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ENTOMOTOXIC ACTIVITY OF POWDER OF CLEISTOPHOLIS PATENS BENTH AGAINST THE INDIAN MEAL MOTH, *PLODIA INTERPUNCTELLA* (HÜBNER) (LEPIDOPTERA: PYRALIDAE)

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A B S T R A C T

This study investigated the insecticidal activity of parts of *Cleistopholis patens* against developmental stages of *Plodia interpunctella* in stored maize grains. The efficacies of the powders as contact and fumigant insecticides were evaluated by admixing different concentrations (0.5, 1.0, 1.5, 2.0 and 2.5g) to maize grains containing developmental stages of the moth. Egg hatchability, adult emergence, larvae mortality and adult mortality of the moth were used as indices of the insecticidal activities at 24hrs, 48hrs, 72hrs, and 96hrs post-treatment periods. The powders from the root bark and stem bark of *C. patens* completely inhibited egg hatching and adult emergence as both contact and fumigant insecticide. Also, they evoked 100% mortality at 2.5% protectant concentration at 96hrs post-treatment period against larvae and adult *P. interpunctella.* The leaf powder was the least effective as both contact and fumigant insecticide.

Keywords: Mortality, development, insecticidal, protectant, powder, oil.

INTRODUCTION

Plodia interpunctella (Hübner), is a cosmopolitan pest that infests wide ranges of stored products including maize grains, nuts, beans, processed foods and dried fruits (Simmons and Nelson 1975). Infestation of commodity by *P. interpunctella* causes 60 - 80% post-harvest losses of staple food crops in Nigeria leading to major economic losses (Oni and Ileke 2008). Infestation of *P. interpunctella* causes direct product loss and indirect economic costs, quality losses and consumer complaints (Philips *et al.* 2000a, b). The feeding activity of the larva results into the entire food surface been matted with web which contaminate the produce, change food colour due to infection by moulds and gives it an unpleasant odour. The webbing also contains larval excreta (frass and exuvia (cast skins)) (Almasi 1984; Fasulo and Knox 2009). Since, insect pest infestation has been reported as the major cause of food grain losses in most developing countries during storage (Adedire *et al.,* 2011), the control of these pests becomes imperative. The control of stored product pest has been centered on the use of synthetic insecticide because of its effectiveness within the shortest post treatment period; but it has serious drawbacks (Sharaby 1988). These include genetic resistance by insect species, toxic residues, increasing cost of application, pollution of the environment and hazard from handling (Leelaja *et al.,* 2007). These have stimulated a search for alternative means of storage-pests control. In view of these, researchers and farmers have diverted their attention toward the use of botanical (plant-based) insecticides in controlling stored product insect pests, because they are eco-friendly, less toxic to humans, easy to use, specific in action and insect pests are not resistance to them (Ileke and Oni 2011). Medicinal plants have demonstrated potential as insect control agents (Adedire and Lajide 2003; Aranilewa *et al*., 2006; Ashamo *et al.,* 2013). Small scale farmers and researchers have often claimed successful use of plant products in insect pest control. Plant materials such as spices, vegetable oils, extracts, powders or inert dust have been reported for their insecticidal efficacy (Keita *et al.,* 2001; Akinkurolere *et al.,* 2006; Akinneye and Ashamo 2009; Adedire *et al.,*

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2011). *Cleistopholis patens* (family: Annonnaceae*)* is a sun-loving tree of about 20 — 35m tall found in many parts of African countries. *C. patens* are commonly known as "salt and oil tree" and its local Nigeria name is Apako or Oke (Yoruba). It is a medicinal plant used in the treatment of headache, malaria, measles and antifertility (Oliver 1960). It can also be used for treatment of infectious diseases caused by *Staphylococcus aureus* (Adonu 2013). This research work is sought to reveal the insecticidal activity of *C. patens* (Benth) against the *Plodia interpunctella* (Hübner) (Lepidoptera; Pyralidae) and its toxicological effect on Albino rats.

MATERIAL AND METHODS

Insect Rearing: The *Plodia interpunctella* larvae used to establish the culture was obtained from naturally infested maize grains from Federal University of Technology, Akure (FUTA) farm, Ondo State, Nigeria. The moths' larvae were reared in 2 litre plastic containers containing 300g of un-infested maize grains. The culture was maintained by continually replacing devoured maize grain and sieving out frass and fragments. The plastic containers were covered with muslin cloth, fastened by rubber band, and placed inside wire mesh cage of dimension 75cm × 50cm × 60cm (L × W × H) with its four stands dipped in water-kerosene mixture contained in a plastic container to prevent entry of predatory ants into the cages. The culture was maintained at a temperature (28 ± 2^{o}C) and relative humidity (75 ± 5%). The whole setup was left inside the postgraduate research laboratory of the Department of Biology, Federal University of Technology, Akure.

Preparation of Plant Materials: The leaf, stem bark and root bark of *C. patens* were harvested from Otasun farm along Ile Oluji road, Ondo, Ondo State, Nigeria. These plant parts were brought to the laboratory, washed thoroughly with water, shade-dried in the laboratory for 30 days. Each plant part was separately pulverized into fine powder using Binatone electric blender (Model 373). The powders were further sieved to pass through 1mm^2 perforations. The fine powders were kept in separate airtight plastic containers and stored at ambient temperature of 28 ± 2^{o}C and 75 ± 5% relative humidity.

