Susceptibility and fecundity of Bedbugs (*Cimex hemipterus*) from Yaba College of Technology Lagos exposed to Selected Classes of Insecticides: A short report

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**ABSTRACT**

**Background:** Tropical bed bug, *Cimex hemipterus*, is a nocturnal obligate blood-sucking ectoparasite of humans that is highly prevalent in Nigeria. Bed bug controls heavily rely on the application of several insecticide-based formulations. Insecticide resistance in bed bug populations has been widely reported. In this study, we assessed the mortality of bed bugs following exposure to different classes of insecticides.

**Methodology:** Active adult female bed bugs were collected from students’ halls of residence and exposed to DDT (4%), permethrin (0.75), bendiocarb (0.1) and malathion (4%) insecticide-impregnated papers. Mortality and number of eggs laid by each exposed group were recorded at 90 minutes, 24hrs, 48hrs and 72hrs.

**Results:** The impact of the different assays on bugs mortality revealed DDT to produce a time-dependent outcome with the highest mortality rate [(36.7% (CI 32.7±38.9)), this was followed by Bendiocarb [31.6% (CI 27.2±35.1)]. In comparison, permethrin and malathion produced the same effect [26.7% (CI 23±30.5)] 24 hours post-exposure. In contrast, malathion and bendiocarb impacted the most mortality [53.3% (49.3±58.7) and 46.6%(42.2±49.5)], followed by permethrin [18.9% (CI 44.6±56.8) after 72 hours. The relative numbers of eggs produced by bedbugs in the DDT, bendiocarb and malathion assays were lower than what was observed in the control and permethrin group 24 hours after exposure. The highest reduction in egg production was observed in the malathion exposed group 48- and 72-hours post-exposure compared to the other insecticides and the control group.

**Conclusion:** This study revealed suspected insecticide resistance to all classes of insecticide used on bed bug populations in Lagos State, Nigeria.

**Keywords:** Bedbugs, Insecticides resistance, *Cimex hemipterus*, ectoparasites, Nigeria
1. INTRODUCTION

The tropical bed bug (*Cimex hemipterus*) is a nocturnal ectoparasite of the family Cimicidae that is commonly distributed in the tropical and subtropical regions of the world [1]. Like in many other developing nations, a high prevalence of bedbugs infestation has been reported in homes and school dormitories across Nigeria [2], with high frequency in untidy and congested households [3]. Bedbug infestation rates of above 50% have been reported in some communities across Nigeria [4, 5, 6]. In households, *C. hemipterus* usually hide in dry, dark places like in mattresses/pillows, carpets, furniture, abandoned appliances and walls/floors cracks [3], where they lay hundreds of eggs that hatch into the adult form.

Bedbug constitutes a public health nuisance even as the relationship between this pest species and humans is well documented and dates back before the Second World War; their bites could result in considerable discomfort, social stigmatisation and psychological stigmatisation distress [7]. Although *C. hemipterus* is not directly associated with disease transmission, they have been shown to aid in the mechanical transmission of plague, hepatitis B virus and tularemia [2, 8].

Following the invention of dichloro-diphenyl trichloro-ethane (DDT), among other insecticides, the elimination of bedbugs was considered successful, especially in the developed world, with a sudden decline experienced in their population [1]. In Nigeria, chemical control using permethrin, DDT, bendiocarb and malathion remain vital in managing most insect pests [1]. Regrettably, the resurgence of bedbugs’ resistance to insecticides has been reported in the last two decades due to indiscriminate and repeated overuse of insecticides. Moreover, the dissemination of mutant bedbugs due to unsupervised international travel has increased [8]. Furthermore, cimicid insects have been documented to be highly resistant to organochlorines, organophosphates (OPs), carbamates and pyrethroids worldwide [9, 10], thereby leaving pyrethroids as the most widely used class of insecticide for bedbug control [8].

Although bedbugs have displayed diverse resistance mechanisms such as penetration resistance through thickening of the cuticle, metabolic resistance by increased activities of detoxification enzymes and knockdown resistance by kdr mutations [11], especially in the developed countries, such information is scarce in the middle to low-income countries. Also, while resistance activities have been reported to chemical treatment in significant high-income countries [12], there is a lack of such information in the tropics, especially in Nigeria. Understanding bedbug susceptibility to chemical treatment is paramount if *C. hemipterus* is to be effectively managed in this part of the world. Against this background, we have evaluated the susceptibility status and fecundity of field-collected bedbugs to four classes of selected insecticides (permethrin, dichloro-diphenyl trichloroethane (DDT), bendiocarb and malathion) using WHO standard test kits. This finding will provide useful information for those attempting to manage bedbug infestations, such as pest management professionals and homeowners, in developing informed control strategies aimed at current and future infestations.

