ABOUT JEN

The Journal of Entomology and Nematology (JEN) (ISSN: 2006-9855) is published monthly (one volume per year) by Academic Journals.

Journal of Entomology and Nematology (JEN) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as applications of entomology in solving crimes, taxonomy and control of insects and arachnids, changes in the spectrum of mosquito-borne diseases etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JEN are peer-reviewed.

Submission of Manuscript

Please read the Instructions for Authors before submitting your manuscript. The manuscript files should be given the last name of the first author

Click here to Submit manuscripts online

If you have any difficulty using the online submission system, kindly submit via this email jen@academicjournals.org.

With questions or concerns, please contact the Editorial Office at jen@academicjournals.org.
Editors

Dr. Mukesh K. Dhillon
ICRISAT
GT-Biotechnology, ICRISAT, Patancheru 502 324, Andhra Pradesh, India

Dr. Lotfalizadeh Hosseinali
Department of Insect Taxonomy
Iranian Research Institute of Plant Protection
Tehran, P. O. B. 19395-1454, Iran

Prof. Liande Wang
Faculty of Plant Protection,
Fujian Agriculture and Forestry University
Fuzhou, 350002, P.R. China

Dr. Raul Neghina
Victor Babes University of Medicine and Pharmacy
Timisoara, Romania

Prof. Fukai Bao
Kunming Medical University
191 Western Renmin Road, Kunming, Yunnan, PR of China

Dr. Anil Kumar Dubey
Department of Entomology,
National Taiwan University, Sec. 4, Lane 119, Taipei, Taiwan 107

Dr. Mona Ahmed Hussein
National Research Centre, Centre of Excellence for Advanced Sciences, El-Behooth Street, Dokki, Cairo, Egypt

Associate Editors

Dr. Sam Manohar Das
Dept. of PG studies and Research Centre in Zoology,
Scott Christian College (Autonomous), Nagercoil – 629 003, Kanyakumari District, India

Dr. Leonardo Gomes
UNESP

Dr. J. Stanley
Vivekananda Institute of Hill Agriculture
Indian Council of Agricultural Research, Almora–263601, Uttarakhnad, India

Dr. Ramesh Kumar Jain
Indian Council of Agricultural Research,
Division of Nematology, IARI
New Delhi-110012 India

Dr. Hasan Celal Akgul
Istanbul Plant Quarantine Service, Nematology Laboratory
Halkali Merkez Mahallesi, Halkali Caddesi, No:2, 34140 Halkali, Kucukcekmece-Istanbul Turkey

Dr. James E. Cilek
Florida A & M University
4000 Frankford Avenue, Panama City, Florida 32405 USA

Dr. Khan Matiayar Rahaman
Bidhan Chandra Krishi Viswavidyalaya
AICRP (Nematode), Directorate of Research, BCKV, PO. Kalyani, Dist. Nadia, PIN-741235, West Bengal, India

Manas Sarkar
Defence Research Laboratory (DRDO, Ministry of Defence, Govt. of India)
Post Bag No.2, Tezpur-784001, Assam, India
Mehdi Esfandiari  
*Department of Plant Protection  
College of Agriculture,  
Shahid Chamran University of Ahvaz,  
Ahvaz, Iran*

Prof. Dr. Mahfouz M. M. Abd-Elgawad  
*Nematology Laboratory  
Department of Phytopathology  
National Research Center El-Tahrir St., Dokki 12622, Giza, Egypt*

Matthew S. Lehnert  
*Department of Entomology, Soils, & Plant Sciences  
Clemson University, Clemson, United States*

Wenjing Pang  
*3318 SE 23rd Avenue  
Gainesville, FL 32641  
Agronomy and Biotechnological College,  
China Agricultural University, Beijing, China*

Dr. G. Shyam Prasad  
*Directorate of Sorghum Research (DSR),  
Rajendranagar, Hyderabad 500030, AP, INDIA*

Dr. Rashid Mumtaz  
*Date Palm Research  
Plant Protection Department  
Food & Agricultural Sciences  
King Saud University, Riyadh  
Kingdom of Saudi Arabia*

Godwin Fuseini  
*International SOS Ghana,  
Newmont Ghana Gold,  
Ahafo mine, Ghana.*

Dr. Waqas Wakil  
*Department of Agriculture Entomology,  
University of Agriculture, Faisalabad, Pakistan*

Gilberto Santos Andrade  
*Universidade Federal de Viçosa  
Avenida Peter Henry Rolfs, s/n Campus Universitário 36570-000  
Viçosa - MG - Brazil*

Ricardo Botero Trujillo  
*Calle 117 D # 58-50 apto. 515  
Pontificia Universidad Javeriana, Bogotá, Colombia*

Dr. D. N. Kambrekar  
*Regional Agricultural Research Station,  
UAS Campus, PB. No. 18,  
Bijapur-586 101 Karnataka-INDIA  
India*

Dr. P. Pretheep Kumar  
*Department of Forest Biology  
Forest College & Research Institute  
Tamil Nadu Agricultural University  
Mettupalayam – 641 301  
Tamil Nadu, India*

Dr. Raman Chandrasekar  
*College of Agriculture Entomology  
S-225, Agriculture Science Center  
University of Kentucky  
Lexington, KY 40546-0091  
USA.*

Dr. Rajesh Kumar  
*Central Muga Eri Research and Training Institute  
Lahdoigarh, Jorhat-785700, Assam, India*
Prof. Ding Yang  
Department of Entomology,  
China Agricultural University,  
2 yuanmingyuan West Road, Haidian,  
Beijing 100193, China

Dr. Harsimran Gill  
University of Florida  
970 Natural Area Drive, PO Box 110620,  
Gainesville, Florida- 32611

Dr. Mehdi Gheibi  
Department of Plant Protection,  
College of Agriculture, Shiraz Islamic  
Azad University, Shiraz, Iran

Dr. Nidhi KakKar  
University College, Kurukshetra University,  
Kurukshetra, Haryana, India

Dr. Marianna I. Zhukovskaya  
Sechenov Institute of Evolutionary Physiology  
and Biochemistry, Russian Academy of Sciences  
44 Thorez Ave, 194223,  
Saint-Petersburg, Russia

Gaurav Goyal  
University of Florida  
282#14 Corry village,  
Gainesville, FL 32603, USA

Gilberto Santos Andrade  
Universidade Federal de Viçosa  
Avenida Peter Henry Rolfs,  
s/n Campus Universitario  
36570-000 Vicosa - MG - Brazil

Joshi Yadav Prasad  
Gyanashwor Kathmandu, Nepal  
G P O Box: 8975 EPC:  
5519, Kathmandu, Nepal  
India

Baoli Qiu  
Department of Entomology,  
South China Agricultural University  
No 483, Wushan Road, Tianhe, Guangzhou,  
PR China 510640

T. Ramasubramanian  
Central Research Institute for Jute and Allied Fibres  
(Indian Council of Agricultural Research)  
Barrackpore, Kolkata – 700 120,  
India

Leonardo Gomes  
UNESP Av. 24A, n 1515, Depto de Biologia,  
IB, Zip Code: 13506-900, Rio Claro,  
SP, Brazil.

