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EFFICACY AND RESISTANCE PATTERN OF SOME COMMONLY USED INSECTICIDES AGAINST ANOPHELES MOSQUITOES IN SIX LOCAL GOVERNMENT AREAS OF ADAMAWA STATE, NORTHEASTERN NIGERIA

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ABSTRACT
The global effort to control malaria vectors has been halted due to resistance mechanisms developed against various insecticides and their associated effects. This study evaluates the efficacy and resistance pattern of some commonly used insecticides against Anopheles mosquitoes using various insecticide concentrates. A ladle was used to collect Anopheles mosquito larvae in the study areas. The collected larvae were transferred to a plastic container and transported to the Institute of Infectious Diseases of Poverty (IIDP) laboratory in Modibbo Adama University, Yola, where the samples were reared to adulthood. Four separate batches of twenty-five (25) female Anopheles mosquitoes were subjected to the test papers of each impregnated insecticide for 1 hour at 27± 1°C and 80± 2% relative humidity. Similar batches were subjected to the non-impregnated insecticide paper as a control. After one hour of subjection, they were conveyed into a holding tube furnished with cotton drenched with a 10% sugar solution. Following 24 hours, mortality and susceptibility were observed and recorded. The findings showed that propoxur, bendiocarb, and pirimiphos-methyl showed 100% susceptibility across all Local Government Areas studied. In contrast, permethrin, deltamethrin, and DDT showed resistance across the Local Government Areas suggesting varying significant resistance levels. These findings outrageously emphasize the significance of ongoing surveillance, resistance management, and context-specific development for vector control strategies to combat malaria effectively in Adamawa state.

Keywords: Adamawa, Anopheles Mosquitoes, Efficacy, Insecticides, Resistance

INTRODUCTION
The Plasmodium parasite transmitted by female Anopheles mosquito causes a significant global health concern (WHO, 2018), and is a disease of public health significance (Aribodor *et al*., 2016). The 2018 World Malaria Report indicates that the African continent had malaria morbidity and mortality cases recorded at 93% and 94%, respectively (Dahan *et al*., 2020), however, there is a profound increase in the number of cases accounting for 94% and 95% of morbidity, and mortality, respectively (WHO, 2023), Nigeria alone recorded 25% of the total cases of malaria infection (WHO, 2019). In Kano State, Northwest Nigeria, a 60% – 65% prevalence was recorded irrespective of increased usage of impregnated bed nets and indoor insecticide usage across several studies (Dawaki *et al*., 2016; Oladele *et al*., 2018). Curtailing vector-borne associated diseases the most recommended and yielded outcomes is vector control strategies (WHO, 2019). The Anophelines are the major vectors of malaria, they comprise about 480 species, and only 80 are considered vectors. Except for Antarctica, malaria vectors were present in all parts of the world (Dahan *et al*., 2020). The *Anopheles gambiae sensu lato* happens to be a significant malaria vector having seven undifferentiated sibling species identified morphologically: *Anopheles gambiae sensu stricto*, *Anopheles arabiensis*, *Anopheles coluzzii*, *Anopheles melas*, *Anopheles merus*, *Anopheles amharicus* and *Anopheles bwambae* and together they are referred to as 'complex' or group (Ebenezer *et al*., 2012). Understanding the current resistance pattern by Anopheles mosquitoes to various insecticides across different localities will help identify insecticides that remain efficacious and may require modification. Therefore, this study presents the efficacy and resistance pattern of some commonly used insecticides against Anopheles mosquitoes in six Local Government Areas of Adamawa State, Northeastern Nigeria.

MATERIALS AND METHODS
Study Area
Adamawa State is situated in Northeastern Nigeria, it has a total land area of 38,700 km² with 4,502,132 estimated population. It lies between latitude 9º19'60.00''N and longitude 122º9'59'99''E. Three (3) states shared a border with Adamawa: Borno, Gombe, and Taraba States to the Northwest, West, and Southwest, respectively (Adebayo *et al*., 2020). The Adamawa eastern part shared a borderline with eastern Cameroon. Guinea and Sudan Savannah characterized the ecological vegetation of the region (NIPC, 2020). The rainfall pattern of the area is from 700mm to 1600mm (Akosim *et al*., 1999). The rainiest months are August and September, drought begins from November to April. January through March recorded the lowest relative humidity ranging from 20% to 30% with a steady increase from April to a peak of about 80% around August and September (Adebayo *et al*., 2020). Mubi-North is located at Lat. 10°06'-10°07-13'30'E, Mubi-South is located at Lat. 10°06'-10°29'N, Long. 13°07'13°30'E, Hong is located at Lat. 9°58'-10° 35°N, Long. 12° 35'-13'E, Gombi LGA is located at lat. 9°59'-10° 27'N, Long. 12°14-12°50'E, Jada LGA is located at Lat. 8°27'-8°54'N, Long. 11°55'-12°48'E and Mayo-Belwa LGA is located at Lat. 8°33-9°12'N, Long. 11°41'-12°11'E (Adebayo *et al*., 2020).

