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Evaluation of Inert and Permethrin Powders against *Cylas puncticollis* Boheman (Coleoptera: Brentidae) on Stored Sweet Potato

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Abstract

The sweet potato weevil *Cylas puncticollis* is one of the insect pests of stored sweet potato in Africa. Due to its perishable nature, infested tubers cannot be stored for long period. Laboratory experiments were conducted to evaluate the efficacy of two inert powders namely Insecto® Diatomaceous Earth (DE) and Oil Palm Inflorescence Ash (OPIA), and a permethrin powder against *C. puncticollis* on white-fleshed sweet potato tubers. Each treatment was applied at 0, 0.3, 0.9 and 1.5 g per 30 g sweet potato, and then infested with ten unsexed adults of *C. puncticollis* in glass jars. The set up was arranged in a completely randomised design with each treatment replicated three times and maintained at 70±5% relative humidity and 28±2°C. Data was collected on adult mortality daily (up to 7 days) while progeny emergence and weevil damage (perforated tubers) were recorded after 28 days. Adult mortality was dose-dependent of insecticide and exposure time, and there were significant differences among all the tested insecticides. Permethrin induced 100% mortality and total progeny suppression against *C. puncticollis*. At the highest dose, DE and OPIA were less effective causing 67.2% and 54.7% mortality, and below 78% progeny suppression, respectively. All powders significantly caused lower weevil damage on tuber compared to control which recorded 37.3%. Permethrin proved the most effective against *C. puncticollis*, followed by DE and OPIA. However, more research is required to explore how these inert powders can provide additive effect with other bio-pesticides against sweet potato weevils.

Introduction

Sweet potato [*Ipomea batatas* (L) Lam.] is the second most important tuber crop in sub-Saharan Africa (SSA) after cassava (FAOSTAT, 2020). It serves as a significant food security crop in many global low income regions, where they are mainly cultivated by women for food, feeds and source of income (Gobena *et al*., 2022; Aritua and Gibson, 2002). The tuber is usually eaten boiled, fried or roasted to serve as meals or snacks, thereby providing valuable and affordable sources of protein and vitamin that can positively affect human health (Qin *et al*., 2022). Due to the perishable nature of this crop which limits significant trade in fresh produce, sweet potato production thus has potential to help regions achieve food self-sufficiency (OECD-FAO, 2022). Its major attributes include ability to withstand climatic variations, adaptation to wide range of agro-ecologies, better productivity with minimal input requirements (Gruneberg *et al*., 2015), thus making Nigeria top sweet potato producer in West Africa region and accounts for 3.8 million tons (FAOSTAT, 2022).

As sweet potato is one of the most extensively produced tuber crops in SSA (Gurmu *et al*., 2018), its yields have remained low in Nigeria and generally in Africa, owing to insect pests notably the African sweet potato weevils, *Cylas* spp., (Coleoptera: Curculionidae) (Mourtala *et al*., 2022; Mugisa *et al*., 2022). *Cylas puncticollis* (Boheman) and *C. brunneus* (Fabricius) are the two most destructive pests of sweet potato in SSA, and have been reported to cause 60-100% losses particularly during extended dry period and under heavy infestation (Sorensen, 2009; Ehisianya, 2019). These pests inflict damage on every harvestable part of the crop while infested storage tubers have bitter taste, quality degradation, and usually are unfit for human or animal feed (Okonya

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et al., 2016; Uwaidem *et al*., 2018) resulting in lower market value and reduced food security (Smit, 1997).

Several sweet potato weevil management strategies have been implemented including improved agronomic practices and chemical control (Smit and Matengo, 1995; Stathers *et al*., 2005). Insect pests control in SSA have largely been based on conventional synthetic insecticides, comprising mostly of contact organophosphate and pyrethroid compounds (Stathers *et al*., 2008). However, insect resistance development and public concerns for health issues related to pesticide residues in treated commodities have prompted extensive research on alternative, non-chemical control measures (Stejskal *et al*., 2021). The use of non-chemical or natural-based agents such as inert dust has long been prioritized for modern pest control and incorporated into integrated pest management protocols (Baliota and Athanassiou, 2023).

