JJBS
Jordan Journal of Biological Sciences

Volume 12, Number 3,August 2019
ISSN 1995-6673
Pages 267 - 273

Evaluation of Repellent Potential of Some Botanical Products against Cowpea Weevil, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae)

Ito E. Edwin[1,*] and Anigboro O. Fidelis[2]

[1]Tropical Disease Research Unit, Department of Animal and Environmental Biology, Delta State University, P.M.B 1, Abraka; [1]Department of Biology/Microbiology, Delta State Polytechnic, P.M.B 03 Otefe-Oghara; [2] Department of Biology, College of Education Agbor, Delta State, Nigeria.

Received July 6, 2018; Revised September 9, 2018; Accepted October 8, 2018

Abstract

The powder and crude extracts from five plant species, namely garlic (*Allium sativum*), manjack or drum tree (*Cordia millenii*), African or calabash nutmeg (*Monodora myristica*), negro-pepper (*Xylopia aethiopica*), and ginger (*Zingiber officinale*) were tested for their repellent activity against *Callosobruchus maculatus* (F.) adults through the cup bioassay technique and filter paper repellency method in the laboratory. *C. millenii* was the most superior repellent against *C. maculatus*. Results indicated that the repellent efficacy of the botanical materials followed this trend: *C. millenii* > *Z. officinale* > *A. sativum* > *X. aethiopica* > *M. myristica.* The former two plants generated a repellency of 66.0% and 65.4%, respectively; Class IV repellency (60.1-80.0%). Whereas, *A. sativum*, *X. aethiopica* and *M. myristica* caused a repellency of 50.3, 49.9 and 45.5%, respectively; Class III repellency (40.1-60.0%). The repellent effect on *C. maculatus* at the application doses of the powders of the selected plant species were statistically significant. There was also a significant difference in repellency due to various concentrations of the extracts of selected plant species with high correlation coefficients and positive significance compared to the powder treatment. Thus, % repellency increased according to doses and concentrations of the tested botanical products and due to the increase in the exposure period.

Keywords: Repellency, *Callosobruchus maculatus,* Botanical products, Bioassay and repellents.

1. Introduction

Callosobruchus maculatus (Fab.), a bruchid coleopteran commonly known as cowpea weevil, is a severe insect pest of stored grains including cowpea seeds (*Vigna unguiculata* (L.) in Sub-Sahara Africa (Al-Moajel and Al-Fuhaid, 2003) where it is responsible for up to a 100 % loss/damage of the seeds in storage and weight loss of about 60 % (Gbaye *et al.,* 2011). Caswell (1981) reported a loss of about 50 % of stored cowpea seeds, three-four months postharvest in Northern Nigeria, and 60 % cowpea seed loss to cowpea weevil in Northern Ghana (Tanzubil, 1991). The damage of this magnitude is incredibly high, and demonstrates the destructive nature of the pest which can threaten food security at both household and national levels. This is a major agricultural problem for farmers in developing countries (Ito and Ighere, 2017a).

Cowpea seeds damaged by bruchids are unfit for consumption, sales and planting because of perforation, weight reduction, overall unacceptability in markets and the impaired germination of the seeds (Ito and Ighere, 2017b; Uyi and Obi, 2017). Consequently, farmers are compelled to sell their products early after harvest when prices are still low partly because of anticipated losses of the grain in storage (Ito and Ighere, 2017a). This is a major and worrisome agricultural problem facing farmers in developing countries. Cowpea is an important source of dietary protein in tropical and subtropical regions of the world especially where availability and consumption of animal protein is low (Ofuya, 1991). The protection of cowpea against *C. maculatus* infestation and damage is necessary because of its economic importance as revenue source and constituent articles of diet.

Several control measures have been adopted over the years to curtail the menace of storage insect pests (Boeke *et al.,* 2004; Ogbonna *et al.,* 2016; Ito and Ighere, 2017a; Uyi and Obi, 2017; Ito and Utebor, 2018). Synthetic insecticides such as Dichlorodiphenyltrichloroethane (DDT) and Lindane (Srivastava and Pant, 1998) as well as botanical products including ashes, powders, and oil have been applied traditionally in the control of insects. The use of plant-derived insecticides was abandoned in favour of synthetic insecticides discovered in 1940s. However, the human-made insecticides became unpopular and wasteful (Ewete *et al*., 1996) owing to their prohibitive cost and technical difficulty of application by the majority of African peasant farmers. Besides, these insecticides are inimical to the environment because of toxic residues in

[*] Corresponding author e-mail: ito.eddie@yahoo.com.

food, pest resistance, and their negative impact on non-target beneficial insects (Cherry *et al*., 2005). These deficiencies made farmers shift away from the reliance on synthetic chemicals towards the use of plant materials to protect plants and stored-food products because they are biodegradable, environmentally-safe, and can delay pest resistance (Ito and Ighere, 2017b).