Hasan Celal Akgul  
Istanbul Plant Quarantine Service,  
Nematology Laboratory  
Halkali Merkez Mahallesi,  
Halkali Caddesi, No:2, 34140 Halkali,  
Kucukcekmece-Istanbul/Turkey

J. Stanley  
Vivekananda Institute of Hill Agriculture  
Indian Council of Agricultural Research,  
Almora– 263601, Uttarakhand, India

Atef Sayed Abdel-Razek  
National Research Centre,  
Dept. of Plant Protection  
El-Tahrir Street, Dokki, Cairo, Egypt
Instructions for Author

Electronic submission of manuscripts is strongly encouraged, provided that the text, tables, and figures are included in a single Microsoft Word file (preferably in Arial font).

The cover letter should include the corresponding author’s full address and telephone/fax numbers and should be in an e-mail message sent to the Editor, with the file, whose name should begin with the first author’s surname, as an attachment.

Article Types
Three types of manuscripts may be submitted:

Regular articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly.

Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections need not conform to that of full-length papers. Short communications are 2 to 4 printed pages (about 6 to 12 manuscript pages) in length.

Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged. Reviews should be concise and no longer than 4-6 printed pages (about 12 to 18 manuscript pages). Reviews are also peer-reviewed.

Review Process
All manuscripts are reviewed by an editor and members of the Editorial Board or qualified outside reviewers. Authors cannot nominate reviewers. Only reviewers randomly selected from our database with specialization in the subject area will be contacted to evaluate the manuscripts. The process will be blind review.

Decisions will be made as rapidly as possible, and the journal strives to return reviewers’ comments to authors as fast as possible. The editorial board will re-review manuscripts that are accepted pending revision. It is the goal of the AJFS to publish manuscripts within weeks after submission.

Regular articles
All portions of the manuscript must be typed double-spaced and all pages numbered starting from the title page.

The Title should be a brief phrase describing the contents of the paper. The Title Page should include the authors' full names and affiliations, the name of the corresponding author along with phone, fax and E-mail information. Present addresses of authors should appear as a footnote.

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 200 words in length. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be avoided. No literature should be cited.

Following the abstract, about 3 to 10 key words that will provide indexing references should be listed.

A list of non-standard Abbreviations should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the solidus presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not be defined.

The Introduction should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific disciplines.

Materials and methods should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer’s name and address. Subheadings should be used. Methods in general use need not be described in detail.
Results should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Discussion section.

The Discussion should interpret the findings in view of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc. should be brief.

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively in Arabic numerals and supplied with a heading and a legend. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text.

Figure legends should be typed in numerical order on a separate sheet. Graphics should be prepared using applications capable of generating high resolution GIF, TIFF, JPEG or Powerpoint before pasting in the Microsoft Word manuscript file. Tables should be prepared in Microsoft Word. Use Arabic numerals to designate figures and upper case letters for their parts (Figure 1). Begin each legend with a title and include sufficient description so that the figure is understandable without reading the text of the manuscript. Information given in legends should not be repeated in the text.

References: In the text, a reference identified by means of an author's name should be followed by the date of the reference in parentheses. When there are more than two authors, only the first author's name should be mentioned, followed by 'et al'. In the event that an author cited has had two or more works published during the same year, the reference, both in the text and in the reference list, should be identified by a lower case letter like 'a' and 'b' after the date to distinguish the works.

Examples:

Abayomi (2000), Agindotan et al. (2003), (Kelebeni, 1983), (Usman and Smith, 1992), (Chege, 1998; 1987a,b; Tijani, 1993,1995), (Kumasi et al., 2001)

References should be listed at the end of the paper in alphabetical order. Articles in preparation or articles submitted for publication, unpublished observations, personal communications, etc. should not be included in the reference list but should only be mentioned in the article text (e.g., A. Kingori, University of Nairobi, Kenya, personal communication). Journal names are abbreviated according to Chemical Abstracts. Authors are fully responsible for the accuracy of the references.

Examples:


Short Communications

Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Discussion should be combined into a single section.

Proofs and Reprints: Electronic proofs will be sent (e-mail attachment) to the corresponding author as a PDF file. Page proofs are considered to be the final version of the manuscript. With the exception of typographical or minor clerical errors, no changes will be made in the manuscript at the proof stage.
Fees and Charges: Authors are required to pay a $550 handling fee. Publication of an article in the Journal of Entomology and Nematology is not contingent upon the author’s ability to pay the charges. Neither is acceptance to pay the handling fee a guarantee that the paper will be accepted for publication. Authors may still request (in advance) that the editorial office waive some of the handling fee under special circumstances.

All rights Reserved. In accessing this journal, you agree that you will access the contents for your own personal use but not for any commercial use. Any use and or copies of this Journal in whole or in part must include the customary bibliographic citation, including author attribution, date and article title.

Submission of a manuscript implies: that the work described has not been published before (except in the form of an abstract or as part of a published lecture, or thesis) that it is not under consideration for publication elsewhere; that if and when the manuscript is accepted for publication, the authors agree to automatic transfer of the copyright to the publisher.

Disclaimer of Warranties

In no event shall Academic Journals be liable for any special, incidental, indirect, or consequential damages of any kind arising out of or in connection with the use of the articles or other material derived from the JEN, whether or not advised of the possibility of damage, and on any theory of liability. This publication is provided "as is" without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, or non-infringement. Descriptions of, or references to, products or publications does not imply endorsement of that product or publication. While every effort is made by Academic Journals to see that no inaccurate or misleading data, opinion or statements appear in this publication, they wish to make it clear that the data and opinions appearing in the articles and advertisements herein are the responsibility of the contributor or advertiser concerned. Academic Journals makes no warranty of any kind, either express or implied, regarding the quality, accuracy, availability, or validity of the data or information in this publication or of any other publication to which it may be linked.
ARTICLES

Toxicological and residual effect of Deltamethrin and Chlorpyrifos against the
German Cockroach, *Blattella Germanica* (Linnaeus) (Insecta: Blattodea: Blattellidae)
Kemabonta, K. A., Ohadiwe, A. and Adetoro, F. A.

Susceptibility test of female anopheles mosquitoes to ten insecticides for indoor
residual spraying (IRS) baseline data collection in Northeastern Nigeria
Umar A., Kabir B. G. J., Amajoh C. N., Inyama P. U., Ordu D. A., Barde A. A., Misau A. A.,
Sambo M. L., Babuga U., Kobi M. and Jabbdco M. A.
Toxicological and residual effect of Deltamethrin and Chlorpyrifos against the German cockroach, *Blattella germanica* (Linnaeus) (Insecta: Blattodea: Blattellidae)

Kemabonta, K. A.*, Ohadiwe, A. and Adetoro, F. A.

Department of Zoology, Faculty of Science, University of Lagos, Akoka, Lagos, Lagos State, Nigeria.

Received 15 June 2014; Accepted 25 June 2014

The toxicological and residual properties of two insecticidal agents, Deltamethrin and Chlorpyrifos were evaluated against the German cockroach, *Blattella germanica* in laboratory bioassay. The insecticides were diluted in both aqueous and oil-based solvents and tested against the roaches in pre-determined concentrations and untreated control. Experimental cages were either completely sealed after exposure or perforated to simulate fumigation and disinfestation regimes, respectively. Mortality data generated from acute toxicity studies revealed that oil-based Deltamethrin (5%v/v) was more effective (100%) than aqueous solution (53.3%) within similar durations in both chambers. Chlorpyrifos (5%v/v) revealed an acute mortality of 100% for both oil-based and aqueous solutions in both chambers. Residual effect of both Deltamethrin and Chlorpyrifos was dose/time-dependent, with oil-based solution more effective than the aqueous solution. Computed lethal time revealed that LT$_{50}$ showed significant difference ($P<0.05$) between aqueous solution of both insecticidal agents for fumigation treatment. A similar trend was observed for the oil-based solutions of both insecticides in the disinfestations treatment. The implication of this finding in terms of choice of insecticides for acute toxicity and residual efficacy, impact of diluting agents, and sustainable approach to roach control in Nigeria was discussed.