EXPERIMENTAL PROCEDURE FOR INSECTICIDAL ACTIVITY

The contact and fumigant toxicity of *Cleistopholis patens* powders and oil extracts were assayed on developmental stages of *Plodia interpunctella* to evaluate their potential entomotoxic effects. All the experiments were conducted at room temperature of 28 ± 2^{o}C and relative humidity of 75 ± 5%.

Contact toxicity of *C. patens* powders on eggs and larval of *P. interpunctella*: Twenty freshly laid eggs (0-24hr old) were placed on 20g of maize grains treated with 0.0 (control), 0.5, 1.0, 1.5, 2.0 and 2.5g root barks, stem barks and leafs powder of *C. patens* inside plastic container of dimension 8cm diameter and 4cm depth. The treated and the control (untreated) were replicated three times. Daily observation were made with dissecting microscope to determine the number of eggs that hatch from the total number of eggs incubated and the setup was left inside insect breeding wire mesh cage measuring (75 × 50 × 60) cm and after 40 days the number of adult emerged insects were determined and percentage calculated. Fine powder of the root barks, stem barks and leaf of *C. patens* was also admixed with maize grains at the rate of 0.0 (control), 0.5, 1.0, 1.5, 2.0 and 2.5g/ 50g of maize in plastic containers (8cm diameter and 4cm depth). The container cover was punched with hot iron rod and lined with muslin cloth on the inside to prevent larvae from escaping and allow aeration. Ten (10) third instars larvae were introduced into the treated and un-infested maize grains and were replicated three times. The numbers of dead larvae were counted after 24h, 48h, 72h and 96h post-treatment and the mean values were calculated.

Contact toxicity of *C. patens* powders on adult *P. interpunctella*: Fine powders of the *C. patens* root bark; stem bark and leaves were admixed with maize grains at the rate of 0.0 (control), 0.5, 1.0, 1.5, 2.0, 2.5g/ 50g of maize in plastic containers (8 diameter and 4cm depth). The container cover was punctured with hot iron rod and lined with muslin on the inside to prevent insect escape and allows for aeration. Ten pairs of newly emerged adult of *P. interpunctella* was introduced into plastic containers containing the treated maize and untreated samples was also infested to serve as control with adult *P. interpunctella* and all treatment were replicated three times. Adult mortality at 24, 48, 72 and 96 hours after treatment were counted and recorded. At the end of the 96 hours post-treatment period, data on percentage adult mortality was corrected using Abbott (1925) formula, stated thus:

$$P_T = \frac{P_0 - P_C}{100 - P_C}$$

Where P_T= Corrected adult mortality

P_O= Percentage mortality of treated insects

P_C= Percentage mortality on untreated insects

Fumigant toxicity of *C. patens* powders on eggs and larvae of *P. interpunctella*: The following concentration 0.0g, 0.5g, 1.0g, 1.5g, 2.0g and 2.5g/50g of maize grain, leaves, stem bark and root powder of *C. patens* were weighed and sealed in muslin cloth of dimension 3cm by 3cm and hanged on the lid of plastic containers of 8cm depth having 4cm diameter. Twenty freshly laid eggs (0-24hr old) were introduced into plastic container containing 50g of maize grains and covered with the lid; the plant powder was hanged at a distance of 4cm from the lid as well from the bottom and was made airtight. The treated and the control (untreated) experiments were replicated three times. Daily observation were made with dissecting microscope to determine the number of eggs that hatch from the total number of eggs incubated and the experiment was left inside the insect breeding wire mesh cage pending adult emergence. At the end of 41 days post-treatment period the total number of emerged adult was determined and percentage calculated. The same of dead larvae were counted after 24h, 48h, 72h and 96h post treatment.

Fumigant effect of *C. patens* powders on adult *P. interpunctella*: The fine powder of the *C. patens* root bark, stem bark and leaves at the rates of 0.0g, 0.5g, 1.5g, 2.0g and 2.5/50g of maize grain were sealed in muslin clothes of dimension 3cm by 3cm and hanged with thread at a distance of 4cm from the lid of the plastic containers of dimension 8cm depth x 4cm width. Ten pairs of newly emerged adult (0-24hrs old) were introduced into plastic containers containing 50g of maize grains and covered with lid hanged with the plant parts powder. Untreated maize grains were on the other hand with adult of *P. interpunctella* and all treatments were replicated three times. Adult mortality at 24h, 48h, 72h and 96 hours after treatment were determined and recorded. At the end of the 96 hours post treatment data on percentage adult mortality were corrected using Abbot (1925) formula:

$$P_T = \frac{P_0 - P_C}{100 - P_C} \times 100$$

Where P_T= Corrected adult mortality

P_O= Percentage mortality of treated insects

P_C= Percentage mortality on untreated insects

RESULTS

Contact toxicity of *C. patens* powders on egg hatchability and adult emergency of *P. interpunctella*: The effect of *C. patens* powder on egg hatchability and adult emergence of *P. interpunctella* is presented in Table 1. Egg hatchability and adult emergence were inhibited at all the concentration relative to the control. There was no significant difference in these responses among the treatment groups.