2. METHODOLOGY

2.1. Study Area: the study was conducted in Yaba College of Technology (YABATECH) Yaba, Lagos State, Nigeria hostels. Bedbugs were collected from seven randomly selected buildings from the Institution, namely four classrooms: Civil Engineering, New building, Mechanical Engineering and Multipurpose building and three hostels: Akata, New hall and PGD hall, respectively, after obtaining approval from the management of the institution.

Yabatech is a higher institution located in Yaba, Lagos (longitude 030 22E and latitude 060 30N). The student population is about 16,000, mostly from middle-low income homes. YABATECH has six student hostel accommodations that are usually beyond capacity: such condition favours bedbug infestation.

2.2. Sample Collection: Using convenient sampling, a total of two hundred and seventy (270) adult blood-fed female bedbugs were blood-fed (as observed by their reddish-brown colour with enlarged right compartment) were selected from a lot of bedbugs collected from crevices of the buildings as mentioned above, and randomly divided into the experimental and control group. Collections were done between 8 pm – 10 pm daily from May to August 2019, following the methods previously described by Punchihewa et al. [8]. The collected bedbugs were transferred to the YABATECH Environmental Biology Laboratory in well-labelled containers. They were maintained in aerated clean plastic containers at a temperature of 25±2°C and relative humidity of 75±10%. Identification was made based on morphological characteristics using a stereomicroscope. The collected samples were
maintained in the laboratory for 24 hours prior to insecticides bioassays.

2.3. Study Procedure: Insecticide susceptibility bioassay adapted from WHO mosquito insecticide bioassay was conducted using filter paper impregnated (with the active ingredient of each insecticide) with 0.75% permethrin, and 4% DDT, 0.1% bendiocarb and 5% malathion. The bioassays were carried out using the WHO insecticides test kit. The bedbugs were covered with tiny mesh at both ends to prevent them from escaping during exposure and supplied optimum air. Each bioassay contains fifteen adult female bedbugs exposed to the insecticide-impregnated papers; the assay was carried out in four replicates (making a total of 60 bedbugs exposed to each insecticide) and accompanied by control. The test tubes were constantly agitated during the exposure to ensure the bedbugs were on the insecticides impregnated papers. The insecticide exposure was carried out for 90 minutes, and the bedbugs were transferred to another aerated container with non-treated paper. Mortality and number of eggs produced were recorded at 90 minutes, 24, 48 and 72 hours. Mortality among the bedbugs was determined by gently moving each individual with forceps. Bedbugs were classified as dead when there was no response, lying on their backs with no movement of any body parts, and alive if there was a coordinated movement.

2.4. Statistical Analysis: Percentage and egg production mortality were computed per assay as follows

Percentage mortality = a number of dead bedbugs/ total number of bedbugs present at the start of each assay x 100.

Mean mortality per replicate was also computed. Mean mortality, which represents the total number of bedbugs deaths over the entire exposure duration, was calculated for each insecticide.

Egg production rate = number of eggs produced/ total number of bedbugs present per assay after each evaluated period (24, 48 and 72 hours) x 100

The mortality of bedbugs to insecticides exposure and time was determined using univariate analysis of variance and Duncan multiple range tests used for post hoc at 95% confidence interval and 0.05 p-value. For all analyses, the replicates of each specific insecticide were combined to give a total of 60 bedbugs. Further, as mortality in the control group was more than 10%, the Abbot formula was used to correct mortality in the test group as follows,

Corrected mortality = (mortality in test [%] - mortality in control [%]) x 100 / (100% - mortality in control bottle [%])

All analyses were done in IBM SPSS version 23.

3. RESULTS AND DISCUSSION

Bedbugs’ infestation has been reported to recently have a worldwide resurgence [13]. They have also been associated with stigmatisation, sleeplessness, and psychological and social distress [2, 14]. In Nigeria, there are not enough epidemiological studies on the distribution of bedbugs and their susceptibility status to various insecticides. Insecticidal resistance is a serious global public health challenge against pest and vector control efforts. As such, there is a need for constant monitoring and evaluation of the potency of major insecticides.

