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Responses of two plant-derived bioinsecticides as protectants of smoke-dried catfish, *Clarias gariepinus* [Pisces: Clariidae] against hide beetle, *Dermestes maculatus* (De Geer) [Coleoptera: Dermestidae]

Kayode David Ileke*

Abstract

Background: Toxicities of *Vernonia amygdalina* and *Tithonia diversifolia* leaf powders and extracts on larva and adult mortality of *Dermestes maculatus* on smoke-dried catfish were evaluated in the laboratory. The leaf powders were admixed at 1, 3, 6, 9 and 12 g/100 g of smoked catfish in 500 ml plastic container while plant extracts were tested at 1, 3, 6, 9 and 12% concentrations.

Results: The toxicities of the plant products were concentrations and exposure time dependent. Significant difference ($P < 0.05$) existed between the toxicity of *V. amygdalina* and *T. diversifolia* leaf powders and control. *Tithonia diversifolia* powder evoked 27.5, 40, 52.7, 60 and 82.5% larval mortalities at the various concentrations after 24 h of exposure of the catfishes to the plant powder. Similarly, *V. amygdalina* leaf powders caused 20, 30, 42.5, 52.5 and 77.5% larval mortalities at varying concentrations of 24 h intervals of exposure to the plant powder. *Tithonia diversifolia* powder achieved 100% mortality at 9 g dosage after 96 h of treatment. Similar trend was achieved on the response of both plant leaf extracts as protectants of smoke-dried catfish against hide beetle.

Conclusion: *Tithonia diversifolia* powder and extract were more lethal than bitter leaf (*V. amygdalina)* and could be integrated as smoked fish protectant against hide beetle (*D. maculatus)*.

Keywords: Bioinsecticide, *Dermestes maculatus*, *Tithonia diversifolia*, *Vernonia amygdalina*

Background

Fish is widely acceptable on the menu table of most inhabitant of the earth irrespective of socio-economic status, age and religious background, and it constitutes about 50% of total animal protein needed for growth (Adesina et al. 2014; Ileke et al. 2020a). Fish protein contains essential amino acids such as lysine, methionine and isoleucine, these are relatively deficient in other animal proteins (Abolagba et al. 2011; Adesina et al. 2014; Ileke et al. 2020b). Fish is also rich in proteins such as riboflavin and thiamine. It contains vitamins A, B, D, E and K as well as some useful minerals (Yem et al. 2006). Fish contains polysaturated fatty acids which reduces blood cholesterol in the system thereby lowering blood pressure in hypertension patient (Okunade 2011; Ileke et al. 2020a, b).

Fresh fishes depend solely on smoking and drying as a means of preservation among the local fish farmers in Nigeria (Adesina et al. 2014). However, the smoked fish is vulnerable to insect damage from the family Dermestidae

*Correspondence: kdileke@futa.edu.ng; kayodeileke@yahoo.com
Applied Entomology Unit, Department of Biology, School of Sciences, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria

and order Coleoptera (Adedire 2001). The activities of the hide beetle can lead to changes in fish appearance, powdering as a result of larval instar growth rendering it unfits for feasting and selling (Adesina et al. 2014, 2016). Insect pests of fish can transmit *Escherichia coli* when the moisture content is high due to high proliferation of the hide beetle. This usually gives room for bacteria and mould growth (Jackson and Ayub 2013; Jose and Adesina 2014). Some of the losses caused by *D. maculatus* infestation are enormous, and these include physical loss that reduces the quantity of fish available for human consumption, economic loss which affects the monetary value of the infested smoked fish. Also, the nutritional loss which results in physical and economic losses thereby increases the retail value of fish beyond the purchasing power of the poor (Adesina et al. 2014).

Effectiveness of synthetic chemical insecticides against weevils, beetles and moths of cereals, legumes and tubers have been documented by many researchers (Ileke 2019; Ileke et al. 2020c, d; Obembe et al. 2020). Nevertheless the adoption of this method to reduce physical, economic and nutritional losses caused by insect pests of smoked fish has not been fully accepted by farmers and consumers. This rejection is due to high toxicity of chemicals to consumers, irritating odour and residual effect on the environment couple with high cost of purchase (Amusan and Okorie 2002; Odeyemi et al. 2000; Ahmed et al. 2013; Ileke et al. 2020a); toxicity to non-targeted organisms, environmental health hazard and slow biodegradation of active compounds (Ileke et al. 2020b;). This research is focusing on the use of plants derived insecticides that is environmental friendly and readily available in our immediate environment. Many entomologists and postharvest fish scientists have reported the efficacy of powders, ash and extracts from the leaf, stem bark, flower, seed and root of many plants to suppress oviposition, prevent adult emergence and reduced fish quality and quantity losses (Adedire and Lajide 2000; Amusan and Okorie 2002; Anyaele and Amusan 2003; Onu and Baba 2003; Fasakin 2003; Adebote et al. 2007; Akinwumi 2011; Abdullahi et al. 2012; Ahmed et al. 2013; Jose and Adesina 2014; Adesina et al. 2014, 2016; Ileke et al. 2020a, 2020b).