**Key words:** *Blattella germanica*, disinfestation, fumigation chambers.

INTRODUCTION

The German cockroach (*Blatella germanica*, Linnaeus) is one of the most common species worldwide and prominent household cockroaches in the world, and can be found throughout many human settlements (Jacobs, 2007). It is particularly associated with restaurants, food processing facilities, hotels and nursing homes. It is however less prominent in temperate environments, probably due to its volume/surface area ratio which is a major hindrance to cold tolerance (Rust et al., 1995). *B. germanica* is the most commonly encountered of the household pests species in Nigeria. It is also the most persistent and difficult to control (Fasulo, 2002). This is due to its larger egg ratio per capsule than other species that infest households and structures. Secondly, it has the shortest developmental period from hatching to sexual maturity; thus, populations of German cock-
roaches usually build up faster than other species. Thirdly, German cockroach nymphs have relatively enhanced chance of survival than other species because the female carries the egg capsule during the entire embryonic development of the nymph. These result in the nymphs avoiding many potential environmental hazards as compared to detached and/or isolated eggs. Thus, more nymphs are likely to hatch, with resultant higher reproductive potential. Fourthly, German cockroach nymphs are smaller than most other cockroaches; thus, they are able to conceal themselves in many places which are inaccessible to those of other species. In fact, in a commercial kitchen, there may be potentially thousands of cracks and crevices young cockroaches can hide in and remain protected (Fasulo, 2002). B. germanica has aggregation pheromones associated with their droppings, which have the effect of increasing the level of aggregation or clumping of individuals in the population (Engelmann, 1970; Roth, 1970). These biological factors, combined with their highly adaptive feeding habits and other behaviors, give the German cockroach advantages toward increased chances for survival and consistently maintaining high populations.

The control of B. germanica using conventional insecticidal agents remains a challenge in many parts of the world, due to increased spate of resistance development. B. germanica resistance to insecticides was first detected in chlordane use in Corpus Christi, Texas, USA in 1952 (Heal et al., 1953). Thereafter, an increasing number of cases have been documented in the USA (Rust and Reierson, 1991, Zhai and Robinson, 1991), Canada (Bath, 1977), Europe (Chapman et al., 1993), and Japan (Umeda et al., 1988). Currently, resistance to all the major groups of insecticides (organochlorines, organophosphates, carbamates and pyrethroids) by B. germanica has been reported (Cochran, 1995). Increased tolerance and potential resistance to other novel insecticides, such as sulfuriramid (Schal, 1992) and abamectin (Cochran, 1994), along with behavioral changes in response to glucose attractant (glucose-aversion) in cockroach bait (Silverman and Ross, 1994) have been reported recently.

Few studies have been carried out on the control of B. germanica using different types and/or formulations of insecticides in Nigeria. This study therefore seeks to investigate the comparative insecticidal efficacies of Deltamethrin and Chlorpyrifos against B. germanica in laboratory bioassay, identify the impact of different diluents on the effectiveness of the two insecticides. Moreover, it seeks to evaluate the residual activities of the two insecticides, both as fumigation and disinfestation agents, against B. germanica.

MATERIALS AND METHODS

Site of the experiment

Culture of the German cockroach, B. germanica was maintained in the laboratory at the Zoological Gardens, Department of Zoology, University of Lagos, where all bioassays were also carried out.

Insecticides used

Insecticides used, Deltamethrin (2.5 and 5% v/v) and Chlorpyrifos (2.5 and 5% v/v) were purchased from registered agrochemical retail stores around Lagos Island axis of Lagos in Lagos State Nigeria. The choice of diluents was water and diesel, respectively.

Insect culture

Adults and nymphs of the German cockroach were collected from students’ cupboards in Fagunwa Hall, a female residential Hostel within the University Campus, as well from the insectary of the Department of Zoology, University of Lagos to set up a mass culture of B. germanica. The insects were kept in plastic vials which where smeared with petroleum jelly to prevent the cockroach from moving out of the vials. The vials were also covered with a muslin cloth and striped with rubber band to keep the insects in place.

While the culture lasted, the roaches were fed thrice a week with crumbs of bread and/or biscuits, with water also placed in the container. The containers were regularly cleaned and insect frass and faeces removed. The petroleum jelly at the edge of the vial was also renewed to prevent escape of the roaches upon opening the vial. Cleaning was done using wet foam rubbed sparingly round the containers and the dirt’s packed out with a piece of serviette paper.

Experimental procedure

The experiment was carried out using the two aforementioned insecticides, two different concentrations and each treatment was replicated three times. Moreover, two different containers were used- perforated at the top (disinfestation procedure I) while the other was fumigation process (I2) and/or perforated to simulate fumigation and disinfestation regimes, respectively. The procedure was in accordance with that of Shahi et al. (2008) with slight modifications.

Toxicity test

All life stages of B. germanica (except the first, second nymphal stages, and gravid females) were used for the toxicity tests. Deltamethrin and Chlorpyrifos insecticide formulation were used in accordance with the instruction on the labels. Four concentrations 2.5 and 5% (v/v) of water; 2.5 and 5% (v/v) of diesel were used. Each formulation was impregnated on filter paper and air-dried. Excess liquid was drained off, and thereafter, ten (10) randomly picked B. germanica were confined into each jar.

The upper surface of the jar was lightly greased with petroleum jelly to prevent escape of the insects (redundancy). There were two controls-jars with only water or only diesel sprayed on the filter paper. Each treatment was replicated three times. Mortality of B. germanica was observed after 5, 10, 15, 20, 30 min to the 4 th h post treatment and the number of dead B. germanica was counted and recorded. The jars containing treated and untreated filter papers were kept aside on laboratory bench and used for the residual experiments.

At one week after treatment, German roaches were re-introduced into the various vials containing the treated filer papers including the control to check the residual effect of these insecticides on the roaches. The same procedure was used as in the first experiments (for four hours), after which the experiment was stopped and cock-
Table 1. Mean mortality values for both water (positive control) and diesel (negative control) against B. germanica.

<table>
<thead>
<tr>
<th>Time</th>
<th>Water</th>
<th>I₀</th>
<th>I₅₀</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 min</td>
<td></td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td></td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>15 min</td>
<td></td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>20 min</td>
<td></td>
<td>0.00±0.00</td>
<td>10.00±0.00</td>
</tr>
<tr>
<td>30 min</td>
<td></td>
<td>6.70±5.80</td>
<td>10.00±0.00</td>
</tr>
<tr>
<td>45 min</td>
<td></td>
<td>13.30±5.80</td>
<td>20.00±0.00</td>
</tr>
<tr>
<td>1 h</td>
<td></td>
<td>13.30±5.80</td>
<td>20.00±0.00</td>
</tr>
<tr>
<td>2 h</td>
<td></td>
<td>26.70±5.80</td>
<td>26.70±5.80</td>
</tr>
<tr>
<td>3 h</td>
<td></td>
<td>26.70±5.80</td>
<td>43.30±5.80</td>
</tr>
<tr>
<td>34 h</td>
<td></td>
<td>36.70±11.60</td>
<td>43.30±5.80</td>
</tr>
</tbody>
</table>

I₀ = Disinfestation; I₅₀ = fumigation.