This study is carried out to determine the repellent potential of the powder and crude extracts from five spicy plant species relative to one another at various doses and concentrations against cowpea weevil *C. maculatus*.

2. Materials and Methods

2.1. Plant Materials

The plant species used for the study included garlic (*Allium sativum;* Family: Amaryllidaceae), manjack (*Cordia millenii*; Family: Boraginaceae), nutmeg (*Monodora myristica*; Family: Myristicaceae), negropepper (*Xylopia aethiopica*; Family: Annonaceae) and ginger (*Zingiber officinale;* Family Zingiberaceae). The plant parts used were: bulb, seed, seed, fruit and rhizome, respectively. The plant materials were obtained from a local market in Abraka, Delta State, Nigeria, and were processed into powder and crude extracts.

2.2. Preparation of Plant Powders

The plant materials were cut into smaller fragments and dried under the sun for seven days (Ito and Ighere, 2017a) and were later maintained in an oven at 60 ^{0}C for five-ten minutes to ensure that the plant materials were dried to constant weight. This treatment was to make sure that the extracts derived from them were devoid of water. The dry plants' materials were each pulverized with the aid of a Binatone electric blender (Model: BLG-400) and sieved through a fine mesh to obtain the powder which was stored in separate labelled airtight bottles to avoid loss of potency (Ito and Ukpohwo, 2018) until required for the repellency test (Okonkwo and Okoye, 1996).

2.3. Preparation of Crude Extracts

The extracts of each plant species were prepared by weighing out 25.0, 37.5 and 50.0 g from the milled powder into three separate 1000ml capacity glass jars and adding 500 mL of 95% ethanol (solvent) into the jars. These preparations corresponded to the concentrations of 50.0, 75.0 and 100.0 mg^{-ml} respectively. The jars containing the extract were shaken regularly and stirred vigorously with a glass rod for a period of three days before filtering using a filter paper (Whatman no. 1). The filtrates were concentrated by a slight application of heat in a water-bath system to evaporate the solvent. Viscous extracts were obtained and stored in airtight bottles in a refrigerator maintained at 5-10 ^{o}C until ready for use.

2.4. Culturing of Callosobruchus maculatus

The cowpea weevil, *C. maculatus*, was reared on cowpea grain by the method of Ito and Ighere (2017a) with modification in plastic containers (1.0 kg). Seeds of Cowpea (*Vigna unguiculata*) that were apparently un-infested with *C. maculatus* and those heavily infested were obtained from traders at a local market in Abraka, Delta State. Batches of 500g un-infested cowpea seeds were placed in each of the seven plastic containers used for the culture. Adult cowpea weevils were picked from the infested cowpea seeds to establish the stock from which batches of 100 unsexed weevils were taken and placed in each culture container. The containers were then covered with polythene nets fastened with rubber bands and were kept for seven days for mating and oviposition to occur. The parent weevils were then removed, and the culture was kept for 65-70 days (Ito and Ighere, 2017a). The adult first filial generation (F_1) weevils that emerged were taken and used for the study.

2.5. Repellency Bioassay with Plants' Powder

Repellency bioassay of the plants' powders against *C. maculatus* was carried out using the cup bioassay techniques of Kumar *et al.* (2004). The cup is a perforated cylinder (10 cm X 7 cm) made of thin aluminum sheet and covered at one end with a lid bearing pores through which weevil could move into a plastic container on which the cup was suspended. The container with the cup was placed in a trough where the weevils that emigrated through the pores in the cup were collected.

The plants' powders were tested at four doses (1.0, 2.0, 3.0 and 4.0g), and were compared with dimethylphthalate, a standard synthetic repellent, at the same doses under laboratory conditions (28-32^{0}C and 65-75 % R.H). The apparently un-infested cowpea seeds used as substrate were kept in a refrigerator under freezing conditions for four days; this is to kill any residual weevil in the seeds in order to safeguard against unwanted weevil infestation. The seeds were then equilibrated to the ambient laboratory conditions for five days prior to the test.

The disinfested cowpea seeds were weighed in batches of 200g and mixed thoroughly with 1.0-4.0g of the powder of each plant material (1.0, 2.0, 3.0 and 4.0g per 200g wt: wt, powder: substrate). Dimethylphthalate (1.0-4.0g) was also mixed thoroughly with 200g cowpea substrate. Three replicates were prepared for each treatment and the control. The admixtures were transferred to the bioassay cups designated for the doses.

Twenty unsexed adult F_1 *C. maculatus* were carefully picked from the culture with aspirator and were released through a long-stemmed funnel into each bioassay cup of substrate powder admixture. A control experiment consisting of 200g cowpea substrate and twenty adult *C. maculatus* without powder was set up. The cowpea weevils were exposed to treatments for 168 hours for each plant dose. Repellency was observed every twenty-four hours for 168 hours (a seven-day exposure period) according to FAO Bulletin (1999) for all plant types at different concentrations.

