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Ojianwuna. C. Cynthia
Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria

Olisedeme Precious
Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria

Ossai. S. Lynda
Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria

Correspondence
Ojianwuna. C. Cynthia
Department of Animal and Environmental Biology, Delta State University, Abraka, Delta State, Nigeria

The toxicity and repellency of some plant extracts applied as individual and mixed extracts against termites (*Macrotermes bellicosus)*

Ojianwuna. C. Cynthia, Olisedeme Precious, Ossai. S. Lynda

Abstract
Study was conducted to evaluate the toxicity and repellency of *Zingiber officinale, Allium sativum, Dennettia tripetala and Capsicum annuum* applied as individual and mixed extracts against termites (*M. bellicocus*) under laboratory and field conditions in Abraka. The experiment was replicated trice with 0.21% Diazinon (a synthetic insecticide) and distilled water as a standard check and untreated control respectively. The result revealed that as concentration of all plant extracts increased, mortality was significant (p< 0.05) after 72hours of exposure. The mixture of *Z. officinale* + *A. sativum* was most toxic having the least LC_{50} of 7.41mgL-1, LT_{50} of 34hrs and a repellency value of 88.89%. Extracts of *C. annuum, D. tripitala, A.sativum* and their mixtures were very effective against termites after 30 days of post treatment in the field because the termitaria were not rebuilt. However, the efficacy of the extract of *Z. officinale* applied singly against termites was slightly reduced after 24 days of post application. All plant botanicals maybe used as plant termiticides as they are readily available and cheap to purchase.

Keywords: *Macrotermes,* Extracts, *Zingiber, Capsicum, Allium, Dennettia*

Introduction
Termites of the *Macrotermes* species are members of fungus-growing sub-family of macrotermitinae. They are mostly mound builders and are one of the largest termite species [1, 2]. This species of macrotermes is one of the most important agricultural, forestry and household pest. It has been reported that *Macrotermes* cause serious damage (100% loss) to agricultural crops such as maize, sugarcane, millets rice, yam and groundnuts and various domestic wooden products such as furniture and farm structures [3, 4, 2]. In some parts of Africa, such as East Africa, *Macrotermes* cause yield loss of 30-60% [3, 2], the loss caused on various crops and tree species due to termites vary ranging from 50-100% [5, 4, 2]. In Nigeria, reports from Mokwa, Lokoja, Onisha and Aba showed yield losses in yams as a result of soil pests and only termites *Macrotermes* species caused 29% of the crop damage [6]. The nuisance caused by termites are enormous, therefore there is need for the control of these pests. The control of termite could either be the use of chemical (synthetic insecticides) or non-chemical methods [7]. The use of synthetic insecticides in the control of termites is known to cause aquatic and environmental pollution, lethal effect on non-target organism [8]. Plant extracts on insect pest are being manifested in several ways, these includes altering the behaviour of the insect, growth retardation, toxicity, oviposition deterrence, feeding inhibition and reduction of fecundity and fertility [9-8]. In essence, plant extracts can be used as insecticides, insect-repellants, antifeedant, insect growth and development regulators [15-8]. Over the years, there has been a renewed interest in the use of various plant extracts on termites but information on the use of plant extracts in combined equal proportions against termites is scanty. In accordance within the above benefits of the use of botanicals initiated the objective of evaluating the toxicity and repellency of some plants extracts; Ginger (*Zingiber officinale*), Red pepper (*Capsicum annuum*), Pepper fruit *(Dennettia tripetala*) and Garlic (*Allium sativum*) applied as individuals and their various mixtures in equal proportions against termites.

Materials and Methods
Description of Experimental Area
The present research was carried out within the period of September to November, 2015 in the laboratory of the Department of Animal and Environmental Biology and on field, Delta State University Abraka, Delta State. The study area was located in the campus (Site 3).

Source of plant materials

Four locally available plant materials were bought from Abraka main market, in Ethiope East Local Government Area, Delta State. The plant botanicals were identified by a taxonomist in the Department of Botany as; *Z. officinale* (ginger) [rhizome], *C. annuum* (red pepper) [fruit], *D. tripetala* (pepper fruit) [fruit] and *A. sativum* (garlic) [cloves].

Preparation of extracts

The plant materials were chopped into bits and air dried for four weeks. They were grinded with micro plant grinding machine and were sieved through a 0.25mm pore size to obtain a uniform fine dust particle [16, 17, 2]. The resulting powders were stored in separate containers with screw cap at room temperature prior to use. The amount of powder mixed with the 100ml of water were calculated on weight by volume, ie: weight of powder/volume of water 10, 20, 30g of each grinded plant materials were soaked in 100ml of water to obtain crude extracts of three concentration levels of 10, 20 and 30% (w/v). Each mixture was filtered with cheese cloth after 24 hours.

Collection and establishment of test organism

Population of termites was collected from a termitarium at the main campus (Site 3). Termite mound was dug up using shovel and soil containing termites was put on plastic sheets. Termites were collected from the plastic sheets using camel hair brush and placed in plastic containers as described by [2]. Termites were fed with dry wood inside the container and the top of the container was covered with muslin cloth to allow free flow of air also to prevent the termites from escaping. The containers carrying the termites were carried to the laboratory of Animal and Environmental Biology and placed in a cool dark area until needed.

Bioassay procedures for botanical toxicity

The prepared plant extracts were weighed and taken into containers containing 100ml of sterile distilled water. The containers containing the botanical powder were shaken thoroughly for about 5minutes to ensure uniform distribution of the solute. Whatman No. 1 filter paper was placed in each Petri dish and treated with 2ml of each plant extract. 20 worker termites were randomly selected from stock population and kept into the Petri dish containing the treated filter papers. Each treatment was tested at 3 concentration (10, 20, 30% cw/v). The experiment was replicated thrice and in all the setup, 0.21% of Diazinon and water served as a standard check and negative control respectively. Mortality of termite was recorded at 24hour interval for 72 hours post treatment application. A mixture of the two plant extracts: Ginger + Red pepper, Ginger + Garlic, Garlic + Pepper fruit in a 50:50 ratio was also made and thoroughly shaken for 5 minutes to ensure uniform distribution of the solvent. The experiment was conducted under laboratory condition (25 ^{0}C and 60 – 70% RH) (This method was adopted from [2] with slight modification).