Tithonia diversifolia is a species of flowering plant commonly called marigold that belongs to a family Asteraceae. The height is about 2–3 m (6.6–9.8 ft) with ligneous stalks in form of woody shrubs. Marigold, a weed that grows fast and has become an alternative to an expensive synthetic fertilizer (Jama et al. 2000). Its presence in soil can lead to high plant yields and improve soil nutrients (Jama et al. 2000). *Vernonia amygdalina* originated in Africa and also belongs to the family Asteraceae (Odugbemi 2006). It can be regarded as a shrub or small tree as it can grow between 2 and 5 m in height with leaves that are green in colour, petiolate and elliptically shaped of about 6 mm diameter (FAO 2001). The characteristic odour and bitter taste of the leaves are due to the presence of saponins, tannins, alkaloids and glycosides. *Vernonia amygdalina* is popularly referred to as bitter leaf (Ologunde et al. 1992; Bonsi et al. 1995). The specific objectives of this research are to evaluate *V. amygdalina* and *T. diversifolia* leaf powders and extracts as toxicants against larva and adult stages of skin beetle (*D. maculatus)* on smoke-dried catfish (*C. gariepinus*).

Methods

Experimental location

The study was conducted in the Research Laboratory of the Department of Environmental Biology and Fisheries, Adekunle Ajasin University, Akungba Akoko (AAUA) at mean temperature and relative humidity of 28.9 °C and 76.4%, respectively.

Collection and preparation of Tithonia diversifolia and Vernonia amygdalina leaves

Fresh *V. amygdalina* and *T. diversifolia* leaves were collected from a farm at Ipinsa, Akure, Ondo State, Nigeria. These plant leaves were brought into the Research laboratory (Department of Plant Science and Biotechnology, Adekunle Ajasin University Akungba Akoko, Nigeria) for identification by a Plant Taxonomist. The plant leaves were washed thoroughly with clean water, air-dried in the laboratory for three weeks. Each of the plant leaves was pulverized separately into fine powder using an electric blender. The powders were further sieved to pass through $1mm^2$ perforation. The fine powder was kept separately inside an air tight sample containers in the refrigerator to retain their freshness before application.

Extraction of experimental plants

About 300 g of *T. diversifolia* powders were soaked in an extraction bottle containing 600 ml of absolute ethanol for 3 days. The dissolved powders were stirred intermittently in order to ensure uniformity in extraction. A double layer Whatman No. 1 filter papers were used for the extraction process. The mixture of the solvent and the extract was separated by means of rotary evaporator (Udo 2011). The resulting extracts were then air-dried to remove any remaining solvent. The same procedure was adopted for the extraction of *V. amygdalina*. The extracts were kept separately in labelled plastic bottles till when needed. Different extract concentrations of 1%, 3%, 6%, 9% and 12% were prepared separately (Ashamo and Akinnowonu 2012).

Collection and preparation of catfish

Fresh catfishes weighing between 400 and 500 g were collected from Hatchery Unit, AAUA. They were smoked locally, free of common salt and seasoning. The smoked fishes were sterilized by re-heating at 40 °C for one hour in a hot air oven (Gallenkamp Oven) in the laboratory in order to kill any developmental stages (egg, larva, pupa and adult) of the insect pests that may be present (Adesina et al. 2016), and allowed to cool at room temperature in the laboratory in order to prevent mouldiness (Adedire et al. 2011).