Quantal response

Mortality readings were taken for cockroaches when no part of the body or limb movement was observed upon pricking with a camel hair brush and waiting for ten minutes for any movement to occur. Responses of cockroaches to the various experimental set up were noted and written down and the parameters used in taking records included the knock down time and rate of mortality per minute/hours. Four hours was used, because that is the maximum time used for insect bioassay or toxicity test as long as it is in contact with the insect.

Statistical analysis

Statistical analysis of the results was also done after the results have been ascertained and its corresponding mean and standard deviation were recorded against time. This was done using the equations:

\[
\text{Mean} = \frac{\sum FX}{\Sigma F} \\
\text{Standard deviation} = \sqrt{\frac{\sum (x - \bar{x})^2 \cdot n}{\Sigma F - 1}}
\]

The lethal time value (LT₅₀) and the regression slope for each treatment were obtained using probit analysis (SPSS 2000). Mean percentage of insect mortality value was subjected to arcsine transformation. Means were compared using LSD test (SPSS 2000).

RESULTS

Mortality rate in B. germanica exposed to diluents and insecticides

Mortality in B. germanica exposed to diesel and water

Insects exposed to diesel started dying at 20 and 30 min after treatment in disinfestation (I₀) and fumigation (I₅₀) chambers, respectively. The highest mortality of 43.3% was recorded in fumigation chambers at 4 h after treatment (I₅₀). No mortality was recorded on insects exposed to water treatment (Table 1).

Acute and residual effect of aqueous and diesel diluted Deltamethrin and Chlorpyrifos exposed to B. germanica

In aqueous Deltamethrin, mortality of B. germanica was recorded after 30 and 45 min for the and 5% (v/v) treatments, respectively. The highest mortality recorded (53.3%) was in 2.5% (v/v) (I₅₀-Disinfestation) (Table 2). On the other hand, 100% mortality was recorded after 45 min in all the replicates and treatments with diesel diluted Deltamethrin.

At one week after treatment, mortality was recorded after 30 min (Table 3) with 5% (I₅₀-fumigation) and 2.5% (v/v) (I₅₀-disinfestation) having the highest (30%) and least mortalities (13.3%), respectively. On Diesel diluted Deltamethrin, mortality was recorded at 15 minutes and highest mortality (40%) was recorded at 4 h after introducing the insects in the fumigation and disinfestation chambers.

No mortality was recorded for B. germanica on water diluted Deltamethrin at 2 weeks after treatment until after 4 h with 5% (v/v) (I₅₀-fumigation) having the highest mortality (10%). On the other hand, diesel diluted Deltamethrin had less than 20% mortality at 2 h after introducing the insects. 5% (v/v) (I₅₀-fumigation) had the highest mortality of 16.7%, respectively (Table 4).

Acute and residual effect of aqueous and diesel-diluted Chlorpyrifos on B. germanica

Mortality of B. germanica exposed to Chlorpyrifos was dose-dependent. Chlorpyrifos (5% (v/v) mixed with diesel applied to B. germanica in the fumigation and disinfestation chambers gave 100% mortality at 30 min after treatment while 100% mortality was recorded at 2 h (I₀) and 3 h (I₅₀) at same concentration with aqueous Chlorpyrifos (Table 5).

No death was recorded in all replicates at one week after treatment until 30 min of exposure, while 5% (v/v) (I₅₀-fumigation) had the highest mortality (33.3%) after 4 h (Table 6).

On the other hand, there was no mortality count for B. germanica introduced two weeks post-treatment, until after 4 and 3 h exposure to aqueous and oil-based Chlorpyrifos, respectively. Higher concentration of 5% v/v, recorded 23% mortality, after 4 h exposure in the fumigation chambers (Table 7).

A summary of the immediate and residual effect of Deltamethrin and Chlorpyrifos after 4 h exposure is shown in Table 8. In all, percentage mortality was directly dose-dependent and inversely time-dependent. 100%
Table 2. Mean mortality of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (initial).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀ &amp; Iₐ</td>
<td>I₀</td>
<td>Iₐ</td>
<td>I₀</td>
<td>Iₐ</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>56.70±23.10</td>
<td>86.70±5.80</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>80.00±10.00</td>
<td>83.30±5.80</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>96.70±5.80</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>6.70±11.60</td>
<td>23.30±20.80</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>6.70±11.60</td>
<td>26.70±15.30</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>10.00±0.00</td>
<td>30.00±17.30</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>30.00±17.30</td>
<td>16.70±5.80</td>
<td>33.30±11.60</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>43.30±28.90</td>
<td>16.70±5.80</td>
<td>43.30±5.80</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>34 h</td>
<td>0.00±0.00</td>
<td>53.30±11.60</td>
<td>23.30±15.30</td>
<td>43.30±5.80</td>
<td>100.00±0.00</td>
</tr>
</tbody>
</table>

Table 3. Residual effect (mortality) of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (one week).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀ &amp; Iₐ</td>
<td>I₀</td>
<td>Iₐ</td>
<td>I₀</td>
<td>Iₐ</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
<td>30.00±0.00</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
<td>30.00±0.00</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
<td>30.00±0.00</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>33.30±5.80</td>
<td>26.70±15.30</td>
<td>36.70±5.80</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>33.30±5.80</td>
<td>26.70±15.30</td>
<td>36.70±5.80</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>20.00±0.00</td>
<td>30.00±0.00</td>
<td>36.70±5.80</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>6.70±5.80</td>
<td>30.00±0.00</td>
<td>30.00±0.00</td>
<td>36.70±5.80</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
<td>33.30±5.80</td>
<td>26.70±15.30</td>
<td>36.70±5.80</td>
</tr>
<tr>
<td>4 h</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
<td>33.30±5.80</td>
<td>26.70±15.30</td>
<td>36.70±5.80</td>
</tr>
</tbody>
</table>

I₀ = Disinfestation; Iₐ = fumigation.

Mortality was recorded in *B. germanica* when newly introduced to both aqueous and oil-based Chlorpyrifos as well as Deltamethrin in both fumigation and disinfestation chambers. Diesel exposed to *B. germanica* gave 43 and 36% mortality in fumigation and disinfestation chambers, respectively. Residual effect of Deltamethrin and Chlorpyrifos recorded a maximum of 40% after 4 h in one week after treatment in the
Table 4. Residual effect (mortality) of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (two weeks).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀ &amp; Iₓ</td>
<td>I₀</td>
<td>Iₓ</td>
<td>I₀</td>
<td>Iₓ</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>3.30±5.80</td>
<td>3.30±5.80</td>
<td>3.30±5.80</td>
<td>10.00±0.00</td>
</tr>
<tr>
<td>4 h</td>
<td>0.00±0.00</td>
<td>3.30±5.80</td>
<td>3.30±5.80</td>
<td>3.30±5.80</td>
<td>10.00±0.00</td>
</tr>
</tbody>
</table>

I₀ = Disinfestation; Iₓ = fumigation.