Life and dead termites were counted and percentage mortality was calculated according to the following equation;

$$\text{Percentage mortality} = \frac{\text{No of dead termite}}{\text{Total no of termite}} \times \frac{100}{1}$$

Termite repellency test due to plant extracts

Three solutions of (10, 20, 30g/mL) for each botanical extracts were prepared. Petri dish having whatman No 1 filter paper with a 9cm diameter was cut into two equal parts (half part was treated and the remaining half part was left untreated). Treated portion consist of plant extract treated filter paper and untreated part contain distilled water and placed about 2cm apart from each other in Petri dishes. Twenty termites were introduced at the centre of both treated and untreated filter paper. The petri dishes with termites were placed in darkness in order to minimize the effect of light on the termites. The experiment was replicated thrice. The number of termites on both treated and untreated filter paper were counted 30 minutes post application. Based on the number of termites which stayed on the extract-treated filter paper, repellency was determined. Percentage repellency was calculated using the equation [1];

$$\text{Repellency x in (\%)} = \frac{C\text{-}T}{C} \times \frac{100}{1}$$

Where C = No of termites collected from the untreated filter paper

T = No of termites collected from the treated filter paper

Field study

The field trial of the plant extracts was conducted on seven field locations at the Delta State University Campus (Site 3) Abraka. Each of the termitarium was scraped to expose the termites to the application of the extracts. 300g of *Z. officinale*, *C.annuum, A. sativum, D. tripetala* and their mixtures were mixed in 2000ml (2 liters) of water separately. The extracts were poured into the different termitaria and left for 30days. This was to observe if the termitaria would be rebuilt [1].

Statistical Analysis

The data recorded for different response variables in the study were analyzed statistically using SARS for analysis of variance (ANOVA) and descriptive statistics. Data collected was subjected to probit analysis to determine the median lethal concentration and median lethal time [17].

Results

The result of the experiment conducted to assess the efficacy of four locally available plant and their mixtures at different concentrations exposed for 72 hours against termites are presented under different sub-titles as follows;

Efficacy of Plant Extracts against Termites; *M. Bellicocus*

The insecticidal effects (mortality) of the plant materials applied as individual and mixed extracts on the insects showed significant difference (p<0.05) as the concentration increased from 10-30% concentration also there was significant difference (p<0.05) in the mortality of the insects as the time of exposure increased from 24-72 hrs. From table 1 below, the highest mortality among the plant extracts was *Z. officinale* + *A. sativum* at concentration after 72hrs of treatments. On the contrary, zero mortality was observed for the negative control (distilled water).

Table 1: Percentage mortality and probit mortality of macroternes spp exposed for24-72 hours to the toxicity of *Z. officinale*, *C. annuum, A. sativum*, and mixture of *Z. officinale and C.annuum* in 10-30% concentration.

Gram conc. of botanicals	Log conc.	Total number of termites	Botanicals	Exposure periods (hours)			Total number of dead termites	% mortality	Probit mortality
				24	48	72			
10	1.00	20	*Z. officinale*	4	3	1	8	40	4.75
		20	*A. sativum*	2	2	1	5	25	4.48
		20	*D. tripetala*	3	2	1	6	30	4.48
		20	*C. annuum*	7	2	1	10	50	5
		20	*Z. officinale + A.sativum*	7	3	2	12	60	5.25
		20	*Z.officinale +C. annuum*	4	1	2	7	35	4.61
		20	*A. Sativum +D. tripetala*	5	2	1	8	40	4.75
20	1.3010	20	*Z. officinale*	7	5	0	12	60	5.25
		20	*A. sativum*	7	1	1	9	45	4.85
		20	*D. tripetala*	7	2	1	10	50	5
		20	*C. annuum*	12	5	2	19	95	6.64
		20	*Z.officinale +C. annuum*	13	5	2	20	100	7.37
		20	*Z.officinale + A.sativum*	10	2	2	14	70	5.52
		20	*A. Satium +D.tripetala*	8	1	1	10	50	5
30	1.4771	20	*Z. officinale*	10	4	1	15	75	5.67
		20	*A. sativum*	9	2	2	13	65	5.36
		20	*D. tripetala*	10	3	1	14	70	5.52
		20	*C. annuum*	14	4	2	20	100	7.37
		20	*Z.officinale + A.sativum*	15	5	-	20	100	7.37
		20	*Z. ofcinale + C. annuum*	10	4	4	18	90	6.28
		20	*A. Satium + D.tripetala*	12	2	1	15	75	5.67
0.21	-0.6778	20	Diazinon	20	0	0	0	100	7.37
2ml		20	Distilled	0	0	0	0	0	0

Determination of Median Lethal Concentration LC50 for Each Plant Extract

The results for the probit analysis for median lethal concentration (LC_{50}) on the mortality of termite are presented in fig1-8. Minimum concentration required to kill 50% of the test organism (termites) was determined for each extract. The LC_{50} value for all plant extracts after treatment indicated that the mixture of *Z. officinale* + *A. sativum* (7.41mgL-1) (fig6) was the most toxic at minimum concentration. *D. tripetala* (20.0mgL- 1) (fig1) was the least toxic extract at the least concentration.

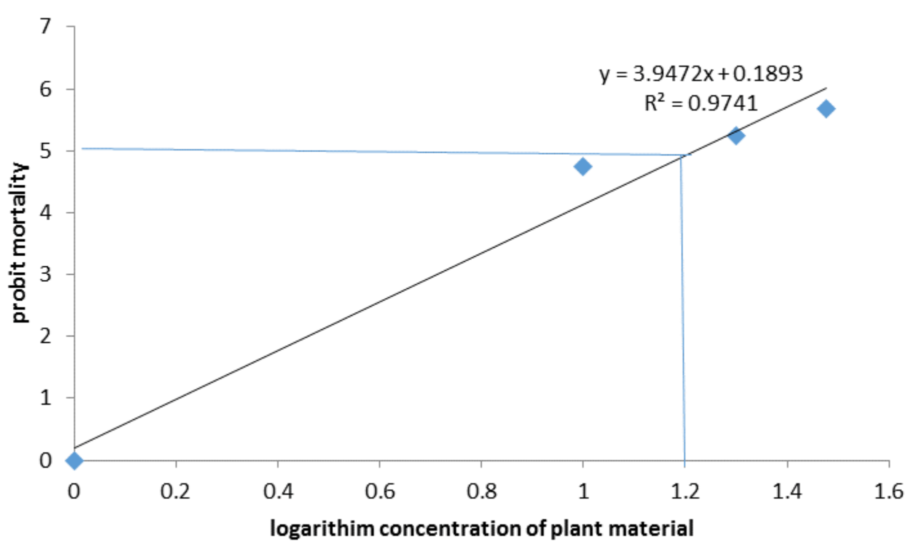

Fig 1: The relationship between mortality and logarithm of concentration of *Z. officinale* to give mgL-1 (antilog) at LC_{50}.