Insect culture

The initial skin beetle (*D. maculatus)* culture used for this study were obtained from an infested smoke-dried catfish collected from smoked fish sellers at Ibaka Market, Akungba Akoko, Ondo State, Nigeria. The skin beetles were introduced into one litre plane glass kilner jar containing 1.5 kg of smoked catfish free of salt and seasoning obtained from Fish sellers. Jar containing the beetles was covered with muslin cloth and placed in an insect rearing cage. Newly emerged larvae (0–3 days) were removed from stock culture and placed on fresh uninfected smoked fish (Adesina et al. 2016). Adults were removed after 14 days of oviposition (egg laying) period. Water was supplied by soaking cotton wool in water (Odeyemi and Daramola 2000). The first filial generation (F1) was used for the skin beetle experiment.

Hide beetle bioassay

Evaluation of V. amygdalina and T. diversifolia powders on D. maculatus larvae

Toxicities of *V. amygdalina* and *T. diversifolia* leaf powders on *D. maculatus* larvae were assessed by admixed separately at concentrations 1 g, 3 g, 6 g, 9 g and 12 g/100 g of smoked catfish in 500 ml plastic container. *Vernonia amygdalina* and *T. diversifolia* powders were thoroughly mixed with the smoked fish. Treated smoked fish and untreated (control) were infested with twenty (20) newly emerged first instar larvae about 0–3 day old of hide beetle, replicated four times and laid out in Complete Randomized Block Design in insect cage. Larval mortality was assessed and recorded every 24 h for 96 h. Abbott (1925) method of correcting mortality of larva was adopted as follows:

$$P_T = \frac{P_o - P_c}{100 - P_o} \times \frac{100}{1} \quad (1)$$

where P_T = corrected mortality (%), P_O = observed mortality (%), P_C = control mortality (%).

The larva bioassay setup was kept inside the insect rearing cage and daily observations were made until adult emergence. The number reaching adult stages was recorded and expressed as percentage adult emergence (Odeyemi and Daramola 2000).

$$\%\text{Adult emergence} = \frac{\text{Total number of adult emergence}}{\text{Total number of larvae introduced}} \times \frac{100}{1} \quad (2)$$

Inhibition rate (IR) of adult emergence was evaluated using the method described by Tapondju et al. (2002).

$$\%\ \text{IR} = \frac{C_n - T_n}{C_n} \times \frac{100}{1} \quad (3)$$

where C_n—Total number of teneral adult insects in control. T_n—Total number of teneral adult insects treated in smoked fish.

Weight loss of the smoked catfish was expressed in percentage by re-weighing after 35 days and the percentage loss in weight was determined (Odeyemi and Daramola 2000).

$$\%\text{Weight loss} = \frac{\text{Change in weight}}{\text{Initial weight}} \times \frac{100}{1} \quad (4)$$

Evaluation of V. amygdalina and T. diversifolia powders on D. maculatus adults

Toxicities of *V. amygdalina* and *T. diversifolia* leaves powders on *D. maculatus* adults were assessed by admixed separately at concentrations 1 g, 3 g, 6 g, 9 g and 12 g/100 g of smoked catfish in 500 ml plastic container. *Vernonia amygdalina* and *T. diversifolia* powders were thoroughly mixed with the smoked fish. Treated smoked fish and untreated (control) were infested with ten (10) newly emerged adults (0–3 day old), replicated four times and laid out in Complete Randomized Block Design in insect cage. Adult mortality was assessed and recorded every 24 h for 96 h. Abbott (1925) method of correcting mortality of larvae was adopted.

Evaluation of V. amygdalina and T. diversifolia ethanolic extracts on D. maculatus larvae

Toxicities of *V. amygdalina* and *T. diversifolia* extracts on *D. maculatus* larvae were assessed by admixed separately at concentrations 1%, 3%, 6%, 9% and 12%/100 g of smoked catfish in 500-ml plastic container. *Vernonia amygdalina* and *T. diversifolia* extracts were thoroughly mixed with the smoked fish. Treated smoked fish and untreated (control) were infested with 20 newly emerged 1st instar larvae between 0 to 3 day old of hide beetles, replicated four times and laid out in Complete Randomized Block Design in insect cage. Larval mortality was assessed and recorded every 24 h for 96 h. The larval bioassay setup was kept inside the insect rearing cage and daily observations were made until adult emergence. The number reaching adult stages was recorded and expressed as percentage adult emergence (Odeyemi and Daramola 2000). Inhibition rate (IR) of adult emergence was identified using the method described by Tapondju et al. (2002). Weight loss of the smoked catfish was determined by re-weighing after 35 days and the percentage loss in weight was determined.