Inert dusts include all dry powders of mineral earths (such as clays, diatomite, wood-ash, silicates and sand) that are chemically unreactive in nature and which provides physical control measures (Subramanyam and Roesli, 2000). Mixing stored products with inert dusts have been used traditionally and shown to control a variety of common storage insect pests (Golob, 1997). More recently, materials including diatomaceous earth and wood-ash have been used increasingly in SSA, replacing conventional chemicals (Otitodun *et al*., 2015; Adarkwah *et al*., 2022). Diatomaceous earths (DEs) are natural products mined from fossilized diatoms which have inhabited water bodies. They are typically comprised of approximately 70–90% amorphous silicon dioxide (Timlick and Fields, 2010) and are fatal to insects by the absorption of the waxy layer causing abrasion of insect cuticle which consequently leads to death through desiccation (Korunic, 1998). Several DE formulations have been found effective against a range of storage insects (Adarkwah *et al*., 2022). On the other hand, plant-ash is the powdery residue remaining from burning of any botanical material. It is known as one of the oldest pest control methods (Panagiotakopulu *et al*., 1995). The burnt by-product of several botanical materials have been used to successfully control various stored product insect pests (Otitodun *et al*., 2015; Bohinc *et al*., 2018). For example, oil palm inflorescence ash have been used for postharvest processing and preservation of food crops (Ayodele and Iwhiwhu, 2011; Popoola and Adenuga, 2013; Azi *et al*., 2019).

Given that DE and botanical-ash are non-chemical pest control options which provides cheap, effective and safe control of several insect pests of stored commodities, this study aims to assess the effect of Insecto® diatomaceous earth and oil palm inflorescence ash for the control of *C. puncticollis* with a view towards substantial need for simple, reduce-risk and physical methods to protect harvested sweet potatoes against *C. puncticollis* and similar pests.

Materials and Methods

The experiment was carried out at the Entomology Research Laboratory, Department of Zoology, University of Ibadan, Nigeria (07° 26‘ N, 03° 53‘ N) (eTrex® 30x handheld GPS, Garmin International Inc., Kansas, USA). Temperature and relative humidity for the cultures, and experiment were at 28 ± 2°C and 70 ± 5%; 12 h dark/light photoperiod (Anymetre JR900A digital thermo-hygrometer).

Test insect

Adults of *C. puncticollis* were originally collected from an infested and abandoned sweet potato tubers found in one postgraduate hall of residence at the University of Ibadan, and then cultured on fresh sweet potatoes in the laboratory. The insect was cultured inside a 2 L plastic jar with a mesh size 0.25 mm created on both sides of the jar.

Collection of sweet potato

Fresh sweet potato tubers (white variety) used in this experiment was purchased from Bodija market, Ibadan, Oyo State, Nigeria. Pristine tubers (with no damage holes) were selected and taken to the Entomology laboratory of the Department of Zoology, where they were cleaned under running tap water and disinfested in a freezer for 2 days at -10°C.

Morphometric measurements

The morphometric description of *C. puncticollis* used in this study was done using Billah *et al*. (2008; 2017) procedure for stage graticles measurement. A total of 30 weevils were dissected using a Leica EZ4D Stereo-microscope. Imaging of the mounted specimens were done using visual microscopy – the Leica EZ4D stereo-microscope fitted with an in-built camera and connected to a computer system. Body parts were measured using the Leica application software - body length (bl), head length (hl), hind leg, fore leg, antennae, membranous wing length and width were calculated.

Storage treatment used

Three treatments tested comprised of diatomaceous earth, inflorescence ash and Rambo (permethrin) insecticide. Insecto® diatomaceous earth (hereafter referred to as DE) is a commercial non-toxic insecticide formulation developed by Insecto Natural Products (Costa Mesa, USA), and has been successfully used for protection of stored food commodities against storage insect pests (Otitodun *et al*., 2015; Asiwaju-Bello, 2023). Inflorescence ash of oil palm (*Elaeis guineensis* Jacq.) (hereafter referred to as OPIA) was prepared by drying and burning male inflorescence of oil palm that were collected from an oil palm plantation to ash. This ash has previously been tested for its effectiveness against some storage beetles (Ayodele and Iwhiwhu, 2011; Popoola and Adenuga, 2013). Rambo™ brand (hereafter referred to as permethrin) is a synthetic pyrethroid and a commercially available insecticide powder commonly used for insect pests control in Nigeria. The manufacturer claimed that the insecticide contains 0.6% permethrin and 99.4% inert carriers (Gongoni Company Limited, Kano, Kano State, Nigeria). The permethrin powder was purchased from a local agrochemical shop within Bodija market, Ibadan. Disposable hand gloves and dust masks were worn during manual application on sweet potato by hand. Prior to the experiment, all the treatment products were kept in an air-tight containers at ambient condition until required for use.

