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Bioefficacy of *Zingiber officinale* against *Callosobruchus maculatus* Fabricius (Coleoptera: Bruchidae) infesting cowpea

*[1] Ogbonna Confidence U, [2] Okonkwo Nnaemeka J, [3] Nwankwo Edith N, [4] Okeke Peter C, [5] Ebi Sowechi E

[1, 5] Lecturer, Department of Biology/Microbiology/Biotechnology, Federal University Ndufu-Alike Ikwo, Ebonyi, Nigeria
[2, 3] Lecturer, Department of Parasitology and Entomology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
[4] Post graduate Student, Africa Regional Post Graduate Studies in Insect Science, University of Ghana, Legon, Ghana

Abstract

Callosobruchus maculatus Fabricius (Coleoptera: Bruchidae) is an important primary insect pest of cowpea in the store causing considerable damage to the grains. In this study, the bio-activities of *Zingiber officinale* rhizome (Ginger) powder and oil extract were investigated against *C. maculatus*. The powders of *Z. officinale* rhizome was screened in the laboratory against adult *C. maculatus* at different proportions (25%, 20%, 15%, 10% and 5% wt/wt) with Actellic dust insecticide as a reference insecticide. The highest proportion (25% wt/wt) of *Z. officinale* powder was shown to be the most effective, and significantly reducing the survival of *C. maculatus* to 0% after 12 days of treatment. The oil extract of *Z. officinale* at different concentrations (700, 350, 175, 87.5 and 44 µL/mL) and Agricombi insecticide (which is a combination of Fenitrothion (30%) and Fenvalerate (10%)) as the reference was equally evaluated for the following: contact toxicity on adult insect by dipping, residual effect, repellency effect, effect on adult emergence in treated grains and damage to grains. Percentage survival of the insects was significantly reduced at higher concentration of the extracts. There was no survival (0%) recorded at 700 µL/mL of *Z. officinale* oil in dipping and in residual toxicity. Grains treated with the different concentrations of *Z. officinale* oil extracts significantly repelled insects with the highest concentration of 700 µL/mL yielding 100% repellency to *C. maculatus*. The least mean adult emergence of 0.0 was recorded for both 700 µL/mL and 350 µL/mL of the oil extract used against *C. maculatus*. Grains treated with the plant powder and oil extract significantly (P<0.05) reduced damage caused by *C. maculatus* as compared to the untreated grains and gave a better protection to the grains compared to Agricombi insecticide. The present studies therefore indicate that *Z. officinale* powder and oil extracts showed promise in the control of *C. maculatus* in stored cowpea.

Keywords: *Callosobruchus maculatus, Zingiber officinale,* infesting cowpea

1. Introduction

Cowpea is commonly known as black-eye bean, catjang, or bachapin bean (Obeng-Ofori, 2007) [13, 16]. It is known to have originated from the semi-arid areas of West Africa (Tweneboah, 2000) [20]. It is estimated that cowpea is grown on 12.5 million hectares around the world, of this area, about 9.8 million hectares are planted in West Africa, which makes it the region with the largest production and consumption of cowpea in the world with Nigeria as the leading producer (60-65%), followed by Niger and Burkina Faso (Obeng-Ofori, 2007) [13, 16]. In Nigeria, cowpea is seen as a poor man's meat as a result of the high cost of animal protein of the grain legumes grown in Ghana, cowpea is one of the most widely grown but commercial production is restricted to some parts of the Volta, Northern, Upper East, Upper West and Brong-Ahafo regions (Tweneboah, 2000) [20].