Evaluation of V. amygdalina and T. diversifolia extracts on D. maculatus adults

Toxicities of *V. amygdalina* and *T. diversifolia* leaves extracts on *D. maculatus* adults were assessed by admixed separately at concentrations 1%, 3%, 6%, 9% and 12%/100 g of smoked catfish in 500 ml plastic container. *Vernonia amygdalina* and *T. diversifolia* extracts were thoroughly mixed with the smoked fish. Treated smoked fish and untreated (control) were infested with 10 newly emerged adults between 0 and 3 day old, replicated four times and laid out in Complete Randomized Block Design in insect cage. Adult mortality was assessed and recorded every 24 h for 96 h.

Statistical analysis

Percentage mortality of larvae and adults was calculated and corrected using Abbott's formula (Abbott 1925). Data were subjected to analysis of variance (ANOVA), and means were separated using the Tukey's Test.

Results

Toxicities of V. amygdalina and T. diversifolia leaves Powder on Mortality of D. maculatus larvae

The toxicities of *V. amygdalina* and *T. diversifolia* powders were concentrations and exposure time dependent (Table 1). *Tithonia diversifolia* leaf powder was the most potent to the larvae of hide beetles (*D. maculatus).* There was significant difference ($P < 0.05$) between the toxicity effects of *V. amygdalina*, *T. diversifolia* powders and the control. *Tithonia diversifolia* powder evoked 27.5%, 40%, 52.7%, 60% and 82.5% mortalities of *D. maculatus* larvae after 24 h of exposure period at concentrations 1 g, 3 g, 6 g, 9 g and 12 g/100 g of smoke-dried catfish, respectively. Similarly, *V. amygdalina* powders caused 20%, 30%, 42.5%, 52.5% and 77.5% mortalities of *D. maculatus* larvae at concentrations 1 g, 3 g, 6 g, 9 g and 12 g/100 g of smoke-dried catfish, respectively. *Tithonia diversifolia* powder caused 100% mortality of hide beetle larvae at concentration 9 g/100 g of smoked catfish after 96 h of treatment while at treatment with *V. amygdalina*, the full mortality was observed after the same exposure period (96 h.) by using higher concentration from the leaf powder (12 g/100 g of smoked catfish).

Toxicities of V. amygdalina and T. diversifolia Powders on % Inhibition, weight loss adult Emergence of D. maculatus

The number of catfish, *D. maculatus* adults (F1) that emerged from treated infested fish with *D. maculatus* larvae was significantly lower ($P < 0.05$) than in the control (Table 2). There was no adult emergence and weight loss in smoked catfish treated with *V. amygdalina* and *T. diversifolia* leaves powders at rate 6 g, 9 g and 12 g/100 g of smoke-dried catfish. The number of surviving larvae from treated smoked fish with *V. amygdalina* and *T. diversifolia* leaf powders decreased as plant powder

Table 1 Percentage mortality of *D. maculatus* treated larvae with *V. amygdalina* and *T. diversifolia* leaves powder

Exposure time (hours)	Plant powders	Mortality percentage (mean ± SE)				
		Concentration (g)/100 g of smoked catfish				
		1	3	6	9	12
24	*T. diversifolia*	27.50 ± 1.25^{bc}	40.00 ± 2.04^{bc}	52.50 ± 2.35^{b}	60.00 ± 3.04^{bc}	82.50 ± 3.35^{bc}
	V. amygdalina	20.00 ± 2.04^{b}	30.00 ± 2.04^{b}	42.50 ± 2.35^{b}	52.50 ± 2.35^{b}	77.50 ± 3.25^{b}
48	*T. diversifolia*	37.50 ± 2.25^{cd}	50.00 ± 2.50^{cd}	67.50 ± 3.15^{cd}	77.50 ± 3.25^{c}	90.00 ± 3.04^{cd}
	V. amygdalina	30.00 ± 2.04^{bc}	42.50 ± 2.35^{bc}	60.00 ± 3.04^{c}	72.50 ± 3.35^{c}	87.50 ± 3.25^{cd}
72	*T. diversifolia*	50.00 ± 3.08^{ef}	67.50 ± 3.25^{de}	80.00 ± 3.04^{ef}	90.00 ± 3.04^{d}	100.00 ± 0.00^{d}
	V. amygdalina	42.50 ± 2.35^{de}	60.00 ± 3.04^{d}	72.50 ± 3.35^{de}	87.50 ± 3.25^{d}	97.50 ± 2.25^{d}
96	*T. diversifolia*	62.50 ± 3.35^{f}	82.50 ± 3.35^{f}	92.50 ± 3.35^{f}	100.00 ± 0.00^{d}	100.00 ± 0.00^{d}
	V. amygdalina	57.50 ± 3.25^{f}	72.50 ± 2.35^{ef}	87.50 ± 3.25^{f}	97.50 ± 2.25^{d}	100.00 ± 0.00^{d}
	Control	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$)