Contact toxicity of *C. patens* powders on larva of *P. interpunctella*: Toxic effect of *C. patens* on larva mortality of *P. interpunctella* is presented in Table 2. Mortality varied with plant parts, rate of application and exposure period. There was no mortality at 24hrs post treatment at 0.5 – 1.0g rate of the leaf powder and stem bark powder and 1.5g rate of the leaf powder. While all rates of the root bark, 1.5g – 2.5g rate of the stem bark powder and 2.0 – 2.5g rate of the leaf powder caused greater than 16.67% larvae mortality of the moth obtained at 0.5g rate of root bark. At 48hrs post treatment, all rates of the stem bark except 0.5g and 1.5 – 2.5g rate of the leaf powder caused greater than 30.0% mortality. The root bark at 2.0g – 3.0g able to achieve 100% larva mortality of the moth at 96hrs post treatment whereas the stem barks at 2.5g attained 100% mortality at 96hrs post treatment. No rate of the leaf powder attained 100% larva mortality of the moth. The larval mortality obtained at 1.5g and 2.0g of the root bark powder and stem bark powder were not significantly different ($P>0.05$) at 96hrs post treatment.

Contact toxicity of *C. patens* on the adult mortality of *P. interpunctella*: The contact toxicity of *C. patens* powder on mortality of adult *P. interpunctella* is presented in Table 3. At 24hrs post treatment, 0.5g rate of the root bark 0.5 and 1.0g rates of the stem bark and leaf powder caused no mortality of the moth, while 1.0 – 2.5g rates of the rook bark, stem bark and leaf powder caused greater than 15.0% adult mortality except 1.5g rate of the leaf powder that caused no adult mortality. At 48hrs post treatment, all rates of the root bark, the 1.0 – 2.5g rates of the stem bark and the 1.0g – 2.5g rates of the leaf powders caused 20 – 68% adult mortality of the moth. The root bark at 2.5g was the earliest to cause 100% mortality at 72hrs post treatment whereas the stem bark at 2.5g attained 100% mortality at 96hrs post treatment. No rate of the leaf powder attained 100% mortality of the moth. The mortality obtained at 1.5g and 2.0g of the root bark and stem bark powder were not significantly different ($P>0.05$) at 96h post treatment.

Table 1. Contact toxicity of *C. patens* powders on egg hatchability and adult emergency of *P. interpunctella*.

Plant powders	Conc.	% Eggs hatch	% Adults Emergence
Root bark	0.0	88.33 ± 4.41^{b}	85.00 ± 2.89^{b}
	0.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Stem bark	0.0	86.67 ± 1.67^{b}	85.00 ± 2.89^{b}
	0.5	5.00 ± 2.89^{a}	3.33 ± 1.67^{a}
	1.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Leaf	0.0	85.00 ± 2.89^{d}	81.67 ± 1.67^{d}
	0.5	33.33 ± 4.41^{c}	28.33 ± 4.41^{c}
	1.0	25.00 ± 2.89^{b}	25.00 ± 2.89^{b}
	1.5	25.00 ± 2.89^{b}	20.00 ± 2.89^{b}
	2.0	18.33 ± 1.67^{a}	16.67 ± 3.33^{a}
	2.5	15.00 ± 2.89^{a}	10.00 ± 2.89^{a}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

Table 2. Contact toxicity of *C. patens* powders on larva of *P. interpunctella*.

Plant Powder	Rate (g/20g) maize grain)	Mean % mortality after			
		24hrs	48hrs	72hrs	96hrs
Root bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	16.67 ± 3.33^{b}	30.00 ± 0.00^{b}	43.33 ± 6.67^{b}	50.00 ± 5.77^{b}
	1.0	26.67 ± 3.33^{c}	40.00 ± 0.00^{c}	53.33 ± 3.33^{c}	70.00 ± 0.00^{c}
	1.5	46.67 ± 6.67^{d}	63.33 ± 3.33^{d}	80.00 ± 11.55^{d}	93.00 ± 6.67^{d}
	2.0	56.67 ± 6.67^{e}	66.67 ± 3.33^{d}	90.00 ± 5.77^{e}	100.00 ± 0.00^{d}
	2.5	60.00 ± 5.77^{e}	76.67 ± 3.33^{e}	93.00 ± 6.67^{e}	100.00 ± 0.00^{d}
Stem bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	26.67 ± 3.33^{b}	36.33 ± 3.33^{b}	40.00 ± 0.00^{b}
	1.0	0.00 ± 0.00^{a}	40.00 ± 0.00^{c}	53.33 ± 5.77^{c}	63.33 ± 6.67^{c}
	1.5	33.33 ± 3.33^{b}	53.33 ± 3.33^{d}	73.33 ± 3.33^{d}	86.67 ± 8.81^{d}
	2.0	53.33 ± 3.33^{c}	63.33 ± 3.33^{e}	83.33 ± 3.33^{e}	90.00 ± 5.77^{d}
	2.5	60.00 ± 5.77^{d}	73.33 ± 3.33^{f}	90.00 ± 5.77^{e}	100.00 ± 0.00^{e}
Leaf	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	20.00 ± 0.00^{b}	26.67 ± 3.33^{b}	30.00 ± 0.00^{b}
	1.0	0.00 ± 0.00^{a}	30.00 ± 0.00^{c}	36.67 ± 3.33^{c}	40.00 ± 5.77^{c}
	1.5	0.00 ± 0.00^{a}	40.00 ± 0.00^{d}	43.33 ± 3.33^{d}	50.00 ± 0.00^{d}
	2.0	33.33 ± 3.33^{b}	40.33 ± 3.33^{d}	50.00 ± 0.00^{de}	60.00 ± 0.00^{e}
	2.5	36.67 ± 3.33^{b}	43.33 ± 3.33^{d}	53.00 ± 3.33^{e}	60.00 ± 5.77^{e}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

Table 3. Contact of *C. patens* powders on adult mortality of *P.interpunctella*.

