to larvae. Saponin toxicity has been demonstrated in *Callosobruchus chinensis* larvae ([21] Applebaum *et al.*, 1969).

Furthermore, *B. dorsalis* larvae that were able to feed on these nutrient media containing total extracts of *C. annuum* and *S. hispidus* were unable to develop into adults. This could be explained by the fact that the larvae may have paralyzed the peristaltic movements of their intestines, thus inhibiting their development. This result is similar to that of [22] Fortin *et al.* (2000), who demonstrated this paralysis of peristaltic movements in the gut of Helicoverpa armigera and tomato thrips due to the presence of secondary metabolites.

4. Conclusion

The most interesting biological products used in plant protection are those with minimal impact on all components of the agro-ecosystem. Extracts of *C. annuum* and *S. hispidus* inhibited the development of *B. dorsalis* during the study, and it would be ideal to exploit the development-inhibiting properties of *B. dorsalis* with the hexane extract of *C. annuum* and *S. hispidus.*

Conflicts of Interest

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

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