Table 5. Mean mortality of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (initial).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
<th>15/300ML</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀ &amp; Iₓ</td>
<td>I₀</td>
<td>Iₓ</td>
<td>I₀</td>
<td>Iₓ</td>
<td>I₀</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>26.70±37.90</td>
<td>33.30±32.20</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>10.00±17.30</td>
<td>60.00±10.00</td>
<td>56.70±20.80</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>50.00±17.30</td>
<td>40.00±30.00</td>
<td>63.30±15.30</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>76.70±5.80</td>
<td>86.70±11.60</td>
<td>76.70±5.80</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>83.30±15.30</td>
<td>93.30±5.30</td>
<td>93.30±5.30</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>93.30±5.30</td>
<td>93.30±5.30</td>
<td>93.30±5.30</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
</tr>
<tr>
<td>4 h</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
<td>100.00±0.00</td>
</tr>
</tbody>
</table>

I₀ = Disinfestation; Iₓ = fumigation.

Fumigation chambers.

In the fumigation chambers, LT₅₀ of aqueous Deltamethrin and Chlorpyrifos (5% (v/v)) were 195 and 15 min respectively, while Deltamethrin and Chlorpyrifos mixed with diesel were 9 and 6 min respectively. While under disinfestation chambers,
Table 6. Mean residual effect (mortality) of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (one week).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>l</em>&lt;sub&gt;0&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;c&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;0&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>16.70±5.80</td>
<td>13.30±5.80</td>
<td>20.00±0.00</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>16.70±5.80</td>
<td>13.30±5.80</td>
<td>20.00±0.00</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>20.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>20.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>20.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>4 h</td>
<td>0.00±0.00</td>
<td>20.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
</tbody>
</table>

*i*<sub>0</sub> = Disinfestation; *l*<sub>c</sub> = fumigation.

Table 7. Mean residual effect (mortality) of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (two weeks).

<table>
<thead>
<tr>
<th>Time</th>
<th>Control</th>
<th>Water 2.5% (v/v)</th>
<th>Water 5% (v/v)</th>
<th>Diesel 2.5% (v/v)</th>
<th>Diesel 5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><em>l</em>&lt;sub&gt;0&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;c&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;0&lt;/sub&gt;</td>
<td><em>l</em>&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>5 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>10 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>15 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
</tr>
<tr>
<td>20 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>16.70±5.80</td>
</tr>
<tr>
<td>30 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>45 min</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
<td>0.00±0.00</td>
</tr>
<tr>
<td>1 h</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>2 h</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>3 h</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
<tr>
<td>4 h</td>
<td>0.00±0.00</td>
<td>10.00±10.00</td>
<td>26.70±5.80</td>
<td>30.00±0.00</td>
<td>33.30±11.60</td>
</tr>
</tbody>
</table>

*i*<sub>0</sub> = Disinfestation; *l*<sub>c</sub> = fumigation.
Table 8. Percentage mortality after four hours of exposure.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2.5% (v/v)</th>
<th>5% (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I₀ (%)</td>
<td>I₅ (%)</td>
</tr>
<tr>
<td>Diesel Control</td>
<td>36</td>
<td>43</td>
</tr>
<tr>
<td>Water Initial</td>
<td>53</td>
<td>23</td>
</tr>
<tr>
<td>Deltamethrin/water One week</td>
<td>16</td>
<td>13</td>
</tr>
<tr>
<td>Deltamethrin/water Two weeks</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Deltamethrin/diesel Initial</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Deltamethrin/diesel One week</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>Deltamethrin/diesel Two weeks</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Chlorpyrifos/water Initial</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Chlorpyrifos/water One week</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Chlorpyrifos/water Two weeks</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Chlorpyrifos/diesel Initial</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Chlorpyrifos/diesel One week</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Chlorpyrifos/diesel Two weeks</td>
<td>10</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 9. Lethal time values for Deltamethrin (initial).

<table>
<thead>
<tr>
<th>Lethal time</th>
<th>Aqueous 2.5% (v/v) I₀</th>
<th>I₅</th>
<th>I₀</th>
<th>I₅</th>
<th>Diesel 2.5% (v/v) I₀</th>
<th>I₅</th>
<th>I₀</th>
<th>I₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>LT₅ (minutes)</td>
<td>49</td>
<td>67</td>
<td>45</td>
<td>16</td>
<td>6</td>
<td>7</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>LT₅₀ (minutes)</td>
<td>209</td>
<td>528</td>
<td>358</td>
<td>195</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>LT₉₅ (minutes)</td>
<td>880</td>
<td>4000</td>
<td>3000</td>
<td>2000</td>
<td>19</td>
<td>11</td>
<td>18</td>
<td>16</td>
</tr>
</tbody>
</table>

the LT₅₀ was 358, 9, 37 and 12 min, respectively (Tables 9 and 10).

DISCUSSION

The study evaluated the effectiveness of two insecticides Chlorpyrifos (an organophosphate) and Deltamethrin (a Pyrethroid) on the control of the German cockroach, B. germanica. Only aqueous and oil-based Chlorpyrifos and Deltamethrin (oil based) gave 100% mortality of B. germanica within the four hours of exposure period. However, the efficacy of both diluents decreased with increase in residual time.

The experiment shows that Chlorpyrifos was more effective than Deltamethrin at the concentration used. The LT₅₀ of (5% (v/v)) aqueous Chlorpyrifos for both disinfestation (13 min) and fumigation (5 min) trials against B. germanica were found to be lower when compared with those exposed to aqueous Deltamethrin (358 and 195 min, respectively), of same concentrations and conditions. Moreover, mortality responses (5% (v/v)) of aqueous Chlorpyrifos for both disinfestations and fumigation trials against B. germanica were found to be higher than those of insects exposed to aqueous Deltamethrin. A similar trend was observed in the diesel-diluted insecticidal exposure at both concentrations for fumigation and disinfestation against B. germanica.

Diesel-diluted insecticidal treatments recorded significantly higher mortality responses than those of aqueous treatments for all concentrations against B. germanica. This result is in conformity with the findings of Limoe et al. (2001), Robison et al. (1999) and Enayati et al. (2007), who revealed that Cypermethrin was more effective than Deltamethrin (Deltamethrin) in the control of B. germanica. In a research carried out by Shahi et al. (2008) toxicity of cypermethrin, deltamethrin, diazinon, lambda-cyhalothrin and Negon® (permethrin+propoxur) commercial formulations were investigated against adult German cockroaches collected in different areas of Bandar Abbas City, southern Iran. Maximum mortality rates of 20, 35, 90 and 100% were obtained after one
hour contact with label-recommended doses of cypermethrin, deltamethrin, lambdacyhalothrin, diazinon and permethrin+propoxur insecticides, respectively. This result is not in conformity with other researches done on the B. germanica using cypermethrin and deltamethrin, as higher mortality was recorded using Deltamethrin than in Cypermethrin. The findings however, of Shahi et al. (2008) on the effects of both insecticides on B. germanica, as well as those of Spring (2010) and Cakir et al. (2008) on other insect pests revealed that Cypermethrin was more effective than Deltamethrin. This study also revealed that fumigation treatments were more effective than dis-infestation treatments in the control of B. germanica. The results on the residual effect (one and two weeks respectively) of Chlorpyrifos and Deltamethrin were in conformity with the findings of Enayati et al. (2007) and Spring (2010).