Evaluating the impact of the different assays on bugs mortality showed that DDT and permethrin produced a time-dependent outcome with the highest mortality rate (36.7% and 26.7% respective) recorded 24 hours post-exposure. In contrast, malathion and bendiocarb impacted the most mortality (53.3% and 46.6%) after 72 hours. Although moderate mortality, which is different from that of the control group, was observed after exposure to permethrin, however, no particular time pattern was noted as more mortality was recorded 24 and 72 hours (26.7% and 18.9%) post-exposure and less after 48 hours (15.9%) (Table 1). Together, the mortality rates observed from the insecticides (DDT, malathion and bendiocarb) exposed to bedbugs were statistically different from the non-exposed control group. This is in accordance with a previous study that also reported the efficacy of malathion and pyrethroids in killing bedbugs [15].

The relative numbers of eggs produced by bedbugs in the DDT, bendiocarb and malathion assays were lower than observed in the control 24 hours after exposure. At the same time, the effect of permethrin on fecundity was not much different from the control (Figure 1). Evaluation of the fecundity after 48 hours showed malathion to have the most potency against egg production, followed by permethrin, while DDT and bendiocarb displayed the same potency. Similarly, assessment of bedbugs’ fecundity after 72 hours revealed malathion to have the most potent outcome on egg reduction. Taken together, malathion showed a time-dependent potency after 72 hours (Figure 1).
The observation of a substantial reduction in egg production 48 and 72 hours after exposure to malathion is similar to a previous study that reported that high reduction in egg production after bedbugs were treated with moxidectin [14]. Thus malathion is shown to be efficient and has potency against *Cimex hemipterus*.

This study shows different levels of reduced susceptibility of *C. hemipterus* to the four selected insecticides at different time intervals. Therefore, a continuous and comprehensive evaluation of Cimex’s response to all classes of approved insecticides is needed. DDT which reduced not only bedbug survival rate but also their egg production rate could be safely recommended for use and would be more helpful in controlling the domestic nuisance caused by *C. hemipterus*.

Although, this study is limited in its study area and genetic evaluation of target genes in the bedbugs that might be associated with the reduced potency. Nevertheless, the results obtained here form the basis for future work involving varied study areas and genetic population analysis.

**Declaration of conflict of interest**

All authors declare that they have no conflict of interest.

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**Table 1: Percentage Mortality of bedbugs exposed to different insecticides**

<table>
<thead>
<tr>
<th>Insecticides</th>
<th>No exposed</th>
<th>24 hours mortality (CI)</th>
<th>48 hours mortality (CI)</th>
<th>72 hours mortality (CI)</th>
<th>Mean mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>30</td>
<td>0</td>
<td>6.7 (4.7±7.1)</td>
<td>10.5 (9.4±11.1)</td>
<td>4.5±1.0</td>
</tr>
<tr>
<td>DDT</td>
<td>60</td>
<td>36.7 (32.7±38.9)</td>
<td>28.9 (48.9±58.2)</td>
<td>14.8 (49.1±69.2)</td>
<td>9.3±2.02</td>
</tr>
<tr>
<td>Permethrin</td>
<td>60</td>
<td>26.7 (23.1±30.5)</td>
<td>15.9 (32.5±41.7)</td>
<td>18.9 (44.6±56.8)</td>
<td>7.5±2.7</td>
</tr>
<tr>
<td>Bendiocarb</td>
<td>60</td>
<td>31.6 (27.2±35.1)</td>
<td>41.7 (37.8±46.3)</td>
<td>46.6 (42.2±49.5)</td>
<td>7±1.30</td>
</tr>
<tr>
<td>Malathion</td>
<td>60</td>
<td>26.7 (23.1±30.3)</td>
<td>45 (42.7±48.7)</td>
<td>53.33 (49.3±58.7)</td>
<td>8±1.30</td>
</tr>
</tbody>
</table>

NB: Superscript a and b indicate similarities in mean values at P < 0.05. Ninety minutes post-exposure effect was excluded from further analysis since no mortality was recorded.

**Fig. 1** Daily eggs production rate in bedbugs after exposure to insecticides

* = p-value of <0.5; ** = p-value of <0.01
Authors’ contribution

IKF Conceptualised and conducted Formal analysis; MII, BTL, IKF carried out data curation; MAO, TSO, IKF wrote the original draft; MAO, TSO, AMA, IKF Wrote the review and did the editing. All authors approved the final version of the manuscript.

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