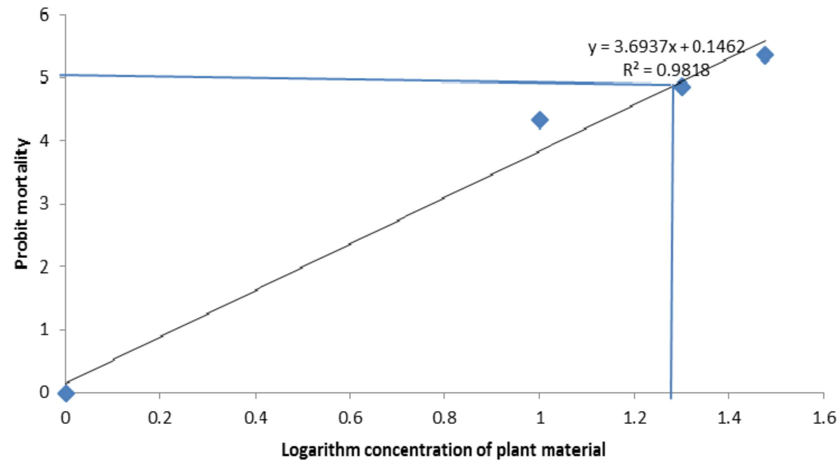

Fig 2: The relationship between mortality and logarithm of concentration of *A. sativum* to give mgL-1 (antilog) at LC_{50}.

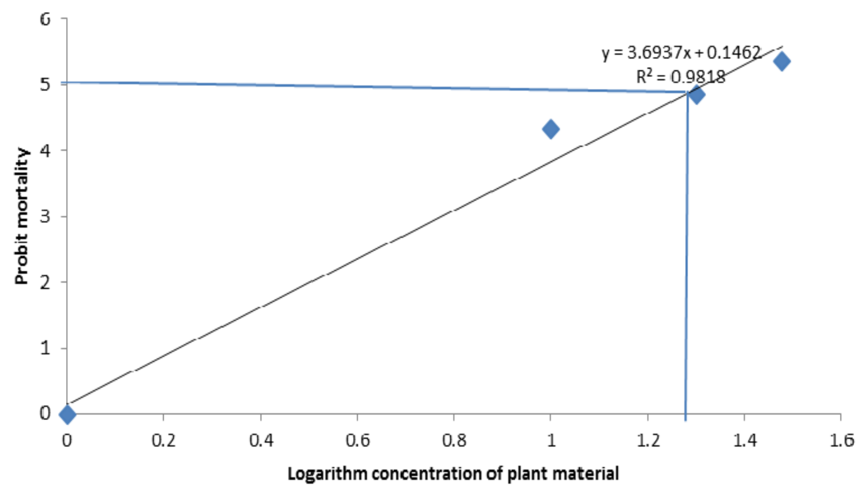

Fig 3: The relationship between mortality and logarithm of concentration of *D. tripetala* to give mgL-1 (antilog) at LC_{50}.

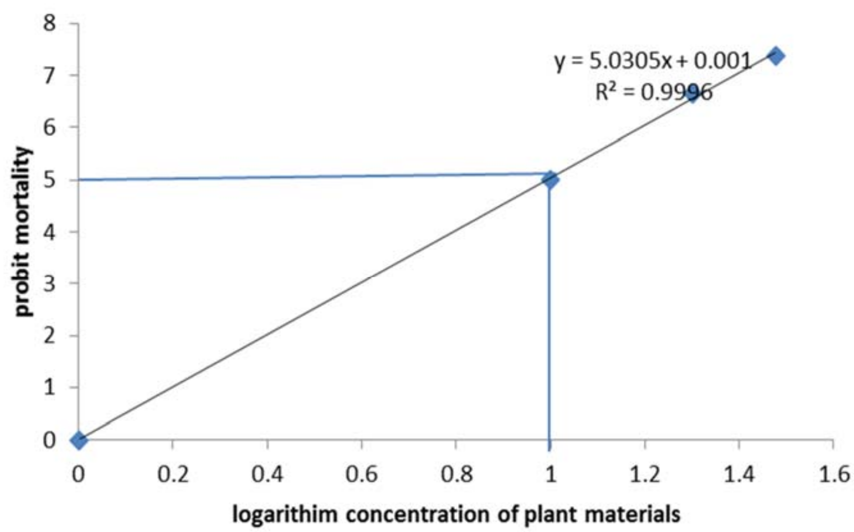

Fig 4: The relationship between mortality and logarithm of concentration of *C. annuum* to give mgL-1 (antilog) at LC_{50}.

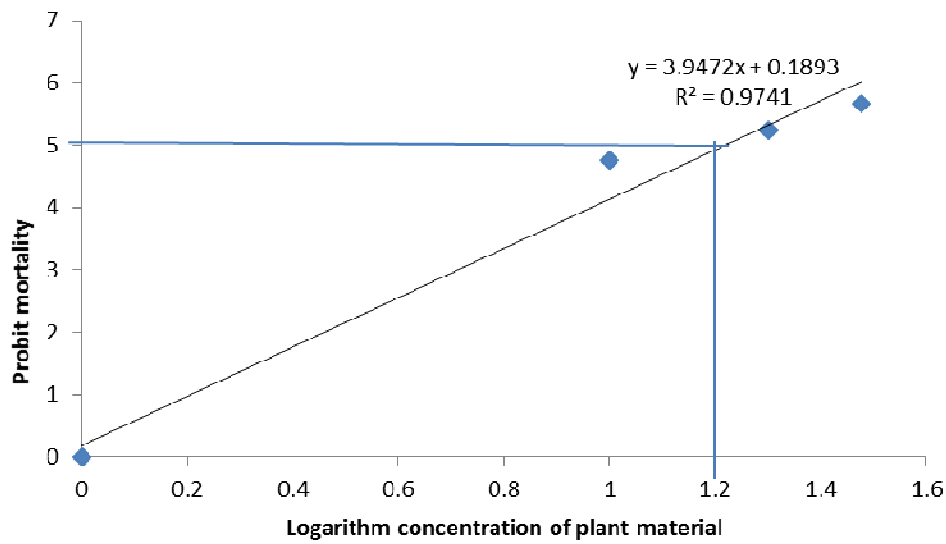

Fig 5: The relationship between mortality and logarithm of concentration of *D. tripetala* to give a mgL-1 (antilog) at LC_{50}.