Table 2 Toxicities of *V. amygdalina* and *T. diversifolia* Powders on % Inhibition, weight loss adult emergence of *D. maculatus*

Conc. (g)	Plant powders	Mean number of surviving larvae ± SE	% adult emergence ± SE	% IR ± SE	% Weight loss ± SE
1	*T. diversifolia*	7.75 ± 0.05^{b}	25.00 ± 2.15^{b}	88.23 ± 3.56^{bc}	6.50 ± 0.05^{b}
	V. amygdalina	9.50 ± 0.03^{b}	42.50 ± 2.35^{c}	76.47 ± 3.32^{b}	8.00 ± 1.08^{b}
3	*T. diversifolia*	3.00 ± 0.04^{b}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	V. amygdalina	5.50 ± 0.03^{b}	20.00 ± 2.04^{b}	94.11 ± 3.79^{c}	2.50 ± 0.03^{b}
6	*T. diversifolia*	1.00 ± 0.04^{ab}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	V. amygdalina	3.00 ± 0.04^{ab}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
9	*T. diversifolia*	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	V. amygdalina	1.00 ± 0.04a^{b}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
12	*T. diversifolia*	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
	V. amygdalina	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	100.00 ± 0.00^{c}	0.00 ± 0.00^{a}
0.0	Control	20.00 ± 2.04^{c}	82.50 ± 4.15^{d}	0.00 ± 0.00^{a}	65.00 ± 3.40^{c}

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$)

concentration increased. The percentage inhibition rate at all concentrations for the *V. amygdalina* and *T. diversifolia* leaf powders increased significantly ($P < 0.05$) compared with the control. The least inhibition rate of 76.47% in progeny development was observed in catfish treated with 1 g/100 g of smoke-dried catfish of *V. amygdalina* leaf powders. The weight loss observed in samples of fish treated with 1 g of *V. amygdalina* and *T. diversifolia* powders was significantly lower ($P < 0.05$) than that of the control.

Toxicities of T. diversifolia and V. amygdalina Powders on Mortality of D. maculatus adults

Vernonia amygdalina and *T. diversifolia* leaf powders at tested concentrations were potent to the adult hide beetle; *D. maculatus* (Table 3). There was a significant difference ($P < 0.05$) between the effect of each plant leaf powder and the control. *Tithonia diversifolia* powder was the most potent which caused 22.5%, 37.5%, 50%, 57.5% and 80% mortalities of adult skin beetle, *D. maculatus* at rates of 1 g, 3 g, 6 g, 9 g and 12 g/100 g of smoke-dried catfish after 24 h of treatment. This was followed by bitter leaf powders which evoked 12%, 27.5%, 40%, 50% and 72.5% of adult mortalities of skin beetle at the above-tested concentrations of smoked catfish after 24 h of treatment. *Tithonia diversifolia* powder achieved 100% death of adult *D. maculatus* at all tested concentrations after 96 h of exposure. Mortality of adult skin beetle (*D. maculatus)* increased with increase in length of treatment and concentrations used.

Toxicities of V. amygdalina and T. diversifolia Extracts on Mortality of D. maculatus larvae

Tithonia diversifolia leaf extract was the most potent to the larvae of skin beetles; *D. maculatus* (Table 4). There was substantial difference ($P < 0.05$) between the

Table 3 Percentage mortality of *D. maculatus* adults treated with *V. amygdalina* and *T. diversifolia* leaf powder