2.6. Repellency Test with the Plants' Extracts

Repellency of the experimental plants' extracts against *C. maculatus* at various concentrations (50.0, 75.0 and 100.0mg^{-ml}) was determined by filter paper repellency method (McDonald *et al.,* 1970). Filter papers (Whatman no. 1) were laminated with aluminium foil and were cut into equal halves and separated into two groups (A and B). Group A filter papers were further divided into three portions marked as A_1, A_2 and A_3. The latter were treated with 50.0, 75.0 and 100mg^{-ml} extracts, respectively. Each treated paper was made triplicate and air-dried overnight to evaporate the ethanol solvent. Group B half filter papers were not treated and served as control. The treated and untreated half filter papers were carefully attached, edge to edge, lengthwise with sellotape on the reverse side to produce full filter papers. Each full filter paper was placed in a petri dish with the seams of the papers oriented in one of three randomly selected different directions to avoid any incidental stimulus that could affect the distribution of the weevils.

Ten adult unsexed *C. maculatus* were released into the centre of each full filter paper in the petri dishes before covers were placed over them. Repellency was observed at every hour for five hours. Mean of percentage repellency was calculated, and the values were used to assign repellency class for the tested plant materials using Jilani and Su scale (1983).

2.7. Statistical Analysis

The percentage repellency was calculated at every twenty-four hours of exposure for each plant species using the equation:

$$\text{Repellency (\%)} = 100\left(\frac{\sum n_1 - n_2}{n_3}\right)$$

$\sum$ = Summation; n_1 = Initial number of weevils per replicate; n_2 = Final number of weevils per replicate; n_3 = total number of weevils per triplicate treatment. The data obtained were subjected to Analysis of Variance (ANOVA) for treatment means comparison; significant differences for treatment means were compared at 0.05 significant level.

3. Results

3.1. Repellent Effects of Plants' Powder Formulation

The strongest repellent effect against *C. maculatus* across doses (1.0 - 4.0 g) over 168 hours of exposure was *C. millenii*, followed by *Z. officinale, A. sativum, X. aethiopica* and *M. myristica*; the range of the cumulative percentage repellency at the lowest (1.0 g) and highest dose (4.0 g) were 75.0 - 98.3, 70.0 - 96.6, 73.3 - 95.0, 61.6 - 90.0 and 60.0 - 88.3, respectively. All the tested plants' powders, except *M. myristica* at low doses, were comparable and/or more repellent against *C. maculatus* than dimethyl phthalate, the standard repellent (Table 1). The ranking for these plant powders is: *C. millenii* (98.3 %) > *Z. Officinale* (96.6 %) > *A. sativum* (95.0 %)> *X. aethiopica* (90.0 %) > Dimethylphthalate (88.3 %) = *M. myristica* (88.3 %). The cumulative mean repellency of *C. maculatus* was affected by the dose of the plants' powders over 168 hours (Figure 1). Statistically, a two-way Analysis of variance (ANOVA) showed a significant difference ($P<0.05$) in the concentrations (F = 649.50; P = 7.4×10^{-21}) of the plants' powders and plants' species (F = 5.33; P = 0.002) used, suggesting that plant species' powders and concentrations had significant effects on *C. maculatus* repellency.

Results of the probit analysis for median repellencies (RC_{50}) of *C. maculatus* allowed determining the minimum concentration required to repel 50 % of the weevils as 0.91, 1.05, 1.15, 1.28, 1.09 and 1.39 g concentrations of *C. millenii, Z. officinale, A. sativum, X. aethiopica,* dimethylphthalate and *M. myristica*, respectively; in terms of the weevils mortality (Figure 1). Furthermore, the regression equations of the five plants suggested that the regression repellency (correlation coefficient) of *C. maculatus* and concentration of plants' powders is highly significant ($P<0.001$).

On the other hand, the effect of the different plants' dusts on the pests varied resulting in significant differences ($p<0.05$) in the mean repellency of the pest weevil over the exposure period of 168 hours (Table 2). The repellency ranking of these plants' powders against *C. maculatus*, showed the efficacy of these powders as repellent agents in the following order: *C. millenii* (89.6 %) > *Z. Officinale* (86.2 %) > *A. sativum* (82.5 %) > *X. aethiopica* (82.1 %) > *M. myristica* (76.6 %).