Plant Powder	Rate (g/20g) maize grain)	Mean % mortality after			
		24hrs	48hrs	72hrs	96hrs
Root bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	20.00 ± 2.87^{b}	33.33 ± 1.67^{b}	51.67 ± 4.14^{b}
	1.0	15.00 ± 2.87^{b}	33.33 ± 7.26^{c}	53.33 ± 6.00^{c}	93.33 ± 4.41^{c}
	1.5	23.33 ± 3.33^{c}	48.33 ± 6.01^{d}	66.67 ± 4.41^{d}	96.67 ± 3.33^{d}
	2.0	28.33 ± 1.67^{c}	60.00 ± 5.77^{e}	83.33 ± 8.82^{e}	100.00 ± 0.00^{d}
	2.5	45.00 ± 2.89^{d}	68.33 ± 4.41^{ef}	100.00 ± 0.00^{f}	100.00 ± 0.00^{d}
Stem bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	16.67 ± 2.87^{b}	23.33 ± 1.67^{b}	33.33 ± 4.14^{b}
	1.0	0.00 ± 0.00^{a}	25.00 ± 0.00^{c}	43.33 ± 1.67^{c}	53.33 ± 1.67^{c}
	1.5	20.00 ± 2.89^{b}	40.00 ± 5.77^{d}	53.33 ± 3.33^{d}	63.33 ± 3.33^{d}
	2.0	28.33 ± 3.33^{bc}	45.00 ± 2.89^{d}	58.33 ± 1.67^{d}	76.67 ± 3.33^{e}
	2.5	38.33 ± 4.41^{d}	60.00 ± 5.77^{e}	90.00 ± 5.77^{e}	100.00 ± 0.00^{f}
Leaf	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	11.67 ± 1.67^{ab}	16.67 ± 1.67^{b}	31.67 ± 10.93^{b}
	1.0	0.00 ± 0.00^{a}	25.00 ± 0.00^{c}	33.33 ± 1.67^{c}	45.00 ± 0.00^{c}
	1.5	0.00 ± 0.00^{a}	28.33 ± 4.41^{c}	43.33 ± 3.33^{cd}	51.67 ± 1.67^{d}
	2.0	28.33 ± 3.33^{b}	40.00 ± 5.00^{d}	55.00 ± 5.00^{e}	65.00 ± 2.89^{e}
	2.5	35.00 ± 2.89^{c}	41.67 ± 1.67^{d}	60.00 ± 2.89^{e}	70.00 ± 2.89^{ef}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

Fumigant toxicity of *C. patens* powders on egg hatchability and adult emergence of *P. interpunctella*: The effect of various plant parts powder of *C. patens* on the development of *P. interpunctella* from egg to adult are presented in Table 4. There was no egg hatched and adult emergence in all the grains protected with root and stem bark powder whereas 26.7% eggs were hatched and 20% adult emerged in the grain protected with leaf powder. At 1.5g/ 20g of maize, 11.7% eggs were hatched and 8.3% adult emerged and there was no significant difference (P> 0.05) when compared with the 2.0g protectant concentrations of the leaf powder. Also at 2.5g/ 20g of maize, 6.7% eggs were hatched and only 1.7% adult emerged using the leaf powder. There was significant difference (P< 0.05) in the mean number of egg hatched and adult emergence when compared with their control, which had 68.3% hatchability and 61.6% adult emergence.

Fumigant toxicity of *C. patens* powders on larvae of *P. interpunctella*: The fumigant effect of *C. patens* powders on larval mortality of *P. interpunctella* at different concentrations and exposure period is presented in Table 5. The percentage mortality varied with plant parts, the period of exposure and concentrations of the plant powders. After 24hrs of post treatment, all rates of the root bark, the 1.0 – 2.5g rate of the stem bark and the 2.0 – 2.5g rate of the leaf powders caused 33.33 – 80% larvae mortality of the moth. At 48hrs post-treatment, all rates of the root bark, the 1.0 – 2.5g rate of the stem bark and 1.5 – 2.5g rate of the leaf powder caused 50.0% -- 93.3% larvae mortality of the moth. The root bark powder at 1.5g was able to caused 100% mortality of the larvae of *P. interpunctella* at 96hrs post treatment and also the root bark powder at 2.0g was able to evoke 100% mortality of the larvae within 72hrs of post treatment whereas the stem bark powder at 2.5g attained 100% larvae mortality at 96hrs post treatment. However, this was followed by leaf powder which evoked 40.0%, 50.0%, 63.3%, 66.6% and 73.3% mortality of the larvae *P. interpuncella* at rate 0.5, 1.0, 1.5, 2.0 and 2.5g/20g of maize grains after 96hrs post treatment of application respectively. The mortality attained at 1.5g -- 2.5g rate of the root bark and stem bark were not significantly different (P>0.05) at 96hrs post treatment.