However, a wide spectrum of pest attack and destroy cowpea both in the field and in the store causing severe economic damage. Most importantly is the *Callosobruchus maculatus* Fabricius (Coleoptera: Bruchidae) which is a cosmopolitan insect pest of cowpea (Obeng-Ofori, 2008) [14]. Grain damage in the store may reach up to 100% if these insects are not managed (Owusu-Akyaw, 1991) [18]. Umeozor (2005) [23] reported that *C. maculatus* damage to cowpea could range between 10% - 50%. Therefore, to meet the demand of the ever growing population, man has employed several options in order to curb the damaging effect of these insects and hence increase food production. One of the mostly used control measure is the use of synthetic insecticide, but there have been problems associated with their use such as toxicity to man and other non-targeted organism, resistance and problem of residue in food (Ogbonna *et al*., 2014) [15, 17]. Therefore, it has become unavoidable to find substitute that are more ecologically friendly, cheap and easily available also with a high efficacy, hence the use of botanicals (Ogbonna *et al*., 2014) [15, 17].

Ginger root which is commonly called ginger is the rhizome of the plant *Zingiber officinale.* It is mainly cultivated in the tropics from sea level up to 1500 m although it can be grown over diverse conditions compared to most other spices (Obeng-Ofori *et al*., 2007) [13, 16]. The proximate analysis of ginger shows that it contains 80.8% water, 2.3% protein, 1.0% fat, 12.3% carbohydrate, 2.4% fibre and 1.2% ash (Obeng-Ofori *et al*., 2007) [13, 16]. It also contains 1% -3% of volatile oil, which is primarily made up of Sesquiterperne, Zingiberene, and Zingerone, which gives the pungent smell (Obeng-Ofori *et al*., 2007) [13, 16]. Oil extract of ginger have been reported to exhibit toxic and repellent effects on *Prostephanus truncatus* Horn (Ogbonna *et al*., 2014) [15, 17]. Ginger oil has been found to repel *Periplaneta americana* (Linnaeus) and control the growth of *Fusarium moniliforme* Sheldon on mung seed also diarylheptanoid which is a non-volatile constituent of ginger oleoresin have been found to be active against the rice fungus, *Pyricularia oryzae* Cavara

(Ahmad *et al*., 1995) [3]. This paper investigated the effects of *Z. officinale* dust and oil extracts against *C. maculatus* using Actellic dust and Agricombi insecticides (which is a combination of Fenitrothion (30%) and Fenvalerate (10%)) as standard checks in the laboratory.

2. Materials and Methods

Insect culture

The initial stock of *C. maculatus* was obtained from infested cowpea purchased at the Madina market, Accra, Ghana. Untreated cowpea was also bought from the market and sterilized in the oven at 60 °C for 3 hours and allowed to cool for an hour. The adult *C. maculatus* were then introduced into the uninfested (sterilized) cowpea and allowed to oviposite, after which the adults were sieved out. The emerged adults were transferred into another jar of sterilized grains. This was to make sure that the F1 adults used as the culturing stock for the experiment were of uniform size and age. The culture was kept under a temperature of 32 ± 2 °C, 70% relative humidity and 12L: 12D photo regime.

Preparation of *Z. officinale* powder and oil extract

The ginger root was cut in smaller pieces and air dried under shade. The dried ginger was then pulverized with an electric blender to obtain fine powder. The extraction was carried out in the MPhil laboratory of the Chemistry Department, University of Ghana, Legon, Accra. One hundred and fifty grams (150 g) of the plant powder was soaked in a litre of 100% petroleum ether and allowed to stand for a week. This was then filtered off and concentrated using the rotary evaporator. Serial dilution of the plant oil was prepared in acetone. The oil extracts were diluted serially to obtain 70%, 35%, 17.5%, 8.75%, and 4.4% using acetone, thus, yielding 700 µL/mL, 350 µL/mL, 175 µL/mL, 87.5 µL/mL and 44.0 µL/mL of oil per 1 mL aliquot respectively.