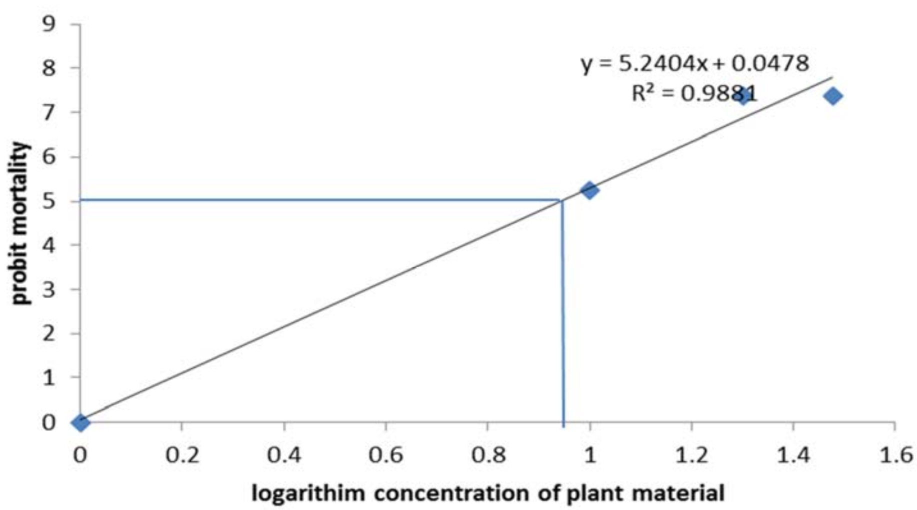

Fig 6: The relationship between mortality and logarithm of concentration of *Z.officinale + A.sativum* to give mgL-1 (antilog) at LC_{50}.

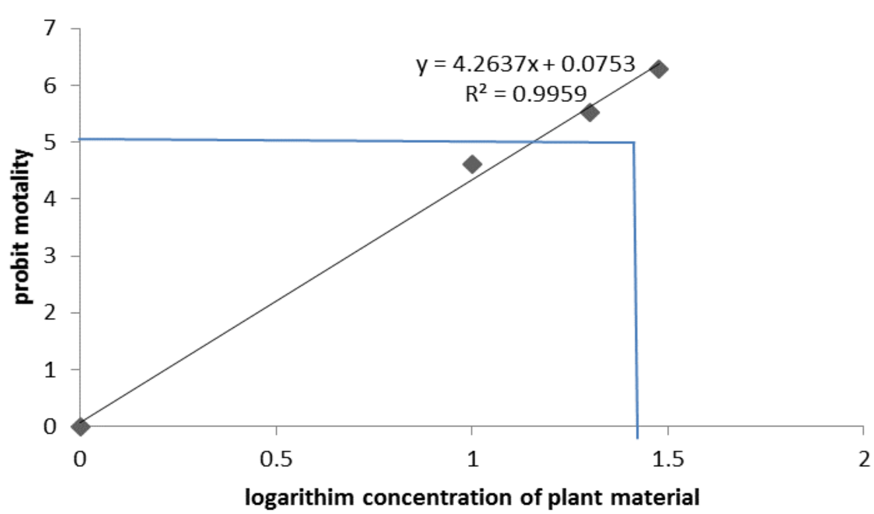

Fig 7: The relationship between mortality and logarithm of concentration of *Z.officinale + C. annuum* to give mgL-1 (antilog) at LC_{50}.

Determination of LT_{50} for the Plant Extracts at Different Concentrations

The lethal time (LT_{50}), the time required to kill 50% of worker termite due to different botanical extracts at different concentration (10-30%) were found be significantly different
(p<0.05). The LT_{50} and are represented in the figures below.

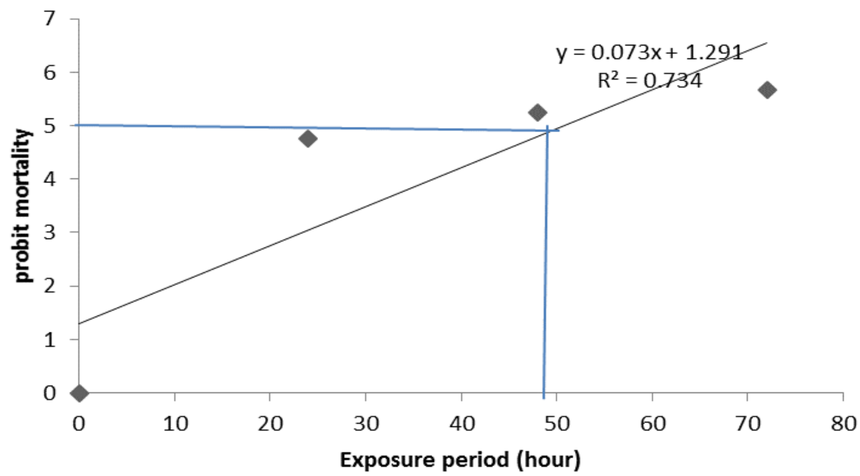

Fig 8: The relationship between mortality and exposure period of *Z. officinale* to give LT_{50}

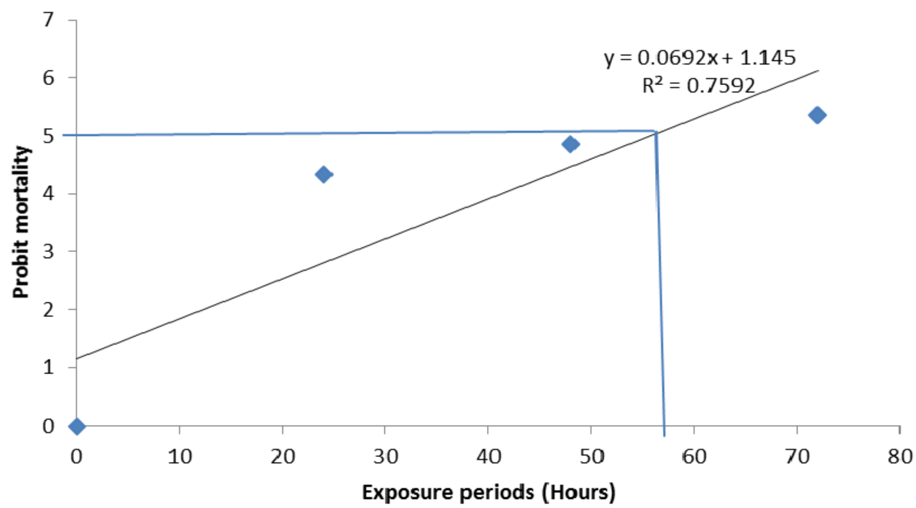

Fig 9: The relationship between mortality and exposure period *A. sativum* to give LT_{50}