Results from this study revealed a higher insecticidal effect of Chlorpyrifos over Deltamethrin (for both fumigation and disinfestation) against B. germanica. Chlorpyrifos had a faster knock down effect and higher percentage mortality than Deltamethrin, and this was observed for both concentrations and diluents used for the study. The importance of this finding implies that Chlorpyrifos (organophosphate) insecticides may be adopted for the control of B. germanica within Lagos metropolis. The diesel-diluted treatments were more effective than aqueous treatment for both insecticides. The residual properties of both insecticides followed a similar trend observed in initial exposure. The mortality response was however relatively low (<40%) for both insecticides at the maximum time lapse of two weeks. This implies that both insecticidal agents will perhaps become ineffective over a 2-week duration, hence the need to reapply these chemicals when necessary. Ultimately, the sustainable control of B. germanica in the long-term will involve various approaches in an integrated manner in order to safeguard the ecosystem for other organisms.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES


Susceptibility test of female anopheles mosquitoes to ten insecticides for indoor residual spraying (IRS) baseline data collection in Northeastern Nigeria


1Department of Biological Sciences, University of Maiduguri, Maiduguri, Borno State, Nigeria.
2Department of Crop Protection, University of Maiduguri, Maiduguri, Borno State, Nigeria.
4Federal Ministry of Health, Abuja, Nigeria.
5Department of Biology, Abubakar Tafawa Balewa University, Bauchi, Bauchi State, Nigeria.
6Department of Biology, College of Education, Azare, Azare, Bauchi State, Nigeria.
7Bauchi State Malaria Control Booster Project, Bauchi, Bauchi State, Nigeria.

Malaria is a major public health problem in Nigeria, accounting for about 60% of all outpatient attendances and 30% of all hospital admissions. Indoor residual spraying (IRS) was scaled up in Nigeria to supplement long lasting insecticide treated nets (LLINs) for malaria vector control. The success of IRS partly depends on the susceptibility of local anopheles mosquitoes to insecticides. The WHO standard insecticides-impregnated papers and tubes were used to conduct bioassay tests against local populations of Anopheles species in Misau Bauchi State Nigeria with a view of selecting the suitable insecticides for IRS. The tests papers include: Cyfluthrin (0.15%), DDT (4%), Deltamethrin (0.05%), Lambda-cyhalothrin (0.05%), Malathion (5%), Permethrin (0.75%), Propoxur (0.01%), Cypermethrin (0.75%), Bendiocarb (0.1%), Bifenthrin (0.15%) and untreated (control). Twenty (20) two to three day-old, female Anopheles species, glucose fed, none blood fed, were exclusively used in the bioassay per treatments which was replicated three times. The post exposure 1 h knockdown and 24 h mortality was assessed. The results of the knockdown assessment indicate that Alfacypermethrin had the lowest KD50 (time taken to knockdown fifty percent of the exposed mosquitoes) value of 4.8 min. Relatively moderate KD50 values (minutes) were obtained with Propoxur (11.34), Deltamethrin (13.20), Malathion (15.82), Bendiocarb (17.29), Permethrin (18.43), Cyfluthrin (20.28) and Lambda-cyhalothrin (23.11). Relatively higher KD50 values were obtained with Bifenthrin (27.29) and DDT (32.12) impregnated papers. The results of mortality assessment indicate that Anopheles mosquitoes were susceptible to Alfacypermethrin, Malathion and Propoxur with 100% mortality. The Anopheles species were less susceptible to Bifenthrin, Lambda-cyhalothrin, Permethrin, Deltamethrin, Bendiocarb, Cyfluthrin and DDT. The Anopheles species used in the tests were morphological identified as Anopheles gambiae, Anopheles funestus and Anopheles nili. The public health significance of these findings is discussed.

Key words: Nigeria, Anopheles mosquitoes, resistance, Misau, Bauchi State, indoor residual spraying (IRS).
INTRODUCTION

WHO current estimates show that malaria mortality rates were reduced by about 42% globally and by 49% in the WHO African Region between 2000 and 2012 and during the same period, malaria incidence rates declined by 25% around the world, and by 31% in the African Region (WHO, 2013a).

In Nigeria, malaria accounts for 60% of outpatient visits to health facilities, 30% of childhood deaths, 25% of death in children under one year and 11% maternal death in addition to about 132 billion naira financial loss in the form of treatment costs, prevention, loss of man-hours, etc in Nigeria (FMoH/ NMCP, 2009). In Nigeria, the economic impact of malaria can be attributed to low gross national income per capital (GNI) of US$260 (FMoH, 2005).

In recent times, IRS is being adopted and scaled up to protect the entire household and community members who possibly have no access to treated bed nets in Africa (Beier et al., 2008).

The Federal Government Policy on Malaria Control in Nigeria focuses on LLINs, IRS, intermittent preventive treatment (IPT) and environmental management (NMCP, 2014). In line with these strategies, the National Malaria Elimination Programme (NMEP) in Nigeria has scaled up indoor residual spraying (IRS) to achieve 85% coverage in 20% of eligible structures in Nigeria in 2014. To achieve these target, IRS activities was progressively expanded in the seven World Bank Supported Malaria Booster States of Bauchi, Gombe, Kano, Jigawa, Rivers, Anambra, Akwa Ibom states, Nigeria from 2009 to 2014 to supplement LLIN and environmental management.

Currently, WHOPES recommends 12 insecticide compounds and formulations, belonging to four chemical classes, for deployment in IRS program (WHO, 2009). The major challenge in use of these insecticides in malarial vector control has been the development of resistance to insecticides among the vector populations. Anopheles mosquitoes resistance to insecticides is spreading rapidly across African countries (Awolola et al., 2002, 2005, 2007; Ndams et al., 2006; Oduola et al., 2010; Ranson et al., 2011; Kabula et al., 2012; Natacha et al., 2013; Ibrahim et al., 2014) and could reduce the impact of malaria prevention interventions using IRS and LLINs, particularly in sub-Saharan Africa (NGuessan et al., 2007; Awolola et al., 2008).

The successful implementation of IRS program partly depends on availability of insecticide(s) susceptible Anopheles mosquitoes in the local environment. Therefore, it is imperative to periodically conduct bioassays tests to assess the susceptibility status of local mosquito species to IRS interventional insecticides. The susceptibility of Anopheles mosquitoes against insecticides was fairly evaluated in southern parts of Nigeria (Olayemi et al., 2011; Oduola et al., 2012) but there was dearth of information in the northern Nigeria (Molta and Ali, 1998; Ndams et al., 2006). No documented evidence on the susceptibility status of Anopheles mosquitoes to guide procurement of IRS insecticide in Northeast Nigeria is available. Therefore, the presents study was conducted to provide baseline data on insecticides susceptibility status of local Anopheles mosquito in Misau, Bauchi State, Nigeria.

MATERIALS AND METHODS

Study area and period

The study was conducted in August 2010 in Misau town, Misau L.G.A located at latitude 11.31897 and longitude 10.47587, human population of 263,487 as at the 2006 census with an area of 1,226km². IRS was scaled up in 2009 in the three wards of Misau (Gundari, Kukadi A and Kukadi B) where Lambda-cyhalothrin, Deltamethrin and bifenthrin respectively were used. The total coverage for insecticides was 52,000 households. The community has been using LLINs since 2002 till date. The farmers in the suburb cultivate vegetables, rice and wheat on the wetlands where agrochemicals (cypermethrin, lambda-cyhalothrin, deltamethrin, dichlovos and primiphos-methyl) are used in pest control. The wetlands also has number of tube bore holes to supplement provision of portable water to Misau community. Pools of standing water from the wetlands and tube bore holes provide active breeding sites for the Anopheles mosquitoes.