Toxicity effect of *Z. officinale* powder on adult *C. maculatus*

Whole cowpea (2 kg each) was weighed separately and sterilized in an oven at 60 °C for 3 hours. Cowpea (100 g each) were put into separate plastic jars and the plant powders admixed in the following proportions 5%, 10%, 15%, 20%, and 25% (Wt (g) of dust/100 g of grains). Actellic dust (Pirimiphos methyl) was used as the reference at the recommended rate of 1000 kg of grains to 500 g of the dust while the control had no plant powders admixed to it. After one hour, 20 of the adult insects were introduced into the treatments (male to female ratio was 1:1). Each treatment was replicated three times. The setup was kept under a temperature of 32 ± 2 °C, 70% relative humidity and 12L: 12D photo regime in the laboratory. Mortality was recorded daily for 12 days starting from 24 hours after treatment. This was done by putting the set up in the refrigerator at 4 °C before sieving out the insect from the set ups for counting. This was to reduce the flight action of the insect. An insect was considered dead if it does not respond to probing using a blunt probe.

Toxicity effect of *Z. officinale* oil extracts on adult *C. maculatus*

Adult *C. maculatus* (20 each) was placed in petri dishes lined with filter paper. The insects were then dipped in turns into the different concentrations of the extracts prepared (700 µL/mL, 350 µL/mL, 175 µL/mL, 87.5 µL/mL and 44.0 µL/mL) and transferred back into the petri dishes. Agricombi insecticide (which is a combination of Fenitrothion (30%) and Fenvalerate (10%) was used as the reference at the recommended concentration of 20 mL/L of water while acetone alone was used as the control. Each treatment was replicated three times and the set up kept under the temperature of 32 ± 2 °C, 70% relative humidity and 12L: 12D photo regime. Mortalities were recorded after 24 hours. Insect were considered dead if they do not respond to probing using a blunt probe.

Repellent effect of the plant extracts

The method used by Ogbonna *et al*. (2014) [15, 17] was adopted. Filter paper disc was cut into small hexagonal shapes which were large enough to contain 4 cowpea seeds. Four of these small cut filter papers were placed at equidistance from each other on a petri dish with 4 whole sterilized grains placed on each filter paper in the dish. With the use of a syringe, two of the filter papers with the grains were carefully treated with each concentration of the oil extracts while the other two filter papers were treated with acetone as the control. Agricombi insecticide was also used as the reference insecticide. The treatments were air-dried for 48 hours to avoid the direct contact of the insect with the treatments. Adult *C. maculatus* (20) were then introduced at the centre of each petri dish after chilling them in the refrigerator at 4 °C for 5 min and covered. Each of the treatments was replicated three times. The treatments were kept in the dark at a temperature of 32 ± 2 °C and 70% relative humidity. Adult insects on treated and untreated portions of the filter papers were counted after 24 hours for 4 days. The percentage repellency (PR) was determined using the formula adopted by Ogbonna *et al.*, (2014) [15, 17]. PR= [(Nc – Nt) / Nc + Nt)] × 100%. Where: Nc- Number of insect pests on control and Nt- Number of insects on the extracts sides.

Effect of *Z. officinale* oil extracts on *C. maculatus* adult emergence

The effect of extracts on progeny development and adult emergence was determined by adopting the method used by Ogbonna *et al.* (2014) [15, 17]. Grains of 100 g each were weighed and put into separate plastic jars. This was then infested with 50 unsexed adults of *C. maculatus* (at the ratio of 1:1 male to female). The set up was allowed to stand in the lab for 2 weeks to allow for oviposition. Then the set up was treated with the different concentrations of the plant extracts (700 µL/mL, 350 µL/mL, 175 µL/mL, 87.5 µL/mL and 44.0 µL/mL). The setup was monitored for 25 days for larval and pupal development (Obeng-Ofori, 2008) [14] at temperature of 32 ± 2 °C and 70% relative humidity. Agricombi insecticide was used as the reference while acetone was used as the control. Each treatment was replicated three times. The number of adults that emerged after the 25 day period were counted and recorded.