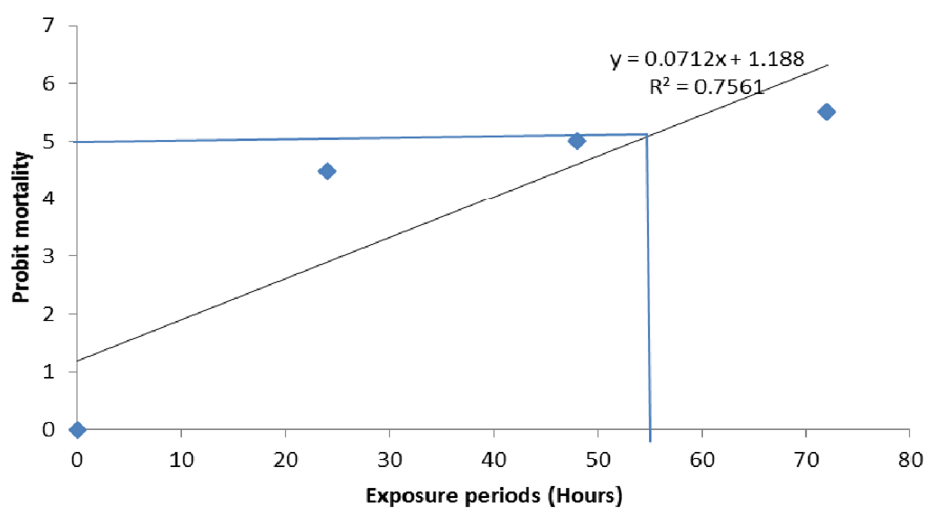

Fig 10: The relationship between mortality and exposure period *D. tripetala* to give LT_{50}.

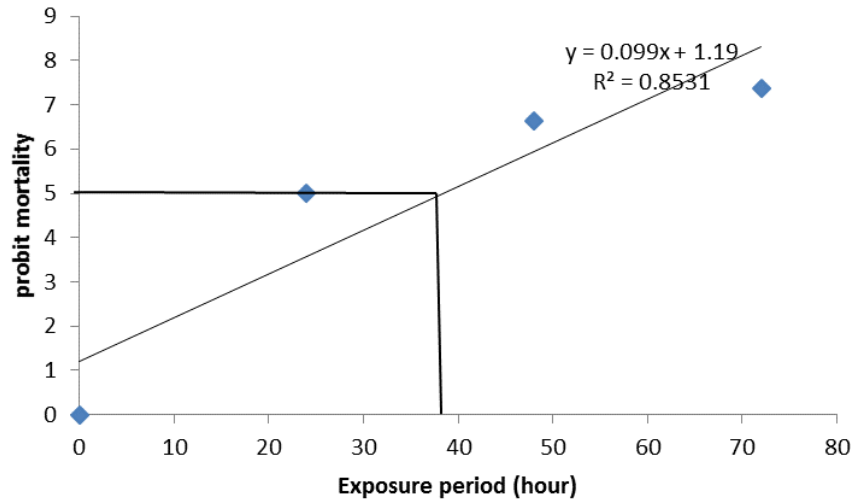

Fig 11: The relationship between mortality and exposure period of *C. annuum* to give LT_{50}.

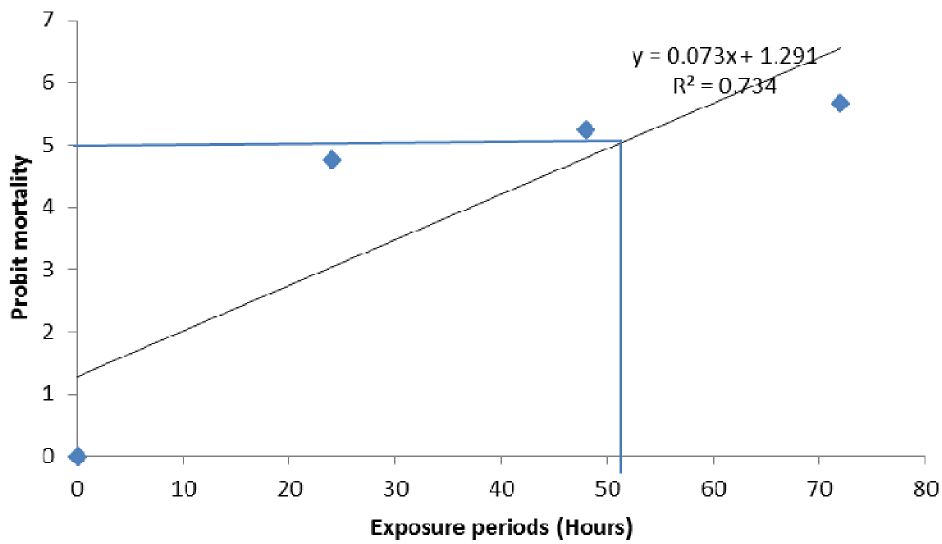

Fig 12: The relationship between mortality and exposure period of *A. sativum and D.tripetala* to give LT_{50}

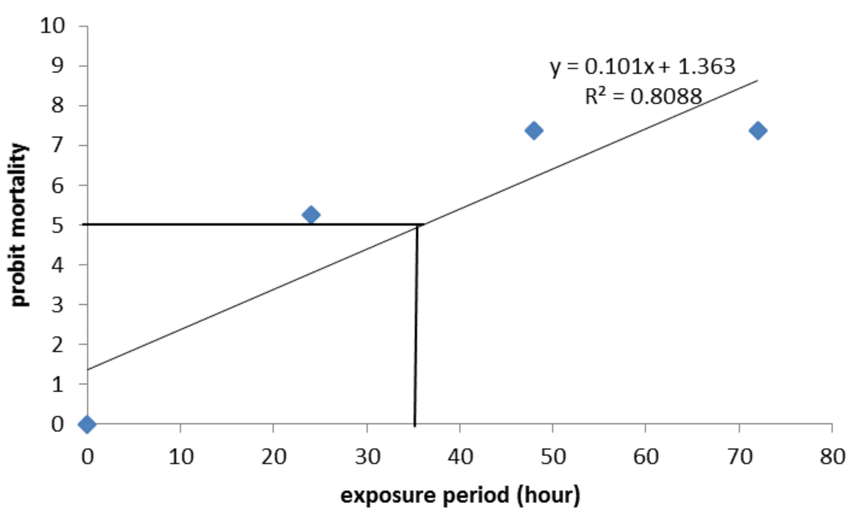

Fig 13: The relationship between mortality and exposure period of *Z. officinale + A. sativum* to give LT_{50}