Exposure time (hours)	Plant powders	Mortality percentage (mean ± SE)				
		Concentration (g)/100 g of smoked catfish				
		1	3	6	9	12
24	*T. diversifolia*	22.50 ± 1.35^{bc}	37.50 ± 2.25^{bc}	50.00 ± 3.04^{bc}	57.50 ± 3.25^{bc}	80.00 ± 3.04^{b}
	V. amygdalina	12.50 ± 1.35^{b}	27.50 ± 2.25^{b}	40.00 ± 2.04^{b}	50.00 ± 3.04^{b}	72.50 ± 3.35^{b}
48	*T. diversifolia*	32.50 ± 2.35^{cd}	47.50 ± 2.25^{cd}	62.50 ± 3.35^{cd}	72.50 ± 3.25^{c}	87.50 ± 3.2^{bc}
	V. amygdalina	27.50 ± 2.25^{c}	40.00 ± 2.04^{bc}	57.50 ± 3.25^{c}	67.50 ± 3.25^{c}	82.50 ± 3.35^{b}
72	*T. diversifolia*	47.50 ± 3.25^{ef}	62.50 ± 3.35^{de}	77.50 ± 3.25^{ef}	87.50 ± 3.25^{d}	97.50 ± 2.25^{cd}
	V. amygdalina	40.00 ± 2.04^{de}	57.50 ± 3.25^{d}	70.00 ± 3.04^{de}	82.50 ± 3.35^{d}	92.50 ± 3.35^{cd}
96	*T. diversifolia*	57.50 ± 3.25^{f}	80.00 ± 3.04^{f}	87.50 ± 3.25^{f}	97.50 ± 2.25^{d}	100.00 ± 0.00^{d}
	V. amygdalina	50.00 ± 3.04^{f}	70.00 ± 3.04^{ef}	82.50 ± 3.35^{f}	92.50 ± 3.35^{d}	97.50 ± 2.25^{d}
	Control	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$)

Table 4 Percentage mortality of *D. maculatus* larvae treated with *V. amygdalina* and *T. diversifolia* extracts

Exposure time (hours)	Plant extracts	Mortality percentage (mean ± SE)				
		Concentration (%)/100 g of smoked catfish				
		1	3	6	9	12
24	*T. diversifolia*	50.00 ± 3.04[bc]	62.50 ± 3.35[bc]	80.00 ± 3.04[bc]	92.50 ± 3.35[b]	100.00 ± 0.00[b]
	V. amygdalina	40.00 ± 2.04[b]	60.00 ± 3.04[b]	77.50 ± 3.25[b]	90.00 ± 3.04[b]	97.50 ± 2.25[b]
48	*T. diversifolia*	62.50 ± 3.35 [cd]	80.00 ± 3.04 [cd]	90.00 ± 3.04[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	57.50 ± 3.25[c]	72.50 ± 2.35[bc]	87.50 ± 3.25[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
72	*T. diversifolia*	77.50 ± 3.25[ef]	87.50 ± 3.25[de]	100.00 ± 0.00[d]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	70.00 ± 3.04[de]	82.50 ± 3.35[d]	92.50 ± 3.35 [cd]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
96	*T. diversifolia*	90.00 ± 3.04[f]	100.00 ± 0.00[e]	100.00 ± 0.00[d]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	87.50 ± 3.25[f]	90.00 ± 3.04[e]	100.00 ± 0.00[d]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	Control	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$)

toxicities of *V. amygdalina*, *T. diversifolia* extracts and the control. *Tithonia diversifolia* extract caused 50%, 62.5%, 80%, 92.5% and 100% larval mortalities at concentrations of 1%, 3%, 6%, 9% and 12%/100 g of smoke-dried catfish after 24 h of exposure, respectively. Similarly, *V. amygdalina* leaf extract caused 40%, 60%, 77.5%, 90% and 97.5% larval mortalities of *D. maculatus* at concentrations of 1%, 3%, 6%, 9% and 12% / 100 g of the smoke-dried catfish after 24 h of exposure to plant extract, respectively. *Tithonia diversifolia* extract caused 100% death of skin beetle larvae at concentration of 3%/100 g of the smoked catfish after 96 h of treatment. Similarly, *V. amygdalina* evoked 100% death of hide beetle larvae at concentration of 6%/100 g of smoke-dried catfish after 96 h of treatment.

Toxicities of V. amygdalina and T. diversifolia Extracts on percentage Inhibition, weight loss adult Emergence of D. maculatus

The number of catfish (*D. maculatus)* adults (F1) that emerged from treated fish infested with larvae of *D. maculatus* was significantly lower ($P < 0.05$) than in the control (Table 5). There was no adult emergence and weight loss in smoke-dried catfish treated with *V. amygdalina* and *T. diversifolia* leaf extracts at rates of 1%, 3%, 6%, 9 g% and 12%/100 g of the smoked fish. The number of surviving larvae from treated smoked fish with *V. amygdalina* and *T. diversifolia* leaf extracts decreased with increased in concentration of the plant extracts. The percentage inhibition rate at all concentrations for the *V. amygdalina* and *T. diversifolia* leaf