Damage assessment

After mortality count in both the grains treated with the powder and oil extract was done, the set up was left to stand for 25 days before damage assessment was done, since the damage was not caused by the adult insect introduced but by the larval stage (Beck and Blumer, 2007) [4]. This was done by separately counting the number of damaged and undamaged grains in the setup of treated cowpea. Damage was assessed using the method of FAO (1985) [9] which is as follows: % Weight loss = [(UNd – DNu) / U (Nd + Nu)] × 100%. Where U = Weight of undamaged grains; D = Weight of damaged grains; Nd = Number of damaged grains and Nu = Number of undamaged grains.

Data collection and Analysis

The data collected was analyzed using Gen Stat Package 9.2 (9th edition). Analysis of Variance was run at 95% confidence level. Percentage survival was calculated and control mortality was also corrected using Abbott's formula: [(No of Survival in control – No of Survival in treatment)/ (No of survival in control)] X 100 (Abbott, 1925) [1].

3. Results

Toxicity of *Z. officinale* powders against *C. maculatus*

The different concentrations used showed various levels of toxicity against adult *C. maculatus.* The powder of *Z. officinale* resulted in no survival at 25% and 20% of the dust, after 12 days of exposure while the lowest concentration of 5% gave a survival of 40.7% to *C. maculatus*. Actellic dust treatment resulted in no survival to *C. maculatus* while the control resulted in 100% survival of the insects. Insects treated with *Z. officinale* powder had a significantly lower (P<0.001) survival compared to the control (Figure 1).

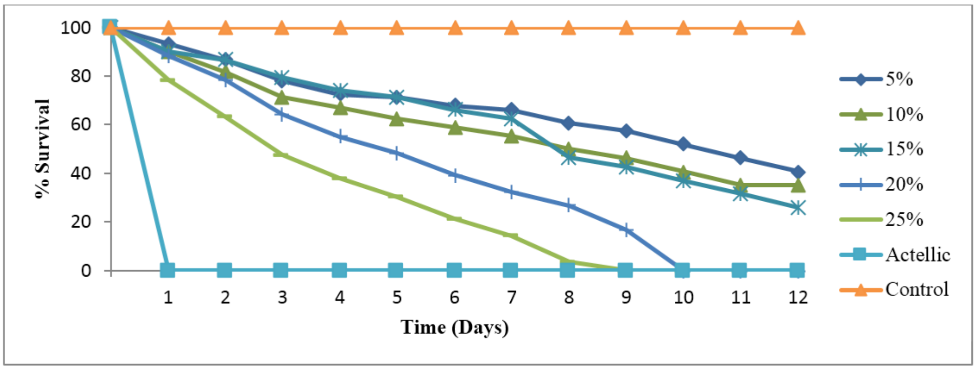

Fig 1: Percentage survival of adult *C. maculatus* treated with different concentrations of *Z. officinale* rhizome powder.

Contact toxicity of oil extracts of the *Z. officinale* to *C. maculatus*

Generally, percentage survival of the insects reduced as the concentration of each treatment increased. *Zingiber officinale* oil at 700 µL/mL and 350 µL/mL had no survival (0%) recorded after 4 days. The lowest concentration of 44 µL/mL of *Z. officinale* oil resulted to 69.5% survival of *C. maculatus*. Agricombi insecticide recorded no survival (0%) to *C. maculatus* while 100% survival was recorded in the control after 4 days. *Zingiber officinale* oil showed a significant (P<0.001) lower survival of the insects compared to the control (Figure 2).