Table 1. Overview of cumulative percentage repellency (Mean ± S.E) of *Callosobruchus maculatus* exposed to 1.0-4.0g plant powders over 168 hours*****

Dose (g)	Plants' Powders/*C. maculatus* repellency					
	C. millenii	*Z. officinale*	*A. sativum*	*X. aethiopica*	Dimethylphthalate	*M. myristica*
0.0	0.04 ± 0.002 (4.0)	0.04 ± 0.002 (4.0)	0.04 ± 0.002 (4.0)	0.04 ± 0.002 (4.0)	0.04 ± 0.002 (4.0)	0.04 ± 0.002 (4.0)
1.0	0.75 ± 0.1 (75.0)	0.7± 0.09 (70.0)	0.73 ± 0.09 (73.3)	0.61 ± 0.07 (61.6)	0.73 ± 0.09 (73.3)	0.6 ± 0.07 (60.0)
2.0	0.91 ± 0.11 (91.6)	0.86 ± 0.11 (86.6)	0.78 ± 0.1 (78.3)	0.83 ± 0.1 (83.3)	0.8 ± 0.1 (80.0)	0.76 ± 0.09 (76.6)
3.0	0.93 ± 0.12 (93.3)	0.91 ± 0.11 (91.6)	0.83 ± 0.11 (83.3)	0.86 ± 0.11 (86.6)	0.86 ± 0.11 (86.6)	0.81 ± 0.1 (81.6)
4.0	0.98 ± 0.12 (98.3)	0.96 ± 0.11 (96.6)	0.95 ± 0.12 (95.0)	0.9 ± 0.11 (90.0)	0.88 ± 0.11 (88.3)	0.88 ± 0.11 (88.3)

*****Each percentage (in parenthesis) is mean of triplicate observations with 20 weevils per replicate

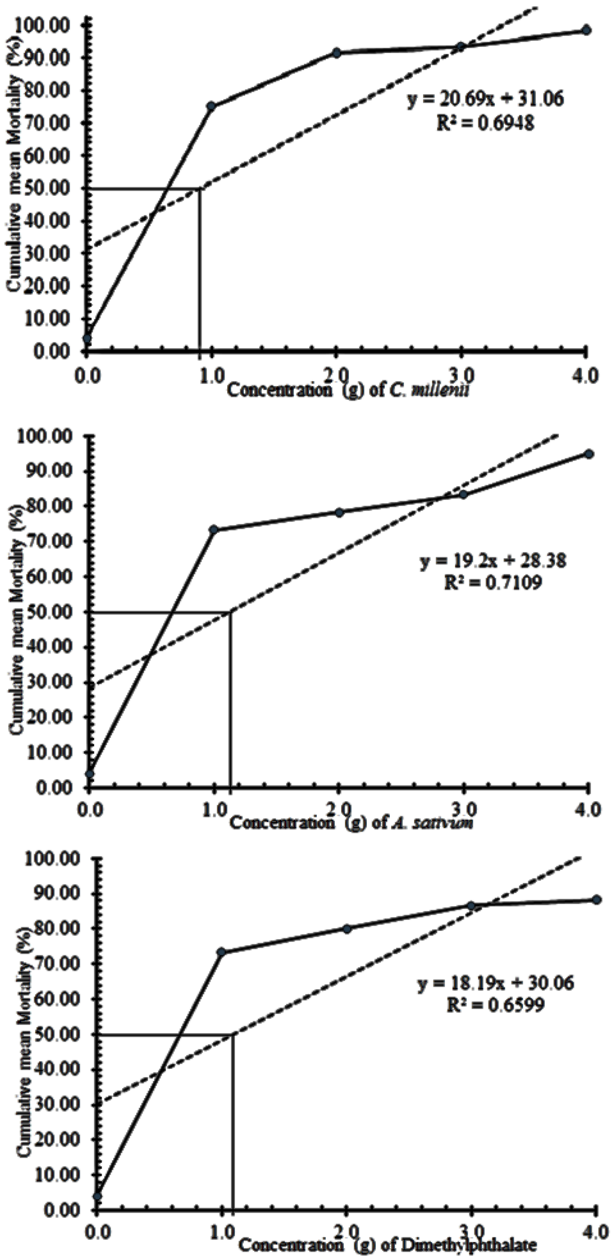

Figure 1. Median cumulative percentage repellency (RC_{50}) of *Callosobruchus maculatus* exposed to five (5) plants' powders at 168 hours post-treatment with regression equations

Table 2. Ranking of repellent potentials of experimental plant powders on *Callosobruchus maculatus* after 168 hours exposure

Plant Powder	Repellency Ranking (%)				
	1st	2nd	3rd	4th	5th
C. millenii	89.6				
Z. officinale		86.2			
A. Sativum			82.5		
X. aethiopica				82.1	
Dimethylphalate				82.1	
M. myristica					76.6