Table 5 Toxicities of *V. amygdalina* and *T. diversifolia* extracts on percentage inhibition, weight loss and adult emergence of *D. maculatus*

Conc. (g)	Plant extracts	Mean number of surviving larvae ± SE	% adult emergence ± SE	% IR ± SE	% Weight loss ± SE
1	*T. diversifolia*	1.00 ± 0.04[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
	V. amygdalina	2.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
3	*T. diversifolia*	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[c]	0.00 ± 0.00[a]
	V. amygdalina	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
6	*T. diversifolia*	0.00 ± 0.00[b]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
	V. amygdalina	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
9	*T. diversifolia*	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
	V. amygdalina	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
12	*T. diversifolia*	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00[b]	0.00 ± 0.00[a]
	V. amygdalina	0.00 ± 0.00[a]	0.00 ± 0.00[a]	100.00 ± 0.00	0.00 ± 0.00[a]
0.0	Control	20.00 ± 2.04[b]	87.50 ± 3.25[b]	0.00 ± 0.00[a]	67.50 ± 3.25[b]

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$)

extracts increased significantly ($P < 0.05$) when compared to the control. The weight loss observed in samples of fish treated with 1 g of *V. amygdalina* and *T. diversifolia* extracts was significantly lower ($P < 0.05$) than that of control.

Toxicities of V. amygdalina and T. diversifolia Extracts on Mortality of D. maculatus adults

Vernonia amygdalina and *T. diversifolia* leaf extracts at the tested concentrations were toxic to the adult hide beetle, *D. maculatus* (Table 6). There was a significant difference ($P < 0.05$) between the effect of each plant powder and the control. *Tithonia diversifolia* extract was the most toxic which caused 47.5%, 60%, 77.5%, 90% and 100% mortality of adult hide beetle (*D. maculates)* at the different concentration tested of smoked catfish after 24 h of treatment. This was followed by bitter leaf, *V. amygdalina* extract (Table 6). *Tithonia diversifolia* extract caused 100% death of adult *D. maculatus* at concentration of 12%. Mortality of adult skin beetle (*D. maculatus)* increased with increase in length of treatment and concentrations used.

Discussion

Insect and fish postharvest scientists were equipped with many procedures to screened botanicals for their efficiency in management of coleopteran insect pests such as hide beetle (*Dermestes maculatus)* that infested smoke-dried catfish during storage (Amusan and Okorie 2002; Odeyemi et al. 2000). In any method employed, a potent material is adversely toxic to insect developmental stages (eggs, larvae, pupae and adults). It also serves as oviposition deterrent or preventing the full expression of its oviposition through antifeedant, repellence, attractant for contact poisoning (Akinkurolere 2012).

Toxicity of *T. diversifolia* and *V. amygdalina* powders and extracts on larval and adult mortality of hide beetle (*Dermestes maculatus)* on smoked dried catfish was revealed in this research study. *Tithonia diversifolia* powder achieved 100% death of hide beetle larvae at concentration of 9 g/100 g of smoked catfish after 96 h of treatment. Adedire and Akinneye (2004) reported on the effectiveness of *T. diversifolia* in the control of cowpea beetle (*Callosobruchus maculatus).* The authors reported that *T. diversifolia* powder was lethal at high dosages and exposure time dependent. The higher the concentration, the higher the mortality rate. The results also validated the report of Adoyo et al. (1997) who found *Tithonia* to be toxic to termites in a farm in Busia district of Kenya. The toxicity of the *Tithonia* could be attributed to the presence of two sesquiterpene lactones, seven germacranolides and four eudesmanolides isolated from *T. rotundifolia* (Bohlmann et al. 1984). Isolation of a novel dinorxanthane sesquiterpene called diversifolide [4, 15-dinor-3-hydroxy-1 (5)-xanthen—12, 8-olide], a new chromone and four other known compounds from the root of *T. diversifolia* by Chen and Lin (1999). These compounds may be responsible for its insecticidal actions (Adedire and Akinneye 2004).