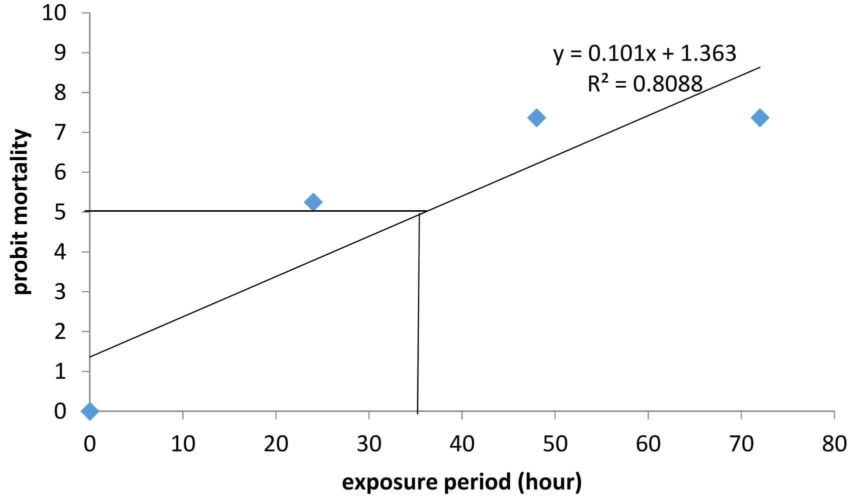

Fig 14: The relationship between mortality and exposure period of *Z. officinale* + *C. annuum* to give LT_{50}.

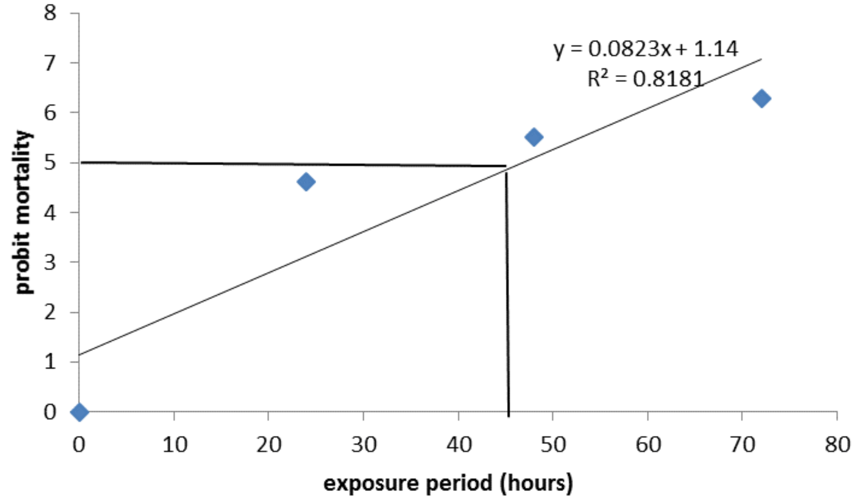

Fig 15: The relationship between mortality and exposure period of diazinon to give LT_{50}

Table 3: summary of the toxicity test carried out for 72 hours against *M. bellicocus*. Using *Z. officinale, A.sativum, C. annuum* and their mixture to get the median lethal concentration (LC_{50})

Plant materials	Regression equation	R^2 value	Correlation (%)	LC_{50} (MgL^{-1})
Z. officinale	Y= 3.9472$_x$ + 0.1893	0.9741	97.41	15.85
A.sativum	Y=3.693 + 0.146	0.981	98.1	19.1
D. tripetala	Y=3.806 + 0.154	0.980	98.0	20.0
C.annuum	Y= 5. 0305$_x$ + 0.001	0.9996	99.96	10
A. sativum + D.tripetala	Y=3.947 + 0.189	0.974	97.4	16.2
Z. officinale + A.sativum	Y= 5.2404$_x$ + 0.0478	0.9881	98.81	7.41
Z. officinale + C. annuum	Y= 4.2637$_x$ + 0.0753	0.9959	99.59	13.49

Table 4: summary of the toxicity test carried out for 72 hours against M. bellicocus. Using *Z. officinale, A.sativum, C. annuum* and their mixture to get the median lethal time (LT_{50})

Plant materials	Regression equation	R^2 value	Correlation (%)	LT_{50} (h)
Z. officinale	Y= 0.073$_x$ + 1.291	0.784	78.4	48
A.sativum	Y = 0.069 + 1.145	0.759	75.9	56
D. tripetala	Y = 0.071 + 1.188	0.756	75.6	54
C. annuum	Y= 0.099$_x$+1.19	0.8531	85.31	38
A. sativum + D.tripetala	Y = 0.073 + 1.291	0.734	73.4	52
Z. officinale + A.sativum	Y= 0.101$_x$+1.363	0.8088	80.88	34
Z. officinale + C. annuum	Y= 0.0823$_x$+1.14	0.8181	81.81	45
Diazinon	Y= 0.2768$_x$+1.634	0.7805	78.05	8

Repellency Test Due to Different Botanicals

The repellency effect of the plant extracts on termite is presented in table 4. Among the plant extracts, highest insect repellency was caused by water extracts from the mixture of *Z. officinale* + *A. sativum* (88.89%) at 30% concentration. The mean repellency caused by all the plant extracts were however, not significantly different ($p>0.05$) ($p=0.24$) from the mean insect repellency caused by the synthetic insecticide ($p<0.05$) ($p=0.01$). However, no repellency was observed in the negative control (Distilled water).