Fumigant toxicity of *C. patens* powders on adult mortality of *P. interpunctella*: The fumigant effect of *C. patens* powders on the mortality of adult *P. interpunctella* at different concentrations and exposure period is presented in Table 6. The percentage mortality varied with plant parts, rate of application and exposure period. After 24hrs of post treatment, at all rates of root bark powder, the 1.0 – 2.5g rates of stem bark powder and the 1.0g – 2.5g of leaf powder caused 3.33% – 48.3% adult mortality. At 48hrs post treatment, all rates of root bark powder, the 1.0 – 2.5g of stem bark and the 1.0 – 2.5g of leaf powder were able to achieve 30% – 78% adult mortality. The root bark after 96hrs, 100% mortality was obtained except at 0.5g and 1.0g where 61.67% and 98.33% was achieved. The stem bark at 2.5g/20g maize grains attained 100% mortality at 96hrs post treatment. No rate of the leaf powder achieved 100% mortality of the moth. The mortality attained at 1.0 – 2.5g rate of the root bark were not significantly different ($P<0.05$) at 96hr post–treatment.

Table 4. Fumigant toxicity of *C. patens* powders on egg hatchability and adult emergence of *P. interpunctella*.

Plant powders	Conc. G	Eggs hatch	% Adults Emergence
Root bark	0.0	73.33 ± 3.33^{b}	63.33 ± 3.33^{b}
	0.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Stem bark	0.0	76.67 ± 3.33^{b}	66.33 ± 3.33^{b}
	0.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	1.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	2.5	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
Leaf	0.0	68.33 ± 4.41^{e}	61.67 ± 4.41^{e}
	0.5	26.67 ± 0.33^{d}	20.00 ± 2.89^{d}
	1.0	16.67 ± 1.67^{c}	13.33 ± 1.67^{bc}
	1.5	11.67 ± 1.67^{b}	8.33 ± 1.67^{b}
	2.0	10.00 ± 1.67^{b}	6.67 ± 1.67^{b}
	2.5	6.67 ± 1.67^{a}	1.67 ± 1.67^{a}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different ($P>0.05$) using New Duncan's Multiple Range Test.

Table 5. Fumigant toxicity of *C. patens* powders on larvae of *P. interpunctella*.

Plant Powder	Rate (g/20g) maize grain)	Mean % mortality after			
		24hrs	48hrs	72hrs	96hrs
Root bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	33.33 ± 3.33^{b}	50.00 ± 0.00^{b}	60.00 ± 5.77^{b}	63.33 ± 5.77^{b}
	1.0	46.67 ± 3.33^{c}	60.00 ± 0.00^{c}	73.33 ± 3.33^{c}	83.33 ± 6.67^{c}
	1.5	56.67 ± 6.67^{d}	73.33 ± 3.33^{d}	93.33 ± 6.67^{d}	100.00 ± 6.67^{d}
	2.0	73.33 ± 3.33^{e}	86.67 ± 3.33^{e}	100.00 ± 0.00^{e}	100.00 ± 6.67^{d}
	2.5	80.00 ± 5.77^{ef}	93.33 ± 3.33^{f}	100.00 ± 0.00^{e}	100.00 ± 6.67^{d}
Stem bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	46.67 ± 3.33^{b}	56.67 ± 3.33^{b}	60.00 ± 0.00^{b}
	1.0	20.00 ± 10.00^{b}	53.33 ± 3.33^{c}	66.67 ± 3.33^{c}	83.00 ± 3.33^{c}

	1.5	36.67 ± 6.67^{c}	73.33 ± 3.33^{d}	86.67 ± 6.67^{d}	93.33 ± 3.33^{d}
	2.0	53.33 ± 3.33^{d}	83.33 ± 3.33^{e}	96.67 ± 3.33^{e}	96.67 ± 3.33^{d}
	2.5	63.33 ± 3.33^{e}	86.67 ± 3.33^{e}	100.00 ± 0.00^{e}	100.00 ± 0.00^{d}
Leaf	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	23.33 ± 0.00^{b}	40.00 ± 0.00^{b}	40.00 ± 0.00^{b}
	1.0	3.33 ± 3.33^{b}	30.00 ± 0.00^{bc}	46.67 ± 3.33^{c}	50.00 ± 5.77^{c}
	1.5	23.33 ± 3.33^{c}	53.33 ± 3.33^{c}	60.00 ± 0.00^{d}	63.33 ± 3.33^{d}
	2.0	33.33 ± 3.33^{d}	63.33 ± 3.33^{d}	66.67 ± 3.33^{d}	66.67 ± 3.33^{d}
	2.5	40.00 ± 0.00^{de}	66.67 ± 3.33^{d}	73.33 ± 3.33^{e}	73.33 ± 3.33^{e}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

Table 6. Fumigant toxicity of *C. patens* powders on adult mortality of *P. interpunctella*.