Vernonia amygdalina powder and extract were also toxic to larvae and adults skin beetle. *Vernonia amygdalina* powder evoked 100% mortality of hide beetle larvae at concentration of 12 g/100 g of smoked catfish after 96 h of treatment. The extract evoked 100% mortality of hide beetle larvae at concentration of 6%/100 g of the smoked catfish after 96 h of treatment. The results obtained in this work is in agreement with many earlier researchers on the utilization of bitter leaf as entomocides (Ileke 2015; Adedire and Lajide 2003; Musa et al. 2009; Moses and Dorathy 2011). Ileke (2015)

Table 6 Percentage mortality of *D. maculatus* adults treated with *T. diversifolia* and *V. amygdalina* leaf extracts

Exposure time (hours)	Plant extracts	Mortality percentage (mean ± SE)				
		Concentration (%)/100 g of smoked catfish				
		1	3	6	9	12
24	*T. diversifolia*	47.50 ± 2.25[b]	60.00 ± 3.04[bc]	77.50 ± 3.25[b]	90.00 ± 3.04[b]	100.00 ± 0.00[b]
	V. amygdalina	42.50 ± 2.35[b]	57.50 ± 3.25[b]	72.50 ± 3.25[b]	87.50 ± 3.25[b]	92.50 ± 2.35[b]
48	*T. diversifolia*	60.00 ± 3.04[cd]	77.50 ± 3.25[de]	92.50 ± 3.25[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	52.50 ± 3.35[bc]	70.00 ± 2.04[cd]	90.00 ± 3.04[c]	97.50 ± 2.25[b]	100.00 ± 0.00[b]
72	*T. diversifolia*	72.50 ± 3.35[d]	82.50 ± 3.35[e]	100.00 ± 0.00[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	67.50 ± 3.25[d]	80.00 ± 3.04[de]	97.50 ± 3.25[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
96	*T. diversifolia*	87.50 ± 3.25[e]	97.50 ± 2.25[f]	100.00 ± 0.00[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	V. amygdalina	82.50 ± 3.35[e]	87.50 ± 3.25[ef]	100.00 ± 0.00[c]	100.00 ± 0.00[b]	100.00 ± 0.00[b]
	Control	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]	00.00 ± 0.00[a]

Mean followed by the same letters within the same column are not significantly different ($P > 0.05$

reported on protectability of *V. amygdalina* against cowpea beetle (*Callosobruchus maculatus)* infesting cowpea seeds. Adedire and Lajide (2003) reported the effectiveness of *V. amygdalina* in the control of maize weevil (*Sitophilus zeamais).* Musa et al. (2009) reported the effectiveness of *V. amygdalina* in the management of cowpea bruchid. Moses and Dorathy (2011) who reported efficacious of bitter leaf over garlic and ginger as the most toxicant that protected cowpea seeds against cowpea weevil (*C. maculatus*).

Toxicity of *V. amygdalina* powder and extract on larvae and adults of *D. maculatus* could be as a result of the presence of some chemical compounds like alkaloids and sesquiterpene lactones which contain and 11, 13-dihydrovernodalin, vernodalol and vernodalin (Pascual et al. 2001). These compounds contain antifeedant and repellent properties and also act as ovicidal, larvicidal and adulticidal (Pascual et al. 2001).

Bitter leaf (*V. amygdalina*) and *T. diversifolia* powders and extracts prevented the emergence of *D. maculatus* adults in the treatment against larval and adult stages. This result is in agreement with the observation of Jose and Adesina (2014). The powders and extracts of *V. amygdalina* and *T. diversifolia* adversely affected survival and growth of skin beetle. Deterrent properties of plants could lead to growth inhibition in insects (Akhtar and Isman 2004).

The development of *D. maculatus* larvae was inhibited in all the treated smoked catfishes compared to the control. This agreed with earlier scientists who have reported on the bioefficacy of plant products as contact insecticides on *D. maculatus* (Fasakin 2003; Adebote et al. 2007; Akinwumi 2011; Jose and Adesina 2014). The significant reduction in progeny development could be as a result of higher mortality of *D. maculatus* larva which in turn results in lower adult emergence. The powders and extracts of the tested plants were more lethal to the larval than the adult stage of hide beetle.

Conclusion

The results of this study clearly revealed that powders and extracts of the tested plants were more lethal to larval than adult stage. The larvae were more mobile and feed voraciously than adults (Adedire 2001). *Tithonia diversifolia* powder and extract were more toxic than *V. amygdalina* and can be integrated as smoked fish protectant against skin beetle (*D. maculatus).* The experimental plants were readily and widely available in all ecological zone in Nigeria. I therefore recommend it adoption for fish farmers or traders for the management of *D. maculatus* infestation during processing, transportation and storage of smoke-dried catfish (*C. gariepinus).*

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Authors' contributions
KDI conceived, designed the study, collected data, search references and manuscript write up. All authors read and approved the final manuscript.

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