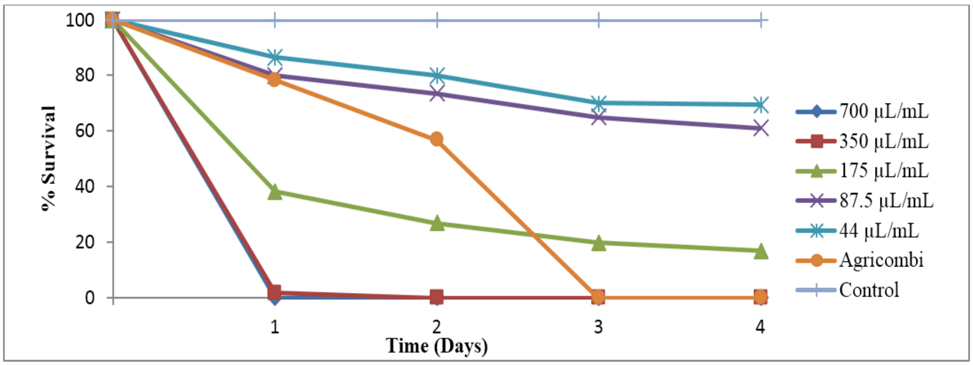

Fig 2: Percentage survival of adult *C. maculatus* treated with different concentrations of *Z. officinale* rhizome oil.

Residual effect of oil extracts of *Z. officinale* on adult *C. maculatus* in treated grains

The highest concentration of 700 µL/mL of *Z. officinale* oil resulted in no survival (0%) of *C. maculatus* after the second day while the lowest Concentration of 44µL/mL gave a survival of 85% to *C. maculatus* after the twelfth day. Agricombi insecticide gave 0% survival to *C. maculatus* while 100% survival was recorded for the control after 12 days. There was a significant (P<0.001) lower survival of insects in grains treated with *Z. officinale* oil compared to the control (Figure 3).

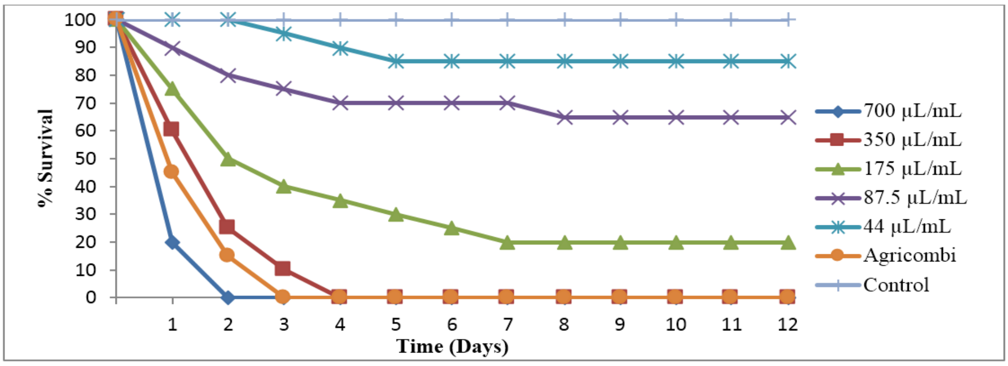

Fig 3: Percentage survival of adult *C. maculatus* in cowpea grains treated with different concentrations of *Z. officinale* rhizome oil.

Repellent effect of *Z. officinale* oil extracts on adult *C. maculatus*

At the highest concentration of 700 µL/mL, *Z. officinale* oil, gave a mean repellency of 100% to *C. maculatus* after 4 days while the lowest concentration of 44 µL/mL gave a repellency of 58.7%. Agricombi insecticide recorded repellency of 95.24%. The highest concentration of 700 µL/mL significantly (P<0.001) repelled more of the insect compared the lowest concentration of 44 µL/mL (Table 1).

Table 1: Mean percentage repellency of *Z. officinale* rhizome oil against *C. maculatus*

Conc. (µl/ml)	% Repellency Time (Days)				Mean % Repellence ± SE
	1	2	3	4	
700	100	100	100	100	100.00±0.00
350	100	100	100	89.47	97.37±6.63
175	90	78.95	70	70	77.24±4.75
87.5	88.89	87.5	70	52.94	74.83±8.47
44	66.67	70	50	48.2	58.72±5.61
Agricombi	100	100	100	80.95	95.24±4.76

LSD (P<0.001) 15.45

Effect of *Z. officinale* oil extracts on adult emergence of *C. maculatus*

There was no emergence of adult *C. maculatus* in grains treated with 700 µL/mL, 350 µL/mL and 175 µL/mL concentrations of *Z. officinale* oil. At the least concentration of 44 µL/mL there was an emergence of 6.3 adults. Agricombi insecticide recorded no emergence while the control recorded the highest emergence of 131.3 adult *C. maculatus*. The numbers of adult emergence for grains treated with the plant extracts were significantly (P<0.001) lower compared to the control (Table 2).