3.2. Repellency of Plants' Extracts

The repellency of *C. maculatus* to the plants' extracts of different concentrations over five hours is indicated in the following trend (Table 3): At 50.mg^{-ml}: *C. millenii* (76.6 %) > *X. aethiopica* (63.3 %) > *Z. officinale* (60.0 %) > *A. sativum* (53.3 %) > *M. myristica* (46.6 %) > Dimethylphthalate (43.3 %) > Control (3.3 %). At 75mg^{-ml}: *C. millenii* (86.6 %) > *X. aethiopica* (80.0 %) > *Z. officinale* (76.6 %) > *A. sativum* (66.6 %) = *M. myristica* > Dimethylphthalate (46.6 %) > Control (3.3 %). At 100.mg^{-ml}*: C. millenii* (90.0 %) > *X. aethiopica* (83.3 %) = *Z. officinale* > *M. myristica* (73.3 %) > *A. sativum* (66.6 %) = Dimethylphthalate > Control (3.3 %). The cumulative mean percentage repellency produced at the lowest (50.0mg^{-ml}) and highest (100. 0mg^{-ml}) extract concentrations against *C. maculatus* five hours after treatment was in the range of 76.6 - 90.0, 63.3 - 83.3, 60.0 - 83.3, 46.6 - 73.3 and 53.3 - 66.6 % for the extracts of *C. millenii, X. aethiopica, Z. officinale, M. myristica* and *A. sativum*, respectively (Table 3). Furthermore, data analysis showed a significant difference (*p<0.05*) in mortality due to the concentrations of plants' extracts (F= 145.36; df = 3; P= $2.62x10^{-11}$) and plants' species (F = 6.51; df = 4; P = 0.0021), suggesting that the concentration and plant species had a significant repellent effect on *C. maculatus*.

Table 3. Survey of cumulative mean percentage repellency of *Callosobruchus maculatus* exposed to different concentrations of plants' extracts 5 hours post-treatment

Conc. (mg^{-ml})	Experimental Plants' Extracts/ Repellency (%)					
	C. millenii	*X. aethiopica*	*Z. officinale*	*M. myristica*	*A. sativum*	Dimethylphthalate
0.0	3.3	3.3	3.3	3.3	3.3	3.3
50.0	76.6	63.3	60.0	46.6	53.3	43.3
75.0	86.6	80.0	76.6	66.6	66.6	46.6
100.0	90.0	83.3	83.3	73.3	66.6	66.6

The mean percentage of the repellency of the plant extracts was in the following decreasing order: *C. millenii* > *Z. officinale* > *X. aethiopica* > *A. sativum* > *M. myristica* versus the Dimethylphthalate and the control of 45.4 % and 3.3 %, respectively. Similarly, the repellency ranking of the plants' extracts (100.0 mg^{-ml}) was in the same order: *C. millenii* > *X. aethiopica* = *Z. officinale* > *M. myristica* > *A. sativum* (Table 4). However, all the extracts were more repellent than dimethylphthalate.

Table 4. Repellency status of plants' extracts in 100 mg^{-ml} treatment of *Callosobruchus maculatus* over 5 hours

Plants' Extracts	Repellency Status (%)				
	1st	2nd	3rd	4th	5th
C. millenii	90.0				
X. aethiopica		83.3			
Z. officinale		83.3			
M. myristica			73.3		
A. Sativum				66.6	

Data analysis showed that 50 % of *C. maculatus* were repelled at the application of 41.30, 47.50, 49.95, 60.05, 60.0 and 74.10 mg^{-ml} concentration of *C. millenii, X. aethiopica, Z. officinale, M. myristica, A. sativum* and dimethylphthalate, respectively (Table 5). Similar to the powder treatments, the correlation coefficients of *C. maculatus* and plants' extracts were highly and positively significant (*P<0.001*).

Table 5. Regression equation, correlation coefficient and median repellency (RC_{50}) of *Callosobruchus maculatus* over 5 hours of plants' extracts treatment

Plants' Extracts	Regression equation	Spearman correlation (r^2)	Correlation (%)	RC_{50}
C. millenii	y = 0.8954x + 13.757	0.8717	87.17	41.30
X. aethiopica	y = 0.8344x + 10.54	0.919	91.90	47.50
Z. officinale	y = 0.8265x + 9.3086	0.9427	94.27	49.95
M. myristica	y = 0.7275x + 6.5257	0.9698	96.98	60.05
A. Sativum	y = 0.6663x + 9.9714	0.8936	89.36	60.40
Dimethylphthalate	y = 0.6091x + 5.6857	0.9622	96.22	74.10