Table 4: Mean Percentage Repellency of Termites by the Various Plant Extracts

Botanical	Concentration	Treated	Untreated	Repellency(%)
Z. officinale	10	5	7	28.51
	20	4	8	50.00
	30	3	8	62.00
A. sativum	10	5	8	37.50
	20	3	5	40.00
	30	4	7	42.00
D. tripetala	10	4	8	50.00
	20	3	7	57.14
	30	2	5	60.00
C. annuum	10	2	8	75.00
	20	2	3	81.81
	30	1	7	87.50
A. Sativum + D. tripetella	10	4	12	66.67
	20	2	7	71.43
	30	1	6	83.33
Z.officinale + A.sativum	10	2	11	81.81
	20	1	7	85.71
	30	1	9	88.89
Z.Officinale + C.annuum	10	5	7	28.57
	20	1	2	50
	30	2	5	60
Diazinon	0.1	1	19	94.74
Distilled water	2ml	10	10	1

Field trial of treatment

As shown in table 5 below, water extract of *C. annum* and *A. sativum* was highly effective. The termitaria treated with these plant extracts were not rebuilt after 30 days. The extract of *Z. officinale* was slightly effective as the termite population gradually started rebuilding the termitaria after 24 days of application as shown plates below.

Table 5: Rate of effect of plant materials on treated termitaria

Botanicals	No. of days	Rate of Effect
Z. Officinale	0-8	Highly effective
A. sativum		Highly effective
C. annum		Highly effective
D. tripetella		Highly effective
Z.officinale + A.sativum		Highly effective
Z.Officinale + C.annuum		Highly effective
A.Satívum + D. tripetella		Highly effective
Z. officinale	9-11	Highly effective
A. sativum		Highly effective
C. annuum		Highly effective
D. tripetella		Highly effective
Z.officinale + A.sativum		Highly effective
Z.Officinale + C.annuum		Highly effective
A.Satívum + D. tripetella		Highly effective
Z. Officinale	12-24	Moderately effective
A. sativum		Highly effective
C. annuum		Highly effective
D. tripetella		Highly effective
Z.officinale + A.sativum		Highly effective
Z.Officinale + C.annuum		Highly effective
A.Satívum + D. tripetella		Highly effective
Z. Officinale	25-30	Slightly effective
A. sativum		Highly effective
C. annum		Highly effective
D. tripetella		Highly effective
Z.officinale + A.sativum		Highly effective
Z.Officinale + C.annuum		Highly effective
A.Satívum+ D. tripetella		Highly effective

Plate 1: A; termitarium treated with the water extract of *Z. officinale*. B; termitarium rebuilt after 30 days of post treatment.

Plate 2: A; termitarium treated with the water extract of *A. sativum.* **B**; termitarium after 30 days of post treatment

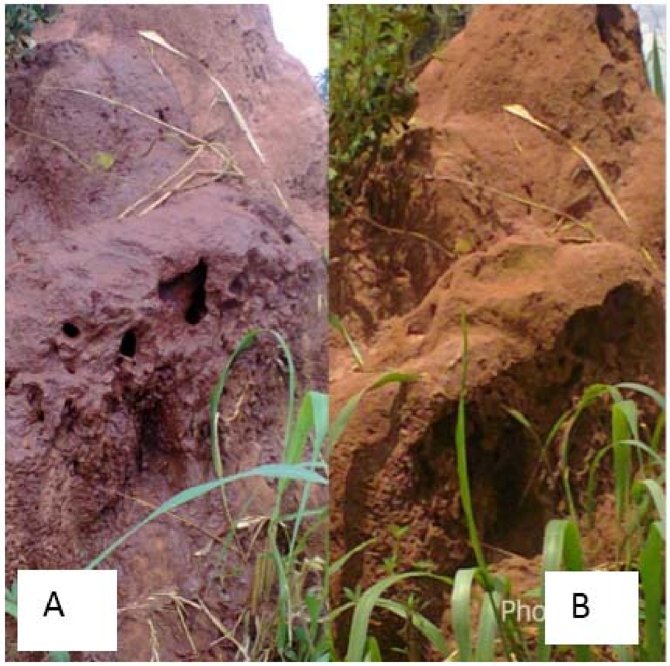

Plate 3: A; termitarium treated with the water extract of *C. annuum.* **B**; termitarium after 30 days of post treatment

Plate 4: A; termitarium treated with the water extract of *D. tripetala.* **B**; termitarium after 30 days of post treatment

Plate 4: A; termitarium treated with the water extract from the mixture of *Z. officinale* + *A sativum.* **B**; termitarium after 30 days of post treatment

Plate 5: A; termitarium treated with the water extract from the mixture of *D. tripetala+ A. sativum.* B; termitarium after 30 days of post treatment

Plate 6: A; termitarium treated with the water extract from the mixture of *Z. officinale* + *C. annuum* B; termitarium after 30 days of post treatment

Discussion and conclusion

The toxicity and repellency of *Z. officinale*, *C. annuum*, *D. tripetala* and *A. sativum* applied as individual and mixed extracts *(Z. officinale + A. sativum, A. sativum+D. tripetala and Z. Officinale + C. annuum*) at a ratio of 50:50 was carried out against termites (*M. bellicocus*) by ascertaining the mortality, LC_{50}, LT_{50} and repellency of the termites using 0.21% of Diazinon as a positive control and of distilled water as negative control.

All plant materials were toxic to the termites and there was significant difference in the mortality as concentration increased from 10-30% when plant extracts were applied as individuals and mixed extracts. The mortality caused by the mixture of Z. *officinale* + *A. sativum* was the highest as compared to the mortality caused by diazinon while the least mortality was observed in *D tripetala* when applied alone. This indicates that the efficacy of the plant materials depends on the plants' active ingredients. The extracts of *A.sativum*, *D.tripetala*, *C annuum* and their mixtures also caused significant mortality on the termites. The active constituents of *A. sativum* includes phenols, saponins and sapogeins [19]. The main constituents of *D. tripetala* includes; Tannins, Saponins, Flavonoids and alkaloids [20]. The mode of action might be through contact of the water extract with the body wall of the insects. These constituents might probably get into the body system of the insect and interfere with the normal development causing mortality of the termite. The finding is also in consonance with the finding of [21] who evaluated the antifeedant, toxicant and growth regulatory effects of the acetone leaf extracts of *Curcuma longa* and *A. sativum* against adults of *T. castaneum*. Both *A. sativum* and *C. longa* significantly reduced the larval and adult emergence as well as weight loss but *A. sativum* performed better as compared to the *C. langa*. The precise mechanism of action of the extract of *C. annuum* is the presence of capsaicin which is classified as a biochemical pesticide. The mode of action includes; Inhalation resulting in inflammation of pulmonary tissue and damage to respiratory cells [22]. Contact causing irritation of the skin [23]. Metabolic disruption, membrane damage and nervous system dysfunction. The findings may also be compared to the finding of [24] who reported that *C. annuum* cause mortality at high dosage (5%) after 14days. It was stated that red pepper was equitoxic to both adult insect of *R.dominica* and *S.granarius*. On the contrary, [25] reported that the leave power of *C. annuum* had no apparent effect on termites, this may be because the leaves were over dried until brittle and then boiled in water. This process might have killed almost or all the active ingredients required to cause mortality against the termites. Also, [26] investigated the insecticidal properties of extracts and powder prepared from different neem parts (seed, leaf, stem and root) against the *M. bellicocus*. The seed extract of neem caused higher mortality ranging from 40-55% and was more toxic when compared to the powder; also, water extract of *Z. officinale, C. annuum and A. sativum* in this study caused significant mortality ranging from 40-100% consequently, it could be said that water extracts of plant are more effective than their powders [26]. The use of plant parts and derivatives to control insect pest of stored products, vegetable, soil, and human properties have been an age long practice in African agriculture [27], this indicates that naturally occurring anti-termite compound extracted from locally available plant have potentials for managing the population of termites.