Table 2: Mean adult emergence of *C. maculatus* in grains treated with *Z. officinale* rhizome oil.

Conc. (µl/ml)	No of adult emergence			Mean Adult emergence± SE
	R_1	R_2	R_3	
700	0.00	0.00	0.00	0.00± 0.00
350	0.00	0.00	0.00	0.00 ± 0.00
175	0.00	0.00	0.00	0.00 ± 0.00
87.5	0.00	0.00	0.00	0.00 ± 0.00
44	6.00	5.00	8.00	6.30 ± 0.90
0.00 (control)	110.00	120.00	164.00	131.33 ± 16.59
Agricombi	0.00	0.00	0.00	0.00±0.00

LSD (P<0.001) 7.03

Damage assessment of grains treated with *Z. officinale* powders

Grains treated with *Z. officinale* powder recorded the lowest percentage weight loss of 0.0%, when 25% of the powder was admixed with the grain infested with adult *C. maculatus* while the lowest concentration of 5% gave percentage weight loss of 1.5%. Actellic (Pirimiphos-methyl) dust recorded no percentage weight loss while the highest percentage weight loss of 2.6% was recorded in the control. Grains treated with the *Z. officinale* rhizome powder significantly (P<0.001) reduced damage caused by *C. maculatus* compared to the untreated grains (Table 3).

Table 3: Mean percentage weight loss of cowpea treated with *Z. officinale* powder after 12 days of exposure to *C. maculatus.*

Concs. (wt/wt)	% Damage				Mean % Damage ± SE
	R_1	R_2	R_3		
25%	0.00	0.00	0.00		0.00 ± 0.00
20%	0.10	0.20	0.00		0.10 ± 0.06
15%	0.30	0.40	0.50		0.40 ± 0.06
10%	1.10	0.90	1.90		1.30 ± 0.31
5%	1.40	1.70	1.40		1.50 ± 0.10
0.0 (control)	2.50	2.70	2.60		2.60 ± 0.06
Actellic	0.00	0.00	0.00		0.00±0.00

LSD (P<0.001) 0.19

Damage assessment of grains treated with *Z. officinale* oil extracts

There was no damage to cowpea grains treated with 700 µL/mL, 350 µL/mL and 175 µL/mL of *Z. officinale* oil while the lowest concentration of 44 µL/mL gave only 0.2% damage to the seeds compared to the control where damage of 2.0% was recorded. Grains treated with Agricombi insecticide had no damage recorded. Grains treated with *Z. officinale* rhizome oil extracts significantly (P<0.001) reduced damage caused by *C. maculatus* compared to the untreated grains (Table 4).

Table 4: Mean percentage weight loss of cowpea treated with *Z. officinale* oil extract after 4 days of exposure to *C. maculatus.*

Conc. (µl/ml)	% Damage			Mean % Damage ± SE
	R_1	R_2	R_3	
700	0.00	0.00	0.00	0.00 ± 0.00
350	0.00	0.00	0.00	0.00 ± 0.00
175	0.00	0.00	0.00	0.00 ± 0.00
87.5	0.10	0.20	0.00	0.10 ± 0.06
44	0.20	0.30	0.10	0.20 ± 0.06
0.0	1.80	2.00	2.20	2.00 ± 0.16
Agricombi	0.00	0.00	0.00	0.00±0.00