Plant Powder	Rate (g/20g) maize grain)	Mean % mortality after			
		24hrs	48hrs	72hrs	96hrs
Root bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	3.33 ± 1.67^{a}	30.00 ± 2.87^{b}	43.33 ± 1.67^{b}	61.67 ± 4.41^{b}
	1.0	25.00 ± 2.89^{b}	43.33 ± 7. 26^{c}	70.00 ± 5.00^{c}	98.33 ± 1.67^{c}
	1.5	30.00 ± 2.89^{bc}	55.00 ± 2.89^{d}	86.67 ± 7.26^{d}	100.00 ± 0.00^{c}
	2.0	38.00 ± 1.67^{c}	70.00 ± 5.77^{e}	96.67 ± 3.33^{e}	100.00 ± 0.00^{c}
	2.5	48.33 ± 4.41^{d}	78.33 ± 4.41^{f}	98.33 ± 1.67^{e}	100.00 ± 0.00^{c}
Stem bark	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	26.67 ± 1.67^{b}	33.33 ± 1.67^{b}	55.00 ± 2.89^{b}
	1.0	10.00 ± 5.00^{b}	36.67 ± 1.67^{c}	53.33 ± 1.67^{c}	63.33 ± 1.67^{c}
	1.5	23.33 ± 5.77^{c}	46.67 ± 3.33^{d}	63.33 ± 3.33^{d}	73.33 ± 3.33^{d}
	2.0	28.33 ± 3.33^{cd}	55.00 ± 2.86^{e}	66.67 ± 3.33^{d}	86.67 ± 3.33^{e}
	2.5	45.00 ± 2.89^{d}	70.00 ± 5.77^{f}	90.00 ± 5.77^{e}	100.00 ± 0.00^{f}
Leaf	0.0	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}	0.00 ± 0.00^{a}
	0.5	0.00 ± 0.00^{a}	21.67 ± 1.67^{b}	33.33 ± 1.67^{b}	43.33 ± 4.41^{b}
	1.0	3.33 ± 3.33^{a}	35.00 ± 0.00^{c}	43.33 ± 1.67^{c}	55.00 ± 0.00^{c}
	1.5	21.67 ± 1.67^{b}	40.00 ± 2.89^{d}	53.33 ± 3.33^{d}	61.67 ± 1.67^{d}
	2.0	28.33 ± 3.33^{c}	50.00 ± 8.66^{e}	65.00 ± 5.00^{e}	71.67 ±1.67^{e}
	2.5	35.00 ± 2.89^{d}	55.00± 2.89^{ef}	70.00 ± 2.89^{f}	78.33 ± 3.33^{ef}

Each value is a mean ± standard error of three replicates. Means followed by the same letter along the column are not significantly different (P>0.05) using New Duncan's Multiple Range Test.

DISCUSSION

CONTACT AND FUMIGANT TOXICITY OF *C. PATENS* POWDER ON DEVELOPMENTAL STAGES OF *P. INTERPUNCTELLA*.

Contact and fumigant toxicity of *C. patens* powder on egg hatchability and adult emergence of *P. interpunctella*: The use of plant powders in control of insect pest of stored products is an ancient practice. Many Nigeria medicinal plants and spices have been used as pest control agents (Lale 1992; Ofuya and Dawodu 2002). Several powders of this plant are often used in the control of stored product Coleopteran and Lepidopteran because of their relative high efficacy on all developmental stages of the insects. The result obtained from this research showed that the root bark, stem bark and leaf powder of C*. patens* in both contact and fumigant toxicity were found effective against eggs and emergence of adult of *P. interpunctella* at all levels of concentration. But the leaf powder was slightly effective against the eggs which produced 10 – 28% adult emergence and there was significant difference (P<0.005) when compared with the control. The

inability of the egg to hatch to larval may be due to the fact that the powders inhibit gaseous exchange between the egg and external environment. The performance of the root bark, stem bark and leaf powders of *C. patens* in this study agreed with the findings of Echnedu (1991) that the powdered rhizome of *Zingiber officinale* when admixed at 2.5g/500g brown cowpea seed reduced the emergence of adult by 96% compared to the untreated control. The insecticidal activity of *C. patens* plant powder evaluated against eggs and development to adult in this study was also similar to the observation of Akinneye (2003) that *C. patens* inhibited the egg hatch and development to adult stage in *E. cautella.* Olawumi (2014) reported that *U. afzelli* fruit powder inhibited the egg hatch and development of *P. interpunctella* reared on maize grain.

Contact toxicity of *C. patens* powder on larval of *P. interpunctella*: The contact effect of powders and rate of application of *C. patens* root bark, stem bark and leaf on the mortality of larva of *P. interpunctella* depends on concentration and exposure periods. The result obtained from this research showed that the *C. patens* root bark, stem bark and leaf powders have effect on the larvae of *P. interpunctella*, except at 0.5g – 1.5g of stem bark and leaf powders, no mortality were recorded at 24hrs post treatment. At 72hrs post treatment, and an application rate of 1.5g – 2.5g/ 20g of maize grain 73.33% -- 93% mortality was recorded which was significantly higher ($P>0.05$) than the mortality recorded at 0.5g/20g and 1.0g/20g that caused mortality of 40% -- 63.3% respectively. This was similar to the findings of Ashamo and Akinneye (2004) that *Eugenia aromatica* caused greater than 43.3% mortality of the yam moth *Euzopherodes vapidella.* The mortality of the insect larval may result from inability of the larva to fully cast off their exoskeleton which typically remained linked to the posterior part of their abdomen. This agreed with the result of Adedire (2002) in which nutmeg oil was found to cause asphyxiation and subsequent death of *C. maculatus* on stored cowpea. However, at 96hrs post treatment, at application rate of 2.0 – 2.5g/20g root bark powder and stem bark powder at 2.5g/20g rate caused 100% larval mortality, this showed that the root bark powder and the stem bark powder of *C. patens* were the most effective on mortality of larvae of *P. interpunctella* at the three treatment levels investigated while the leaf powder was slightly effective since the percentage mortality produced at 96hrs post treatment was significantly higher than the control. This agreed with the findings of Pathak and Tiwari (2010) in which powder and oil of *Azadirachta indica* was found to have larvicidal effect on the larvae of *Corcyra cephalonica*.