Mortality and damage assessment

The insecticidal effect of each DE, OPIA and permethrin on adult *C. puncticollis* in stored sweet potato tubers were assessed in the laboratory. Thirty grams of disinfested sweet potato were thoroughly mixed with different dosages of 0.0g (control), 0.3g, 0.9g and 1.5g each of OPIA, DE and permethrin in 250 ml specimen bottles. The dosage rate of each insecticidal powder was measured using Ohaus PR series analytical balance (Ohaus Corporation, NJ, USA). Ten unsexed adults of *C. puncticollis* were introduced into each treatment bottle that contained the treated sweet potato, and covered with muslin cloth which was held in place with rubber bands to allow air exchange and prevent escape of insects. The bottles were arranged in a completely randomized design inside a laboratory cage (28 ± 2°C, 70 ± 5% RH and 12:12 light/day). Each treatment were replicated three times. Adult mortality were observed and counted daily for up to 7 days post treatment and then removed. All insects were confirmed dead when there was no response when their abdomen was gently probed with a camel hair brush. Percentage mortality was calculated using (Eq. 1).

$$\% \text{ Mortality} = \frac{Number\ of\ dead\ weevils}{Total\ number\ of\ weevils} \times 100 \qquad 1$$

The remaining living adults were removed from the bottles after 7 days and the bottles were then kept under the same conditions to monitor F_1 generation emerging from the sweet potatoes. The number of F1 progeny produced was recorded after 4 weeks.

Reduction in progeny production (RPP) relative to the control was calculated as (Eq. 2).

$$\%RPP = \frac{Nc - Nt}{Nc} \times 100 \qquad 2$$

Nc = Number of F_1 in the control; Nt = Number of F_1 in the treatment

The number of weevil damage in stored sweet potatoes were assessed based on number of tubers perforated with more than five exit holes at 4 weeks post treatment. The tubers were carefully examined and data obtained were recorded. The percentage damage caused by *C. puncticollis* was calculated using (Eq. 3):

$$\% \text{ Damage} = \frac{number\ of\ perforated\ tubers}{Total\ number\ of\ tubers} \times 100 \qquad 3$$

Data obtained for respective parameter were summarized in SPSS version 20 using descriptive statistics and analysis of variance (ANOVA).

Results

Morphological description of C. puncticollis

The morphometry of adult *C. puncticollis* body parts showed differences in sizes of individual measured (Table 1).

Effect of storage treatments on insect mortality

Adult mortality of *C. puncticollis* exposed to different dosages of DE, OPIA and permethrin are shown in Table 2. The results showed that there was significant differences ($P < 0.05$) among the three treatments during duration of exposure. Permethrin was more active on *C. puncticollis* than DE and OPIA. Sweet potato tubers treated with permethrin doses of 0.3 – 1.5g after 7 days resulted in 100% mortality of *C. puncticollis* (Table 2).

Table 1: Dimensions (range and mean ±SE) of body parts of 30 adult *C. puncticollis*

Body part	TL	HL	AL	MW		EW	
				Length	Width	Length	Width
Range (mm)	6.4–7.1	1.4–2.0	1.3–2.2	2.6–3.8	1.1–2.9	2.3–3.8	1.2–1.9
Mean (mm)	6.8±0.2	1.7±0.2	1.7±0.2	3.3±0.3	2.1±0.6	3.1±0.4	1.5±0.2

TL – total length, HL – head length, AL – antennae length, MW – membranous wing, EW – elytra wing.

Table 2: Mortality of adult *C. puncticollis* (Mean % ± SE) after 1, 2, 3 4, 5, 6, and 7 days exposure to sweet potato tubers treated with different insecticide products at different dosages