LSD (P<0.001) 0.04

4. Discussion

Toxicity of *Z. officinale* powder

The powder of *Z. officinale* exhibited various levels of toxicity against adult *C. maculatus*. In a work done by Nwankwo *et al*. (2015) [11], where *Moringa oleifera* and *Annona muricata* seed oil extracts was assayed against the larvae of *Aedes aegypti* mosquitoe, it was reported that they were both effective against the insect, which suggest the presence of some toxic substances found in some plant parts which might equally be present in *Z. officinale* rhizome. Also the abrasive nature of *Z. officinale* powder used might have equally contributed to the lower percentage survival recorded against *C. maculatus* as inert dust and sand works on same principle. This is consistent with a similar study by Ogbonna *et al.* (2014) [15, 17] where *Z. officinale* powder was used against *P. truncatus* and 100% mortality was recorded at the same concentration of 25% after 12 days of exposure. As expected Actellic dust gave no survival after 24 hours. This was not so compared to the botanicals used because Actellic dust is a synthetic organophosphate insecticide which already have the active ingredient in a very high concentration.

Contact toxicity of *Z. officinale* oil extracts against *C. maculatus*

The result showed that increase in concentrations of *Z. officinale* rhizome oil extracts led to a significant decrease in survival of the insects and this is consistent with studies by Nwankwo *et al.* (2016) [12], Ogbonna *et al.* (2014) [15, 17], and Okonkwo *et al.* (2014). Also the low survival level observed with increase in the concentration of the oil extracts is suggestive of the fact that higher concentrations contain higher level of the active substance.

In a study by Ogbonna *et al.* (2012) where toxicity of *Z. officicale* oil was assayed against *P. truncatus* adult, it was shown that at concentration of 700 µL/ml, 100% mortality was recorded after 24 hours. Also it was suggested that sesquiterpenes hydrocarbon which is one of the constituents of *Z. officinale* oil might be responsible for the death of the insect since it has a pungent odour while Agarwal *et al.* (2001) [2], indicated that *Z. officinale* oil was effective against the larvae of *Spilosoma obliqua* where it was established that curcumene was a major volatile heat labile constituent of the oil. This may account for the reduced survival observed when the oil was used against adult *C. maculatus*. Comparing this present work with that done by Ogbonna *et al.* (2014) [15, 17] where *Z. officinale* oil extract was assayed against adult *P. truncatus* at the same concentrations, It was observed that at the same concentration of the oils, *C. maculatus* recorded a lower percentage survival than *P. truncatus*. This could be due to the differences in the level of penetration of the oils in these insects, as it could be said that *C. maculatus* is more susceptible than *P. truncatus.*

Residual effect of plant oil extracts of *Z. officinale* on adult *C. maculatus* in treated grains.

The different concentrations of oil extracts of *Z. officinale* oil led to decrease in the survival of adult *C. maculatus* this may be attributed to the toxicant, antifeedant and repellent effect of the extracts. Also comparing this present study with that done by Ogbonna *et al.*, (2014) [15, 17] where same oil extract and at same concentrations was assayed against *P. truncatus*. It was shown that *C. maculatus* was more susceptible to *P. truncatus*. This is consistent with the work done by Nyamador *et al*. (2010) [10], where *Cymbopogon nardus* oil was used against *C. maculatus* and *C. subinnotatus* and it was observed that at 40 µL/L of the oil, 47.5% mortality was recorded for *C. maculatus* while 10% mortality was recorded for *C. subinnotatus* which was concluded that *C. maculatus* is more susceptible than *C. subinnotatus.* Also the low percentage survival recorded when *Z. officinale* oil was treated on the grains showed that the active substance in plant extracts is high and can stick to the grains at a lethal dose since after treatment the grains were air dried for 3 hours and only 2 mL of each concentration was used for the treatment. This suggest that a lower survival may have been recorded if introduction of adult insects where done immediately after treatment (that is without air drying) and if more than 2 mL of each concentration was used for the treatment of the grains.