Mosquito collection and rearing

The Anopheles species larvae were collected in naturally infested waterbodies in Misau using entomological ladies. When culicine larvae were collected, they were separated from the Anopheline larvae and discarded on the land. The emerging pupae were sucked out of the larval containers using pipette and kept in plastic cups inside a mosquito cage made from five (5) litres white plastic bucket, fastened with cone shape white mosquito netting with its rear end tied in to a knot to prevent escape of emerging adult mosquitoes. The adult that emerged in 1-3 days were reared according to methods of Umar et al. (2008).

Test kits and insecticide impregnated papers

The WHO susceptibility test kits (WHO tubes and accessories) and insecticide impregnated papers (0.75% Alpha-cypermethrin, 0.1% Bendiocarb, 0.15% Bifenthrin 0.15% Cyfluthrin, 4% DDT, 0.05% Deltamethrin, 0.05% Lambda-cyhalothrin, 5% Malathion, 0.75%, Permethrin, 0.01% Propoxur and untreated control) were provided by the National Malaria Elimination Program (NMEP), Federal Ministry of Health, Abuja.

*Corresponding author. E-mail: aumar66.ng@gmail.com.

Author(s) agree that this article remain permanently open access under the terms of the Creative Commons Attribution License 4.0 International License.
Bioassay techniques

Insecticide susceptibility tests were carried out using the WHO standard procedures and test kits for adult mosquitoes (WHO, 1998). The bioassay was conducted using 2-3 days old, glucose-fed but non-blood fed female Anopheles mosquitoes.

For each insecticidal paper and the control, a three replicates of 20 adult female Anopheles mosquitoes were exposed to tubes and allowed to stand for 1 h and numbers of knocked-down mosquitoes were recorded at intervals of 10 min. After the exposure, mosquitoes were then transferred to a recovery tubes and fed with a pad of cotton wool soaked in 10% glucose solution. The holding tubes were kept for 24 h in a secluded, shaded and sterile place. Adult mortality was assessed after 24 h post-exposure by inability to stand upright and walk when probed with glass rod. The dead and survived mosquitoes at the end of experiment were separately kept in labeled 1.5 mL Eppendorf tubes containing silica gel, for species identification. The susceptibility tests were conducted in laboratory under fluctuating temperature (25-33°C) and relative humidity (90-95%).

Identification of Anopheles mosquitoes

Morphological keys of Gillies and DeMeillon (1968) and Gillies and Coetzie (1987) were used in morphological identifications of adult Anopheles mosquitoes.

Data analysis

The knockdown data was subjected to probit analysis using a statistical software (Statsdirect, 2013) to compute the KDT50 and KDT90 (time taken to knockdown 50 and 90% of the exposed mosquitoes) and their 95% confidence intervals. The 24 h mortality was manually assessed. The susceptibility of Anopheles mosquitoes to insecticides was assessed using the current WHO (2013b) criteria: A mortality in the range 98-100% indicates susceptibility and a mortality of less than 98% is suggestive of the existence of resistance. The adult mortality in control experiments were less than 5% and hence were not corrected for (Abbott, 1925).

RESULTS

The results of knockdown assessment of female Anopheles mosquitoes exposed to ten different insecticide impregnated papers is presented in Table 1. The results indicates that Alphacypermethrin has the lowest KDT50 and KDT90 values of 4.84 and 24.58 min while Bifenthrin had the highest KDT50 and KDT90 value of 27.29 and 85.95 min among all the pyrethroids tested. Among the cabamates, propoxur was most effective with KDT50 and KDT90 values of 11.35 and 17.30 min than bendiocarb with KDT50 and KDT90 values of 17.87 and 30.68 min, respectively. Malathion and DDT had lower KDT50 and KDT90 values of 15.82 and 29.22 min and higher 32.12 and 65.31 min, respectively.

The results of the 24 h post-exposure mortality presented in Table 2 indicate that the local Anopheles mosquito species were susceptible to Alphacypermethrin, Propoxur and Malathion with 100%. The tested Anopheles mosquito were resistant to Cyfluthrin (55.00%), DDT (78.33%), deltamethrin (83.33%), Lambdaclathothrin (93.33%), Bifenthrin, Permethrin and Bendiocarb (96.67% each). The morphological identifications of stored Anopheles mosquito revealed A. gambiae, A. funestus and A. nili. The members of the Anopheles gambiae and Anopheles funestus were not identified using polymerase chain reactions (PCR) techniques.

DISCUSSION

The present study presents for the first time baseline data on the susceptibility status of Anopheles mosquitoes to WHOPES approved IRS insecticides in Misau, Bauchi State, Northeastern Nigeria to guide procurement of IRS insecticides in the state.

The results of knockdown assessment showed that the tested insecticidal papers induced knockdown of adult Anopheles mosquitoes suggesting that knockdown mechanism could be operating in the local Anopheles mosquito populations. This confirm earlier studies which separately indicates the knockdown effects of impregnated papers against Anopheles mosquitoes in Nigeria (Awolola et al., 2005; 2007; Oduola et al., 2010; Olayemi et al., 2011; Oyewole et al., 2011; Ibrahim et al., 2014). The knockdown of Anopheles mosquitoes exposed to insecticidal papers indicates the presence of KDR resistance mechanism (Kristan et al., 2003; Awolola et al., 2007; Ibrahim et al., 2014) operating in the populations of Anopheles mosquitoes in Misau.

Using the WHO (2013b) criteria for insecticides susceptibility or resistance assessment of mosquitoes, the 24 h post-exposure results indicates that the local Anopheles mosquito species were susceptible to alphacypermethrin, propoxur and malathion each with 100% mortality. Other Principal Investigators for IRS working in Northern Nigeria shown that local Anopheles mosquito species were particularly susceptibility to alphacypermethrin (Mwansat, 2012; Manu, 2013, Yoriyo, 2013).

The local Anopheles mosquito species were resistant to Cyfluthrin, Deltamethrin, Permethrin, Lambdaclathothrin, Bifenthrin, Bendiocarb and DDT. Previous reports have documented evidence on resistant of Anopheles mosquitoes to Cyfluthrin (Coetzee et al., 2006); Deltamethrin (Betson et al., 2009; Oduola et al., 2012; Awolola et al., 2014); Permethrin (Abdalla et al., 2007; Awolola et al., 2007, 2012, 2014; Ramphul et al., 2009; Kemabonta et al., 2013); Lambdaclathothrin (Awolola et al., 2014 ); Bendiocarb (Ibrahim et al., 2013) and DDT (Betson et al., 2009; Oduola et al., 2010, 2012). Sustainable insecticide resistance management strategy is imperative to avoid control failures when the resistant insecticides are used for IRS program in Bauchi State. There is need for periodic monitoring of insecticide resistance in malaria control programmes in Bauchi State, as it affects ITNs and IRS interventions across Africa (Awolola et al., 2008).
Table 1. Knockdown periods of anopheles mosquitoes exposed to ten insecticide impregnated papers in Misau, Bauchi State, Nigeria.