Treatment	Dose (g)	% Mortality (Mean ± SE)						
		1 day	2 days	3 days	4 days	5 days	6 days	7 days
DE	0.3	0.0±0.0^{b}	10.3±1.3^{d}	25.6±2.1^{c}	36.6±3.3^{c}	45.7± 3.3^{c}	55.2±5.3^{c}	61.7±3.3^{b}
	0.9	0.0±0.0^{b}	30.3±3.3^{b}	45.7±1.3^{b}	50.3±2.7^{b}	55.2±5.3^{b}	62.7±3.3^{b}	64.4±5.1^{b}
	1.5	0.0±0.0^{b}	30.3±3.3^{b}	48.2±1.5^{b}	57.4±2.7^{b}	61.0±0.2^{b}	65.7±3.3^{b}	67.2±4.4^{b}
OPIA	0.3	0.0±0.0^{b}	8.5±0.3^{d}	19.3±0.0^{d}	29.7±1.3^{d}	37.7±3.3^{d}	38.0±1.3^{e}	43.6±5.3^{d}
	0.9	0.0±0.0^{b}	18.3±1.3^{c}	26.3±1.7^{c}	36.6±3.7^{c}	47.3±3.3^{c}	48.0±4.7^{d}	51.2±5.8^{c}
	1.5	0.0±0.0^{b}	20.6±0.3^{c}	25.7±3.3^{c}	40.3±3.3^{c}	42.6±6.7^{c}	47.3±4.3^{d}	54.7±4.3^{c}
Permethrin	0.3	95.7±0.3^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}
	0.9	96.7±0.7^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}
	1.5	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}	100.0±0.0^{a}
Control		0.0±0.0^{b}	0.0±0.0^{e}	0.0±0.0^{e}	0.0±0.0^{e}	0.0±0.0^{e}	0.0±0.0^{f}	0.0±0.0^{d}

Treatments: Diatomaceous earth (DE), oil palm inflorescence ash (OPIA) and Permethrin powder. Values followed by different letters are significantly different (P < 0.05) according to Tukey HSD test.

On the other hand, at the same dosages and exposure time, DE and OPIA resulted in reduced mortalities of insect with the effect of DE and OPIA against the test insect increased with increasing of concentration. Where, the percentage mortalities ranged between 10.3 to 67.2% for the applied dose rates of DE over 7 days. In addition, the mortality percentages recorded for OPIA ranged between 8.5 to 54.7% at the same dosage and time (Table 2).

C. puncticollis emergence, progeny suppression and damage on sweet potato tubers

Results on the emerged F1 adults of *C. puncticollis* on sweet potato tubers treated with different dosages of DE, and OPIA showed dose-dependent effect on progeny production (P<0.05) (Table 3). There was significant difference between the treatments to adult *C. puncticollis* emergence and damage (Table 3). Compared to permethrin where there was no adult emergence recorded, DE and OPIA did not result in complete inhibition of F1 adults of *C. puncticollis* irrespective of the dosages. In the DE-treated sweet potatoes, emergence of *C. puncticollis* ranged between 8.9 to 15.2% in the lowest and highest dosages. Similarly, for sweet potato treated with OPIA, the highest number of emergence of 21.8% was found in 0.3g treated sweet potato compared to a low number of 11.3% in 1.5g treated sample. In the DE-treated sweet potato, the number of progeny (F1) production of *C. puncticollis* among the tested dosage reduced in range of 71.7 to 78.3%, while for OPIA treatment, it ranged between 66.6 to 71.7%. The effectiveness of the treatment in suppressing progeny production was dose-dependent as the highest dose rates suppressed production (Table 3). However, the control recorded the highest number of emergence with 65.3% insects after 28 days. In the case of damage, the highest weevil damage was found in the control (untreated sweet potato) with 37.3%, compared to the treated samples where damage ranged between 4.6-13.5% and 8.2-19.4% for DE and OPIA treatments, respectively.

Table 3: Emergence, reduction in progeny production (RPP) and damage caused by *C. puncticollis* on treated sweet potato (Mean % ± SE)

Treatment	Dose (g)	% Emergence	% RPP	% Damage
DE	0.3	25.2±3.4[c]	71.7±2.1[c]	13.5±1.2[c]
	0.9	17.5±1.1[c]	76.9±1.9[b]	9.3±0.7[c]
	1.5	9.9±1.6[b]	78.3±2.7[b]	4.6±2.3[b]
OPIA	0.3	21.8±2.6[c]	66.6±3.5[d]	19.4±0.6[b]
	0.9	17.0±1.9[c]	69.0±1.5[c]	12.7±1.1[c]
	1.5	8.3±0.9[b]	71.7±1.7[c]	8.2±0.9[c]
Permethrin	0.3	0.0±0.0[a]	100.0±0.0[a]	0.0±0.0[a]
	0.9	0.0±0.0[a]	100.0±0.0[a]	0.0±0.0[a]
	1.5	0.0±0.0[a]	100.0±0.0[a]	0.0±0.0[a]
Control	0.0	65.3±4.1[d]	-	37.3±2.9[d]

Treatments: Diatomaceous earth (DE), oil palm inflorescence ash (OPIA), Permethrin powder and Control. Values followed by different letters in the same column are significantly different ($P < 0.05$) according to Tukey HSD test.