Repellency of oil extracts of *Z. officinale* rhizome to C. maculatus

The oil extracts of *Z. officinale* rhizome were repellent to *C. maculatus* at the different concentrations used. This is an indication of the presence of chemical substances contained in the plants that makes the insect move away from the source of the stimulus. This is in agreement with the work done by Ogbonna *et al.* (2014) [15, 17] where *Z. officinale* oil was shown to repel adult *P. truncatus.* (R)-linalool and (S)-2-heptanol monoterpenoids found in *Z. officinale* oil extracts and other monoterpenoids and Citral have been found to be good repellents to *T. castneum* and *R. dominica* (Ukeh and Umoetok, 2011) [21] and these may account for the repellency observed in the results. This is consistent with the work done by Boeke *et al.* (2004), where the slurries of *C. papaya* were found to be repellent on *C. maculatus.*

Effect of oil extract of *Z. officinale* on progeny and adult emergence of *C. maculatus*

It was observed that the different concentrations of the plant oil extract reduced significantly the rate of adult *C. maculatus* that emerged. Generally, the higher the concentrations of the oil used the lower the number of insects that emerged. This is a further confirmation of the fact that the higher the concentration, the higher the presence of the toxic substance which is capable of inhibiting oviposition and progeny development in the stored grains. This is also consistent with the work done by Ukeh *et al*. (2012) [22] where it was observed that different plant extracts contain substances at higher concentrations that is able to reduce the emergence of adult *S. zeamais* significantly. Comparing this study with that done by Ogbonna *et al.* (2014) [15, 17] where same *Z. officinale* rhizome oil was used with the same concentrations against *P. truncatus.*

It showed that the plant oil extract at the various concentrations had more toxic or inhibitory effect on the immature stages of *C. maculatus* compared to *P. truncatus.* This can be as a result of the different oviposition life style of the different insects where female *P. truncatus* normally deposits most of its eggs within the grain in blind ended chambers bored at right angles to the main tunnel and covered with finely chewed maize dust (Bell and Watters, 1982) [5] while *C. maculatus* attaches its eggs on the surface of the grain (Raina, 1970) [19]. Thus the treatments could have had more direct contact with the majority of eggs of *C. maculatus* compared to that of *P. truncatus* which resulted in the lower emergence of *C. maculatus* adult compared to that of *P. truncatus.* Also it could equally mean that the eggs of *C. maculatus* are more susceptible compared to the eggs of *P. truncatus.*

Damage assessment of grains treated with powder and oil extracts of *Z. officinale*

Grain damaged caused by *C. maculatus* was significantly reduced both in the powder and oil extract treatments. The result showed that at higher treatment of the powder and the oil extract, damaged caused by the insects were significantly reduced. This may be due to the low survival and high repellency observed in the treatment. This is consistent with the work done by Ukeh *et al*. (2012) [22] where *Aframomum melegueta* (Alligator pepper) *and Z. officinale* (ginger) significantly reduced the damage caused by *S. zeamais* in traditional African granaries. Since most damage caused in cowpea by *C. maculatus* is done by the larva stage (Beck and Blumer, 2007) [4]. The results of both powder and oil extracts of the plants against *C. maculatus* then implies that, the plant products were able to deter female *C. maculatus* from ovipositing or in the case of oviposition, had significantly reduced progeny development on the grains. This is in agreement with the work done by Eltayeb (2000) [8] where 0.1% crude extract of nine botanicals significantly reduced oviposition and progeny development of *C. maculatus* on stored cowpea. Both plant powder and oil extract also acted as feeding deterrents as this is evident in the reduced damage caused by *C. maculatus* in the treated grains. This is also consistent with the work done by Demissie *et al*. (2008) [7] and Tapondjou *et al*. (2002), where Noug oil, soybean oil and *Chenopodium ambrosiodes* powder and oil extract significantly reduced the damage caused by *S. zeamais* and *P. truncatus* in stored maize grains. This study have clearly shown that both powder and oil extract of *Z. officinale* rhizome were able to offer protection to grains against damage caused by *C. maculatus* just like the standard (Actellic dust and Agricombi Insecticide respectively) commonly used in Ghana.

5. Acknowledgements

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