4. Discussion

Plant species having a repellent property prevent pest damage of food like cereals and legumes as well as other valuable substances in storage by rendering them unpalatable or offensive to the pests, thereby, making the pests avoid such materials. The repellent effectiveness of the powder and crude extracts obtained from the tested plants: *A. sativum, C. millenii, M. myristica, X. aethiopica,* and *Z. officinale* against *C. maculatus*, was determined under laboratory conditions using the cup bioassay and filter paper repellency methods. The results of the study indicated that all the plants' dust constituted effective repellents of the insect pest at the doses (1.0 – 4.0 g) and concentrations (50.0 – 100.0mg^{-ml}). Except for *M. myristica*, all the other plants' dust produced a higher percentage repellency values than dimethylphthalate, the standard repellent used in this study. However, the effect of the different plants' dust on the pests varied resulting in significant differences (*p<0.05*) in the mean repellency of the pests over the exposure period of 168 hours. Repellency of the pest increased gradually throughout the test period. The results indicated that the highest repellency of the pest across the plants' types over 168 hours was produced by the highest treatment of 4.0g/200g (Table 1). These findings agreed with the study of Egwunyenga *et al*., (1997) who reported that the powders and crude extracts of alligator pepper (*Aframemum melagueta*) were most repellent against *C. maculatus* at the highest dose of 0.6/20g substrate; this dose approximated to 0.6g/30g substrate in the current study.

The results of this study indicated that the *M. myristica* powder produced the lowest percentage repellency values against *C. maculatus*. *M. myristica* is strongly aromatic in taste (Oparaeke and Dike, 2005) and has a delightful fragrance due to its essential oil consisting mainly of p-cymene (31.5 %), α-phellandrene (18.1 %), α-pinene (6.1 %), and β-piene (5.1 %) (Owolabi *et al.,* 2009). These are terpene hydrocarbons, terpene derivatives, and phenylpropanoid. Despite the possession of these chemical constituents, the *M, myristica* powder was the least repellent. One plausible reason for this phenomenon may be the ease with which nutmeg loses its fragrance when pulverized into dust. It is, therefore, important that the necessary amount of nutmeg powder to be used should be grated from a whole nutmeg and used immediately to prevent loss of potency. Alternatively, it may be expedient to apply nutmeg as a whole undamaged nut instead of grinding, and to use it as powder in order to achieve its full potential as a repellent.

The extracts and powders of *X. aethiopica* in this study ranked second and fourth with respective repellency values of 83.3% and 82.1%. The high repellency values recorded might be attributed to the presence of toxic complex compounds like terpenes and their derivatives (Pérez *et al.,* 2010) among which are terpinen-4-ol, β-pinene, ά-terpineol, sabinene, 1,8-cineole, myrtenol and kaurane derivatives (Ito *et al*., 2018). The toxicity of terpenes in *X. aethiopica* against the *Sitophilus oryzae* (Byung-Ho *et al.,* 2001) and *C. maculatus* (Ito *et al*., 2018) have been documented. Similarly, Keane and Ryan (1999) have established that terpenes' derivatives affect the nervous system of the wax moth (*Galleria melonella*) by inhibiting the enzymatic activities of acetylcholinesterase.

C. millenii was the most superior repellent of *C. maculatus*. This may be attributed to its pungent aroma due to the active chemicals (Sabinene, pinene, camphene among others) in the plant material. The repellent activity of garlic (*A. sativum*) against *C. maculatus* may be ascribed to its various sulphur compounds which are responsible both for garlic pungent odour and many of its pharmacological properties. Garlic contains sulphur compounds and other chemical constituents which may be responsible for the repellency in this study. Negro pepper contains essential oils which consist of beta-pinene, 1,8-cineol and alpha-terpineol (Motheshard, 2009).

The powders and extracts of *Z. officinale* rhizome ranked second after *C. millenii* in terms of repellency against *C. maculatus* at the different concentrations used. The major phytochemicals in *Z. officinale* are α-zingiberene (28.9 %), β-sesquiphellandrene (13.1 %), z-γ-bisabolene (12.5 %) and arcurcumene (11.3 %) (Owolabi *et al*., 2009). The monoterpenoids (R)-linalool and (S)-2-heptanol found in the *Z. officinale* oil extracts and other monoterpenoids and Citral have been shown to be good repellents to *Tribolium castneum* and *Rhyzopertha dominica* (Ukeh and Umoetok, 2011). These chemicals in the test plants may be responsible for the pungent odour that repelled the insect pest. The repellency results of 86.2 % (powder) and 83.3 % (extract) offered by *Z. officinale* in this study are comparable to Ogbonna *et al.* (2016) who found the *Z. officinale* powder and oil to cause a repellency of 100 % to *C. maculatus* after four days at the application of 700 µl/mL. The repellency of insect pests may generally be attributed to the chemosensory effects of plants' secondary metabolites as terpenes which insects take up through their respiratory system (Xie *et al*., 1995).

In this study, *C. maculatus* responded differently to the repellent effects of the plants' products in accordance with its behavioural tendency. The weevil is a fast moving insect (Mohan and Field, 2002). Hassanli *et al*., (1990) reported the effective repulsion of *C. maculatus* to wild basil plant (*Ocimum suave*) one hour after treatment. The high percentage emigration may be attributed to the fast movement of the pest from the substrates.