Fumigant toxicity of *C. patens* powders on larvae of *P. interpunctellai*: The fumigant toxicity of *C. patens* root bark, stem bark and leaf powders on larvae of *P. interpunctella* observed at 24hrs, 48hrs, 76hrs and 96hrs post treatment revealed the insecticidal potency of *C. patens.* At 24hrs of post treatment, the 0.5g rate of stem bark and leaf powder, caused no larva mortality except for root bark powder which caused 33.33% mortality. At 48hrs post treatment, all rates of the root bark, the 1.0 – 2.5g rate of the stem bark and 1.5 – 2.5g rate of the leaf powder caused less than 50% larvae mortality of the moth. This finding was similar to the findings of Ashamo and Akinneye (2004) that *E. aromatica* caused greater than 43.3% mortality of *E. vapidella* at 0.05g/15g of yam.

Contact toxicity of *C. patens* powder on adult mortality of *P. interpunctella*: The contact toxicity of *C. patens* to adult *P. interpunctella* depends on concentration, part used and exposure periods. Mortality varied with plant parts, rate of application and exposure periods. At 24hrs post treatment, the 0.5g rate of the root bark, the 0.5 and 1.0 rate of the stem bark and 0.5 – 1.5g rate of the leaf powder obtained no adult mortality of the moth. This finding was similar to observation of Akinneye (2011) in the control of *E. cautella* with *C. patens* powder. The root bark powder at the rate of 2.0g and 3.0g and stem bark powder at the rate of 3.0g concentration was effective against *P. interpunctella,* producing 100% mortality within 96hrs post treatment. This observation also tallies with the findings of Adedire and Lajide (2001) that the pulverized powder of *Piper umbrellatum* seed and *E. aromatica* were toxic to *C. maculatus* producing 100% mortality at 24hrs post treatment across all concentrations. The toxic effect of the root and stem bark powder of *C. patens* in this study could be attributed to their pungency which evoked suffocating action on the moth. The leaf powder was the least effective of all the *C. patens* part tested but there was significant difference ($P<0.05$) in the mortality recorded with the leaf powder when compared with the control. Hence, the leaf powder was effective at higher concentration. The powder may also bind to the enzyme, cholinesterase thus preventing the removal and resultant accumulation of acetylcholine, the

neurotransmitter, restlessness convulsion and paralysis may occur resulting in death of moth (Ashamo 2000).

Fumigant toxicity of *C. patens* powders on adult mortality of *P. interpunctella*: The fumigant toxicity of *C. patens* root bark, stem bark and leaf powders on adult mortality of *P. interpunctella* observed at 96h post treatment with different level concentration revealed the insecticidal potency of *C. patens* plant parts. The percentage mortality varied with plant parts, rate of application and exposure periods. There was no mortality at 24hrs post treatment, at 0.5g rate of the stem bark and leaf powder, except for root bark powder, which caused 3.33% mortality. At 48hrs post treatment, all rates of the root bark, the 1.0 –2.5g rate of the stem bark and 1.0 – 2.5g of the leaf powder caused greater than 30% adult mortality of the moth.This findings agree with the work of Adedire and Lajide (2003) that *Uvaria afzelli*, *E*. *aromatica* and *Aframomum melegueta* were toxic to adult *Sitophilus zeamais* at all levels of treatment within 24 hours of application. The root bark at 1.5g/20g maize grains was the earliest to cause 100% mortality whereas the stem bark at 2.5g/20g maize grains attained 100% mortality at 96hrs post treatment. This was in agreement with the observation of Akinneye *et al.,* (2009). The root bark of *C. patens* was the earliest to cause 100% adult mortality of *E. cautella* at 3.0g/20g cocoa beans. No rate of the leaf powder of *C. patens* attained 100% adult mortality. This observation was similar to the findings of Ashamo and Akinneye (2004) in studies with *E. vapidella* in which there was no rate of *Hyptis sauveolens* powder that attained 100% adult mortality of the moth. The powder of *C. patens* acted mainly through fumigant modes of action. This powder may cause death through respiratory inhibition, inhibition of oxidative phosphorylation and amine metabolism (Ashamo 2000).

REFERENCES

Abbott, W. 1925. A method for computing the effectiveness of an insecticide. Journal of Economic Entomology. 18:265-267.

Adedire, C.O. 2002. Use of nutmeg, Myristica fragrans (Houtt) powder and oil for the control of cowpea storage Bruchid, Callosobruchus maculatus. Journal of Plant Disease and Protect 109: 193-199.

Adedire, C.O and L. Lajide. 2001. Efficacy of Powders of some Plants in the Control of the Pulse Beetle, *Callosobruchus maculatus* (F.) (Coleptera: Bruchidae) Journal of Applied Tropical Agriculture 6: 11-15.

Adedire, C.O and L. Lajide. 2003. Ability of extracts of ten tropical plant species to protect maize grains against infestation by the maize weevil, *Sitophilus zeamais*, during storage. Nigeria of Journal Experimental Applied Biology 4:175-179.

Adedire, C.O., O. O. Obembe, R. O. Akinkurolere and O. Oduleye. 2011. Response of *Callosobruchus maculatus* (Coleoptera: Chysomelidae: Bruchidae) to extract of cashew kernels. Journal of Plant Disease and Protection, 118(2), 75-79.

Adonu, C.C., O. P. Ugwu, C. O. Esimone, E. C. Ossai, A. Bawa, A. C. Nwaka and C. U. Okorie. 2013. Phytochemical analyses of methanol, hot water and n-hexane extracts of the aerial parts of *Sassytha filiformis* Linn and leaves of *Cleistopholis patens* (Benth). Resources Journal of Pharmaceutical Biology Chemistry Science 4(2): 1143-1149.