<table>
<thead>
<tr>
<th>Insecticide group</th>
<th>Insecticidal paper</th>
<th>Concentration (%)</th>
<th>Number exposed</th>
<th>KD$_{90}$ (min)</th>
<th>95% Confidence interval</th>
<th>KD$_{90}$ (min)</th>
<th>95% Confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroids</td>
<td>Bifenthrin</td>
<td>0.15</td>
<td>60</td>
<td>27.29</td>
<td>22.83-32.52</td>
<td>85.95</td>
<td>63.09-126.73</td>
</tr>
<tr>
<td></td>
<td>Lambdacyhalothrin</td>
<td>0.05</td>
<td>60</td>
<td>23.11</td>
<td>19.14-27.34</td>
<td>49.11</td>
<td>40.10-62.43</td>
</tr>
<tr>
<td></td>
<td>Alphacypermethrin</td>
<td>0.75</td>
<td>60</td>
<td>4.84</td>
<td>3.14-6.47</td>
<td>24.58</td>
<td>19.78-32.53</td>
</tr>
<tr>
<td></td>
<td>Permethrin</td>
<td>0.75</td>
<td>60</td>
<td>18.43</td>
<td>16.51-20.34</td>
<td>38.09</td>
<td>34.00-43.79</td>
</tr>
<tr>
<td></td>
<td>Cyfluthrin</td>
<td>0.15</td>
<td>60</td>
<td>20.28</td>
<td>17.63-22.66</td>
<td>40.48</td>
<td>36.17-46.74</td>
</tr>
<tr>
<td></td>
<td>Deltamethrin</td>
<td>0.05</td>
<td>60</td>
<td>13.20</td>
<td>10.12-16.89</td>
<td>36.79</td>
<td>27.45-51.13</td>
</tr>
<tr>
<td>Cabamates</td>
<td>Bendiocarb</td>
<td>0.1</td>
<td>60</td>
<td>17.87</td>
<td>14.25-21.78</td>
<td>30.68</td>
<td>25.28-38.24</td>
</tr>
<tr>
<td></td>
<td>Propoxur</td>
<td>0.01</td>
<td>60</td>
<td>11.35</td>
<td>10.34-12.43</td>
<td>17.30</td>
<td>15.46-20.30</td>
</tr>
<tr>
<td>Organochlorine</td>
<td>DDT</td>
<td>4.0</td>
<td>60</td>
<td>32.12</td>
<td>29.21-35.01</td>
<td>65.31</td>
<td>57.29-78.54</td>
</tr>
<tr>
<td>Organophosphate</td>
<td>Malathion</td>
<td>5.0</td>
<td>60</td>
<td>15.82</td>
<td>14.02-17.53</td>
<td>29.22</td>
<td>26.20-33.45</td>
</tr>
</tbody>
</table>

Table 2. Mortality and susceptibility status of anopheles mosquitoes exposed to ten insecticide impregnated papers in Misau, Bauchi state, Nigeria.

<table>
<thead>
<tr>
<th>Insecticide group</th>
<th>Insecticidal paper</th>
<th>Concentration (%)</th>
<th>Number Exposed</th>
<th>No Dead</th>
<th>Mortality (%)</th>
<th>Susceptibility status*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroids</td>
<td>Bifenthrin</td>
<td>0.15</td>
<td>60</td>
<td>58</td>
<td>96.67</td>
<td>Resistance</td>
</tr>
<tr>
<td></td>
<td>Lambdacyhalothrin</td>
<td>0.05</td>
<td>60</td>
<td>56</td>
<td>93.33</td>
<td>Resistance</td>
</tr>
<tr>
<td></td>
<td>Alphacypermethrin</td>
<td>0.75</td>
<td>60</td>
<td>60</td>
<td>100</td>
<td>Susceptible</td>
</tr>
<tr>
<td></td>
<td>Permethrin</td>
<td>0.75</td>
<td>60</td>
<td>58</td>
<td>96.67</td>
<td>Resistance</td>
</tr>
<tr>
<td></td>
<td>Cyfluthrin</td>
<td>0.15</td>
<td>60</td>
<td>33</td>
<td>55.00</td>
<td>Resistance</td>
</tr>
<tr>
<td></td>
<td>Deltamethrin</td>
<td>0.05</td>
<td>60</td>
<td>50</td>
<td>83.33</td>
<td>Resistance</td>
</tr>
<tr>
<td>Cabamates</td>
<td>Bendiocarb</td>
<td>0.1</td>
<td>60</td>
<td>58</td>
<td>96.67</td>
<td>Resistance</td>
</tr>
<tr>
<td></td>
<td>Propoxur</td>
<td>0.01</td>
<td>60</td>
<td>60</td>
<td>100</td>
<td>Susceptible</td>
</tr>
<tr>
<td>Organochlorine</td>
<td>DDT</td>
<td>4.0</td>
<td>60</td>
<td>47</td>
<td>78.33</td>
<td>Resistance</td>
</tr>
<tr>
<td>Organophosphate</td>
<td>Malathion</td>
<td>5.0</td>
<td>60</td>
<td>60</td>
<td>100</td>
<td>Susceptible</td>
</tr>
</tbody>
</table>

*WHO scoring for resistance (WHO, 2013b).

The multiple insecticide resistances of Anopheles mosquitoes to the tested pyrethroids, carbamates and organochlorine insecticides may have grave implications for the malaria control programme. It may compromise the efficacy of interventions and potentially lead to the failure of IRS and ITNs based vector control (Awolola et al., 2008).

The resistance of Anopheles mosquitoes to bifenthrin, lambdacyhalothrin and deltamethrin may be linked to use of these insecticides in 2009 IRS intervention in the communities. It is established that prior exposure of mosquitoes to insecticides may induced selection pressure (Kerah-Hinzoumbé et al., 2008). Pyrethroids based aerosols and coils are used for control of mosquitoes and domestic pests and it might contribute to the development of resistance as reported elsewhere (Kristan et al., 2003). The farmers in the community also use cypermethrin, lambdacyhalothrin, deltamethrin, dichlovos and primiphos-methyl for agricultural crop protection. Previous researchers have reported that exposure of malarial vectors to crop protection insecticides could result in development of insecticide resistance (Etang et al., 2003; Awolola et al., 2007; Müller et al., 2008; Chouaibou et al., 2008; Bigoga et al.,...
2012; Philbert et al., 2014). LLIN was used in Misau for protection against mosquitoes since 2002 to date and it may induce selections to pyrethroids insecticides. Previous studies revealed that use of LLIN could result in development of insecticide resistance in Anopholes mosquitoes (Kabula et al., 2011).

The morphological analysis of preserved mosquito samples showed populations of A. gambiae, A. funestus and A. nili were used in the bioassays. A. gambiae is the principal vector of malaria in sub-Saharan Africa (Gillies and Coetzee, 1987; Samdi et al., 2006; Sinka et al., 2010). The fauna of A. gambiae, A funestus and A nili was earlier documented in northern Nigeria (Molineaux and Gramiccia, 1980; Gadzama, 1983; Molta et al., 1999; Samdi et al., 2006; Ahmed, 2013). The A gambiae and A. funestus are major malarial vector in Nigeria (Molineaux and Gramiccia, 1980) and have great implication in malaria transmission in Bauchi State. Therefore, periodic monitoring of insecticides resistance in this mosquito species is imperative to avoid vector control failures.

Conclusion

It is concluded that procurement of IRS insecticide(s) in the state should be guided by the results of the present study until new susceptibility status is established and resistance management strategies should be considered when using the less susceptible insecticides. It is recommended that future studies should focus on investigation on the A. gambiae and A. funestus complexes and elucidations of resistance mechanisms in these mosquito species.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

The authors sincerely thank the World Bank Supported Malaria Booster Project for supporting Bauchi State Malaria Control Booster Project and the National Malaria Elimination Programme for coordinating roles.

REFERENCES


Manu YA (2012). Personal communications; Susceptibility Status of Anopheles mosquitoes to insecticides in Jigawa State, Nigeria.