This current study indicated further that repellency was more dependent on concentration than exposure time. Dose-dependent repellency has been reported by Mohan and Field (2002) and Egwunyenga *et al*., (2000). Furthermore, the repellency of the pests was relatively higher during the first forty-eight hours of exposure, and thereafter, an additional repellency value decreased progressively. This may probably be attributed to the loss of potency due to the vapourization of the active chemicals in plants' products.

5. Conclusion

The use of botanical products prevents several insect pests from infesting stored food products. The five plants tested in this study exhibited varying degrees of repellency against *C. maculatus*. On this basis, local farmers are advised to use these plants' materials to protect cowpea seeds in storage against weevil infestation. Based on the efficacy of the plants used, it is recommended that similar investigations of different plants' species be carried out to further ascertain their efficacy against *C. maculatus* or/and other storage pests. It is, therefore, expedient to control weevil populations to a tolerable limit in storage since a higher bruchid population results in a higher level of stored grain damage.

Acknowledgment

The authors would like to thank the Administration at Delta State University in Abraka, particularly the Department of Animal and Environmental Biology for their constructive criticism. Thanks are also extended to the Tropical Disease Research (TDR) Unit and the Center for Research in Environmental Resources Management (CREMA) for providing facilities, research grants, and enabling environments for this research.

Conflicts of interest:

There are no conflicts of interest.

References

Al-Moajel NH and Al-Fuhaid WL. 2003. Efficacy and persistence of certain plant powders against Khapra beetle, *Trogoderma granarium*. Everts, Fayoum *J Agric Res Dev.,* **17**: 107-114.

Boeke SJ, Baumgart IR, van Loon JJA, van Huis A. 2004. Toxicity and repellence of African plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus. J Stored Prod Res.,* **40(4)**:423-438.

Byung-Ho L, Won-sik C, Sung-Eun L, and Byeoung-Soo P. 2001. Fumigant toxicity of essential oils and their constituent compounds towards the rice weevil, S*itophilus oryzae* (L). *J Crop Protect.*, **20**: 317-320

Caswell GH. 1981. Damage to stored cowpea in the Northern part of Nigeria *Samaru J Agric Res.,* ***1***, 11-19.

Cherry JE, Bantino A, Djegul D and Lomers C. 2005. Suppression of the stem borer *Sesamia catamistis* (Lepidoptera: Noctuidae) in maize following seed dressing, topical application and stem injection with African isolates of *Beauveria bassiana. Int J Pest Mgt.,* **50**: 67-73.

Egwunyenga AO, Nmorsi OPG and Dibie C. 1997. Repellent effects of *Aframemum melagueta* (K) (Anonaceae) to *C. maculatus* (F) (Coleoptera: Bruchidae) *Bull Sci Assoc Nig.,* **21**: 163-166.

Egwunyenga OA, Nmorsi OPG and Alo EB. 2000. Repellency of two pepper varieties to *cowpea weevil* (*Callosobruchus maculatus*). *Nig J Sci & Environ.,* **2**: 69:73.

Ewete F, Nicol RW, Hengsanwad V, Sukumalanand P, Satasook C, Isman MB, Arnason JT. 1996. Insecticidal activity of *Aglaia odorata* extract and the active principle rocaglamide to the corn borer, *Ostrinia nubilalis* Hubn (Lep., Pyralidae). *J Applied Entomol.,* **120**: 483-488.

FAO. 1999. The use of spices and medicinal as bioactive protestant for grains. www.fao.org/docrep/12230c/x2230c05.htm accessed 15-06-18.

Gbaye OA, Millard JC, Holloway GJ. 2011. Legume type and temperature effects on the toxicity of insecticide to the genus *Callosobruchus* (Coleoptera: Bruchidae). *J Stored Prod Res.,* **47**: 8–12.

Hassanli LW, Ole-Sitayo N, Moreka L, Nokoe S and Chapyg S. 1990. Weevil repellent constituents of *Ocimum suave* leaves and *Caryophyllata* cloves used as grain protectants in parts of East Africa. *Discov & Innov.,* **2(2)**: 91-95.

Ito EE and Ighere EJ. 2017a. Bio-insecticidal potency of five plant extracts against cowpea weevil, *Callosobruchus maculatus* (F.), on stored cowpea, *Vigna unguiculata* (L). *Jordan J Biol Sci.,* **10(4)**: 317-322.

Ito EE and Ighere EJ. 2017b. **Basic Entomology and Pest Control**. 1st Ed., University Printing Press, Delta State University Abraka, Nigeria. ISBN: 978-33772-08-12, 361 pp.

Ito EE and Ukpohwo AR. 2018. Termiticidal Efficacy of *Citrus* Peel Extracts against Termites (*Macrotermes bellicosus*). *J Biol Studies,* **1(3)**: 98-105.