The least concentration required to kill 50% of termites due to different plant extracts at different concentration was found in the mixture of *Z. officinale* + A. *sativum* at 7.41mg/L compared to 13.49mgL-1 from the mixture of *Z. officinale* + *C. annuum* and 16.2 of *A. sativum* +*D. tripetala* however, the active constituent of *Z. officinale*(gingerol, shogaol and zingerone) might be responsible for the low LC_{50}. There would also have been a synergistic effect from mixing of the two materials (*Z. officinale* + A. *sativum)* which might also have been responsible for the low LC_{50}. Individual plant materials had an LC_{50}- 19.1mgL-1, 10mgL-1, 15.85mgL-1, 20.0mgL-1for *A. sativum, C. annuum, Z. officinale* and *D. tripetala* respectively. The correlation coefficient in the acute toxicity test for the LC_{50} and LT_{50} was high for all the plant extracts. This indicates that the mixtures were toxic to the insects. [7] determined the toxicity of *Rhazya stricta, Decnlantna camera L, Ruta chalepensis L* and *Heliotropium bacciferum* (forsk) against subterranean termites *Psamoternes hybostoma* (Desneux) of the four extract, the hexane extract from *R.*

stricta show a relatively more pronounced toxic effect having an acute (24hrs) and chronic (48hrs) LC_{50} of 194.8 and 147.4 ppm compared to 221.7 and 149.9, 2889, 185.6 and 391.3 and 244.5 ppm for *L. camara, R. Chaleponosis* and *H. bacciferum* respectively. This could also be compared to [2] who reported that at 35% concentration the least concentration required to kill 50% of the termite is 6.73h exposure of *J. curcas.*

The least time required to kill 50% of the termites was found in the mixture of *Z. officinale* + *A. sativum* (34hrs). This could be that there was also synergistic effect in mixing the plant extracts causing more mortality in a short time. [8] investigated the activity of methanolic and aqueous extracts of *D.viscosa, A.vasica, N. Odorum, T. Peruvian, D. ajacis, Soleiodes* and *A. scholaris,* applied on filter paper and/or mixed into soil at various concentration against subterranean termites. When methanolic extracts were applied to filter paper and soil, the least LT_{50} was 27.28hrs (*N. odorum*) and 35.2hrs (*D.viscosa*) respectively. Also when aqueous extract of plant materials was applied to filter paper and soil, the lowest LT_{50} was 27.0hrs (*N. Odorum*) and 36.0hrs (*A. vasica*) respectively.

In this study, all the extracts were repellent to the termites. The mixture of *Z. officinale* + *A. sativum* has the highest repellency of 81.81-88.89% and the mixture e of *Z. officinale* + *C. annuum* has the least repellency 0f 28.51-60%. It could be that the active ingredient present in the mixture of *Z. officinale* + *A. sativum* has a stronger fumigative property when compared to other plant materials. This is in agreement with [2] who studied the efficacy of *J.curcas, A. Indica, M. lancelata, C. ambrosoids, V. hymenolepsis* against termites, *M. bellicocus* and reported that all plant extracts repelled termites. [1] also evaluated the bio-insecticidal potential of some tropical plants extract against termites and that the extract of *T. cacao, A. occidentale, T. detersifolia* repels termites. [19] evaluated the toxicity and biochemical efficacy of thyme, Basil, Mint, Garlic, Chamomile and Sesame against *T. confusum* and observed that there was no variation in the repellent effects of the test oil and adults, the oils were highly repellent to the adult insect (PR>70%) compared to the larvae that had moderate repellency effect Pr-61.1 and 64.73% for thyme and basil respectively. Also, [28] evaluated the repellency of *Dennettia tripetala* Baker powder and acetone, ethanol and water extracts to larvae of leather beetle, *Dermestes maculatus* and compared with that of pyrethrum standard. *Dennettia tripetala* showed higher repellency than pyrethrum. Acetone and ethanol extracts were good repellent to *D. maculatus* giving repellency values of 40.1% - 60%.

The plant extracts in this study demonstrated wide spectrum in managing the population of termites in the field. Each extracts applied as individual and in mixed proportions were highly effective against termites even after 30 days of post treatment. The toxicity and repellency of the extracts were effective over time because the termiteria were not rebuilt. However, the efficacy of the extract of *Z. officinale* applied alone against termites was slightly reduced after 24 days of post application because the termites began to rebuild their termiterium. It could be that the toxicity of the *Z. officinale* extract reduced over time when compared to other plant extracts (*C. annuum . A. sativum, D tripetala).* This is in line with [1] who evaluated the bioinsecticidal potential of *C. sinensis, T. cacao, A. occidental* and *T. diversifora* against termites and stated that the comparable effectiveness of the extracts of *T. cacao* with the synthetic insecticide (0.1% chlopyrifos) was a good development for the management of termites in termiterium as the extracts are easily available, affordable and environmental friendly.

Conclusion

The present findings demonstrated that all of the plant extracts tested against termites possess termiticidal properties that can be used in the management of *M. bellicocus*. From the experiment, mixture of *Z. officinale* + *A. sativum* was observed to be the most effective (biopotent) extract at 10-30% concentration test after 24-72 hours and repelled most insects. Plants with repellent effects cause little or no negative impact in the environment when used for pest management because they drive pest by stimulating their sensory organ before the damage is caused to plants. These plant extracts could serve as alternatives to synthetic insecticides in termite management practices because they are biodegradable, cheap, easy to prepare and readily available in common markets in Abraka and Delta State.

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