Akinkurolere, R.O., C. O. Adedire and O. O. Odeyemi. 2006. Laboratory evaluation of the toxic properties of forest anchomanes, Anhomanes difformis, against pulse beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae). Insect Sc. 13: 25-29.

Akinneye, J.O. 2003. Biology and control of the yam moth, Euzopheroides vapidella (Mann) Lepidotera: Pyralidae). Federal University of Technology, Akure, M.Tech.Thesis pp 65.

Akinneye, J.O. 2011. Aspects of Biology and Control of Tropical Warehouse Moth, E. cautella (Walker) (Lepidotera: Pyralidae) in Cocoa Beans. Ph.D. Thesis. Federal University of Technology, Akure, Nigeria. pp. 59.

Almasi, R. 1984. The effect of nutrition on fertility and number of generations of Indian meal moth *Plodia interpunctella* Hbn. (Lepidotera: Pryralidae), infesting cocoa beans in storage. pp 25.

Arannilewa, S.T., T. Ekrakene and J. O. Akinneye. 2006. Laboratory evaluation of four medicinal plants as protection against the maize weevil, *Sitophilus zeamais*. African Journal of Biotechnology 5(21): 2032-2036.

Ashamo, M.O. 2000. Bionomics and control of the yam moth, Dasyses rugosella (Stainton) (Lepidotera: Tineidae). Federal University of Technology,

Akure, School of Postgraduates Studies, Ondo State, Nigeria. D. Phil Thesis 187pp.

Ashamo, M.O and J. O. Akinneye. 2004. Toxicity of powder of some tropical plants against yam moth, *Euzopheroides vapidella* (Mann) (Lepidotera: Pyralidae). Nigeria Journal of Experimental and Applied Biology, 5:63-68.

Ashamo, M.O., O. O. Odeyemi and O. C. Ogunbite. 2013. Protection of cowpea, Vigna unguiculata L. (Walp.) with Newbouldia laevis (Seem.) extracts against infestation by *Callosobruchus maculatus* (Fabricius), Archives of phytopathology and plant protection 46(11): 1295-1306.

Echendu, T.N.C. 1991. Ginger, Cashew and neem as surface protectant of cowpea against infestation and damage by *Callosobruchus maculatus* (F). Tropical Science 31: 209-211.

Fasulo, T.R and M. A. Knox. 2009. University of Florida Featured Creatures. Indian meal moth, Plodia interpunctella (Hubner).

Ileke, K.D and M. O. Oni. 2011. Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (motschulsky) Coleoptera: Curculiondae) on stored wheat grains. African Journal Agriculture Research. 6: 3043-3048.

Keita, S.M., C. Vincent, J. Schmit, J. T. Arnason and A. Belanger. 2001. Efficacy of oil of *Ocimum basilicum* L. and O. gratissimum L. applied as an insecticidal fumigant and powder to control *Callosobruchus maculatus* (Fabr.). Journal of Stored Products Research 37: 339-349.

Lale, N.E.S. 1992. A laboratory study of the comparative toxicity of products from three species to the maize weevil, Post-harvest Biology and Technology 2: 61-64.

Leelaja, B.C., Y. Rajashekar, R. P. Vanitha, K. Begum and S. Rajendran. 2007. Enhanced fumigant toxicity of allyl acetate to stored-product beetles in the process of carbon dioxide. Journal of Stored Product Resources, 43: 45-48.

Ofuya, T.I and E. O. Dawodu. 2002. Aspects of insecticidal of Piper guineense powder against *Callosobrchus maculatus*. Nigerian Journal Entomology Society 19: 40-50.

Olawumi, F.K. 2014. Some Aspects of Biology and Control of *P. interpunctella* (Hubner) (Lepidotera: Pyralidae). M. Tech Thesis, Federal University of Technology, Akure, Nigeria. pp. 74.

Oliver, D. 1960. Medicinal plants in Nigeria 1st edition. Nigerian College of Arts, Science and Technology, Ibadan. Pp 43-53.

Oni, M.O and K. D. Ileke. 2008. Insecticidal efficacy of oil extracts of *Balanites aegyptiaca* seeds and cashew nuts against *Callosobruchus maculatus* Fabr. (Coleoptera: Bruchidae). African Journal of Agricultural Research.

Pathak, C.S and S. K. Tiwari. 2010. Toxicological effects of neem, Azadirachta indica A. Juss leaf powder against the ontogeny of *Corcyra cephalonica* (Staint.) (Lepidotera: Pyralidae). Journal of Biopesticides 3(3):617-621.

Philips, T.W., R. C. Berbert and G. W. Cuperus. 2000a. Post-harvest integrated pest management. In: Francis, F. J. (Ed.), Encyclopedia of Food Science and Technology. 2nd ed. Wiley Inc., New York, pp. 2690-2701.

Philips, T.W., P. M. Cogan and H. Y. Fadamiro. 2000b. Pheromones. In: Subramanyam, B., Hagstrum, D. W. (Eds.), Alternatives to Pesticides in Stored-product IPM. Kluwer Academic Publishers, London, pp. 273 – 302.

Sharaby, A. 1998. Anti-insect properties of the essential oil of lemon grass, *Cymopogen citrates* against the lesser cotton leafworm Spodoptera exiqua (Hbn). Insect Science Applications 9(1): 77-80.

Simmons, P and H. D. Nelson. 1975. Insects on dried fruits. USDA Agricultural Handbook.