Ito EE, Ukpohwo AR and Okiriguo VI. 2018. Insecticidal activity of *Xylopia aethiopica* (Family; Annonaceae) against *Callosobruchus maculatus* (F) (Coleoptera: Bruchidae) and *Sitophilus oryzae* (Coleoptera: Curculionidae). *J Biol Studies,* **1(3)**: 106 – 115.

Ito EE and Utebor EK. 2018. Insecticidal Toxicity of Goat Weed, *Ageratum conyzoides,* Linn. (Asteraceae) on Smoked Fish Weevil, *Dermestes maculatus,* Degeer (Coleoptera: Dermestidae). *Jordan J Biol Sci.,* **11(2)**: 223 – 229.

Jilani G and Su HCF. 1983. Laboratory studies on several plant materials on insect repellants for protection of cereal grains. *J Entomol Soc Am.,* **76(1)**: 154-157.

Keane S and Ryan MF. 1999. Purification, characterization, and inhibition by monoterpenes of acetylcholinesterase from the wax moth, *Galleria mellonella* (L.). Insect Biochem & Mol Biol., **29**:1097–1104.

Kumar PP, Mohan S, and Balasubramanian G. 2004. Effects of whole pea flour and a protein-rich fraction as repellants against stored-product insects. *J Stored Prod Res.,* **40**: 547-552.

McDonald LL, Guy RH and Speirs RD. 1970. Preliminary evaluation of new candidiate materials as toxic, repellants and attractants against stored product insects. *USAD* Mark Rep., 882, 8.

Mohan S and Fields PG. 2002. A simple technique to assess compounds that are repellent or attractive to stored- product insects. *J Stored Prod Res.,* **38***:23-31.*

Motheshard TD. 2009. http/www. Herballegacy.com/ motheshard _chemical.html.

Ofuya TI. 1991. Observations on Insect Infestation and Damage in Cowpea (*Vigna Unguiculata*) Intercropped With Tomato (*Lycopersicon Esculentum*) in a Rain Forest Area of Nigeria. *Exp Agric.,* **27**: 407-412.

Ogbonna CU, Okonkwo NJ, Nwankwo EN, Okeke PC, Ebi SE. 2016. Bioefficacy of *Zingiber officinale* against *Callosobruchus maculatus* Fabricius (Coleoptera: Bruchidae) infesting cowpea. *Intl J Entomol Res.,* **1(4)**: 19-25.

.

Okonkwo EU and Okoye WL. 1996. The efficacy of four seed powders and essential oils as protectants of cowpea and maize grains against infestation by *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) and *Sitophilus zeamais*(Motschulsky) (Coleoptera: Curculionidae) in Nigeria. *Int J Pest Mgt.,* **42***: 143-146.*

Oparaeke AM and Dike MC. 2005. *Monodora myristica* (Gaertn), (Myristicaceae) and *Allium cepa* (Lilliaceae) as protectants against stored cowpea seed Bruchid *(Callosobruchus maculatus)* Infestation. *Nig J Entomol.,* **22**: 84-92.

Owolabi MS, Oladimeji MO, Lajide L, Singh G, Marimuthu P and Isidorov V. 2009. Bioactivity of Three Plant Derived Essential Oils against The Maize Weevils *Sitophilus zeamais* (Motschulsky) and cowpea weevils *Callosobruchus maculatus* (Fabricius). *EJEAFChe,* **8 (9)**: 828-835.

Pérez SG, Ramos-López MA, Zavala-Sánchez MA and Cárdenas-Ortega NC. 2010. Activity of essential oils as a biorational alternative to control coleopteran insects in stored grains. *J Medicinal Plants Res.,* **4(25)**: 2827-2835.

Srivastava KM and Pant JC. 1998. Growth and developmental response of *C. maculatus* (Fabr.) to different pulses. *Indian J Entomol.,* **51**:269-272.

Tanzubil PB. 1991. Control of some insect pests of cowpea *(Vigna unguiculata)* with neem *(Azadirachta indica)* in Northern Ghana. *Trop Pest Mgt.,* **37***:* 216-217

Ukeh DA and Umoetok BA. 2011. Repellent effects of five monoterpenoid odours against *Tribolium casteneum* and *Rhyzopertha dominica* in Calabar, Nigeria. *J Crop Prot.,* **30**:1351-1355.

Uyi OO and Obi BN. 2017. Evaluation of the Repellent and Insecticidal Activities of the Leaf, Stem and Root Powders of Siam weed (*Chromolaena odorata*) against the Cowpea Beetle, *Callosobruchus maculatus. J Appl. Sci. Environ. Mgt.,* **21(3)**: 511-518.

Xie YS, Fields PG, and Isman MB. 1995. Repellency and toxicity of azadirachtin and neem concentrations to three stored product beetles. *J Econ Entomol.,* **88***:* 1024-1031.