Discussion

The general physical appearance of adult *C. puncticollis* is ant-like in structure. However, based on the morphometric measurement of 30 insects, mean body length of *C. puncticollis* was 6.8 mm. This length corresponds to the reported mean body length of 5.0 – 8.0 mm (Okonya *et al*., 2016) and 6.7 – 7.3 mm for male and female *C. puncticollis* collected from four different regions of Ghana (Billah *et al*., 2017). Other morphometric characters representing different parts of the elytra and head showed varied measurements among population examined. Billah *et al*. (2017) noted that variations in body size of individual *Cylas* spp. existed, indicating that the differences in body parts are mostly responsible for the observable traits among the male and female species.

Among the storage treatments used, permethrin was the most effective with 100% efficacy followed by DE and OPIA regarding the mortality of *C. puncticollis* in this study. Differences in effectiveness between synthetic insecticide and inert dust used may be due to their mode of action, storage temperature and commodity moisture (Paponja *et al*., 2020). The relative effectiveness of pyrethroid insecticides on several stored insect pests have been associated to their primary mode of action which targets the nervous system functions, resulting in a very rapid paralytic actions and possibly death in insects even when applied in small dosages. This fast action of pyrethroids and other synthetic insecticides in controlling insect pests makes them a method of choice among most smallholder farmers throughout most of the developing countries. However, as withholding period for various chemicals exist and sweet potatoes have a relatively short storage longevity as a fresh produce, suitable alternatives to replace synthetic chemical use are important. The effectiveness of DE against stored product insects is well studied. In this study, there was a clear indication of increased mortality values with increased dosage and exposure time. Similar observations have been reported on DEs activity to be dosage-time exposure dependent on adult mortalities of stored-product insect pests (Adarkwah *et al*., 2022). Although DEs are slow acting due to their dessicating mode of action, their susceptibilities have been reported to differ among insect species (Shah and Khan, 2014). Also, the lower mortality recorded might be attributed to other factors including storage temperature and relative humidity in this experiment which was difficult to maintain during the experimental period. Quarles (1992) stated that DEs are not effective in a humid surrounding, not because water/heat saturates the absorptive surface, but because insects can constantly replenish their water loss by ingesting moist substrate. A similar low mortality was reported for DE against *Tribolium castaneum* and *Sitophilus zeamais* at

28 and 32 days respectively (Adarkwah *et al*., 2022). In the case of OPIA, no complete mortality was observed across dosage rates over exposure periods, and a similar dosage-exposure time results as in DE was recorded. However, in another experiment, OPIA demonstrated a 70 – 95% mortality on adult *O. surinamensis* in stored date fruits for 10 weeks (Popoola and Adenuga, 2013). Based on the above, it is evident that none of the inert dusts (DE or OPIA) demonstrated total effectiveness against adult *C. puncticollis*. Although DE works by the adsorption of insect cuticular waxes by silica and causing insect to die from desiccation (Athanassiou and Steenberg, 2017), it is unclear whether OPIA which belongs to the non-silica group of inert dust also works in a similar manner as DEs. However, several authors have reported the ineffectiveness of other inert-based materials against a number of insect pests such as the bostrichids and psocids (Stathers, 2008; Otitodun *et al*., 2017). Regarding the damage (weevil perforation) on sweet potato tubers, the observed entomotoxic effect of treatments used varied. *Cylas puncticollis* develops inside sweet potato roots, therefore, its feeding activity causes severe damages. In this study, the synthetic insecticide (permethrin) offered a high degree of protection from damage compared to the non-chemical products used. The extent of damage induced in the DE-treatments was less than in OPIA. Previous laboratory bioassay using botanical powders from *Aframomum melegueta, Dennettia tripetalla* and *Xylopia aethiopica* fruits have demonstrated protection of sweet potato tubers from damage by sweet potato weevil, with low damage of 11.5%, 15.1% and 10.6%, respectively (Nta *et al*., 2018).

Conclusion

Based on data collected from this study, the inert products used showed low efficacy against *C. puncticollis* on sweet potato tubers. It is therefore important that further research be conducted to evaluate the efficacy of DE or OPIA by combining with other natural products such as botanicals for control of *C. puncticollis* and other sweet potato insect pests.

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