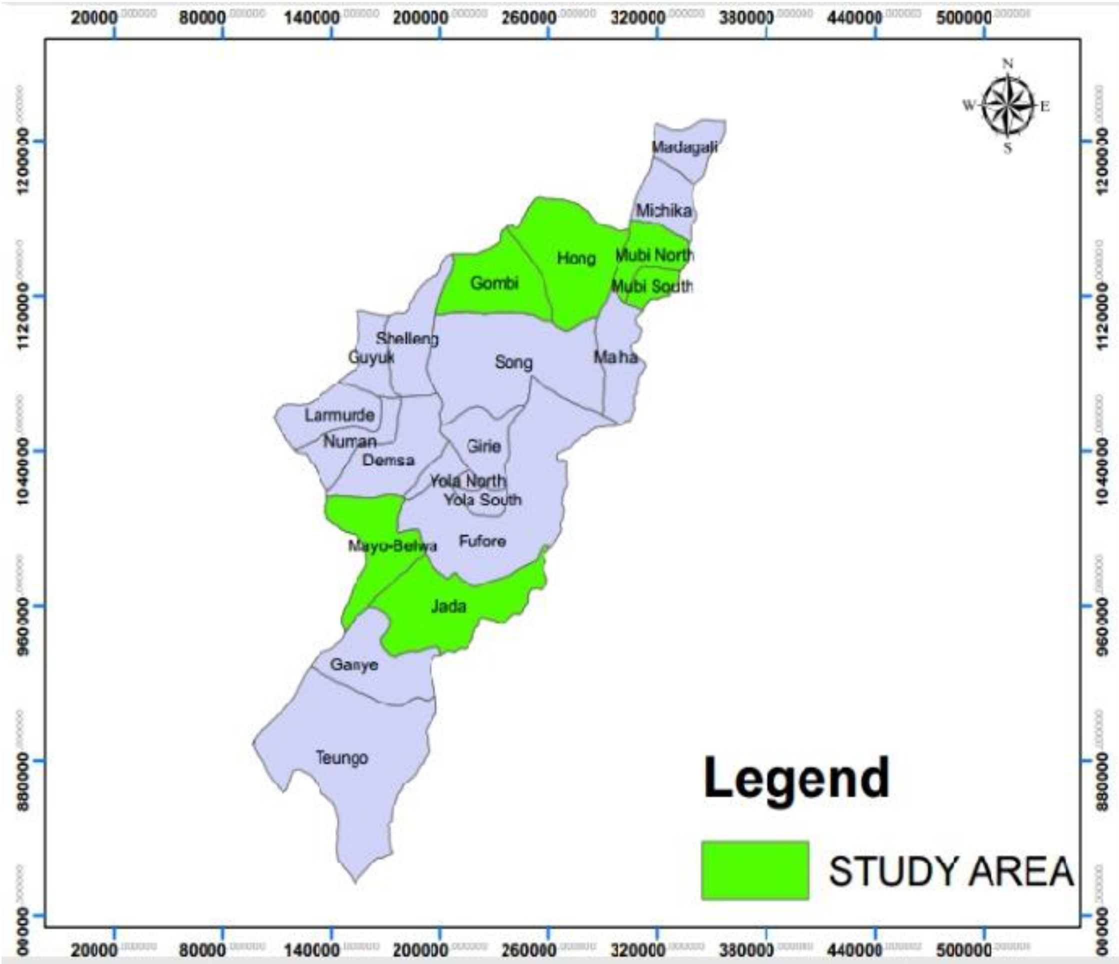

Figure 1: Map of Adamawa State highlighting the Study Area.

Larval Collection

Anopheles mosquito larvae were collected following the method described by WHO (2012). A ladle was used to collect Anopheles mosquito larvae in Mubi-North, Mubi-South, Hong, Gombi, Jada, and Mayo-Belwa Local Government Areas. The collected larvae were transferred to a plastic container and transported to the Institute of Infectious Diseases of Poverty (IIDP) laboratory in MAU Yola, where the samples were reared to adulthood.

Insecticides Susceptibility Assay

WHO-impregnated test papers containing 0.75% (permethrin), 0.05% (deltamethrin), 0.1% (propoxur), 0.1% (bendiocarb), 4% (DDT), and 0.25% (pirimiphos-methyl) were used for the tests, following WHO operational procedures (WHO, 2013).

Four separate batches of twenty-five (25) female Anopheles mosquitoes (non-blood-fed 2-5 days old) were subjected to the test papers of each impregnated insecticide for 1 hour at 27± 1°C and 80± 2% relative humidity. Similarly, twenty-five (25) separate batches of female Anopheles mosquitoes were subjected to the non-impregnated insecticide paper as a control. After one hour of subjection, they were conveyed into a holding tube furnished with cotton drenched with a 10% sugar solution. Following 24 hours, mortality was observed and recorded, and the susceptibility status was determined following WHO criteria (WHO, 2016).

Data Analysis

The data was analyzed and interpreted according to WHO criteria (WHO, 2016). A mortality rate between 98% and 100% indicates susceptibility, 90% to 97% suggests possible resistance and less than 90% indicates resistance.

RESULTS AND DISCUSSION

The susceptibility test results indicated that the percentage mortality of permethrin varied across the LGAs from 31-39%. In Jada (39%) and Mubi-North (38%), Mayo-Belwa exhibits the lowest mortality percentage at 32%. The percentage mortality of deltamethrin ranges from 32% to 43%. Jada recorded the highest mortality at 43%, while Mubi-South showed the lowest mortality at 32%. There is a notable variability in the susceptibility status of deltamethrin levels across the LGAs evaluated. The percentage mortality of DDT ranged from 25% to 31%. Mubi-North records the highest mortality at 31% while Mayo-Belwa exhibits the lowest mortality at 25%. The concentration of DDT demonstrates a moderate degree of variability across all LGAs evaluated. However, bendiocarb, propoxur, and pirimiphos-methyl maintained a constant percentage mortality of 100% across all LGAs. (Figure 2).

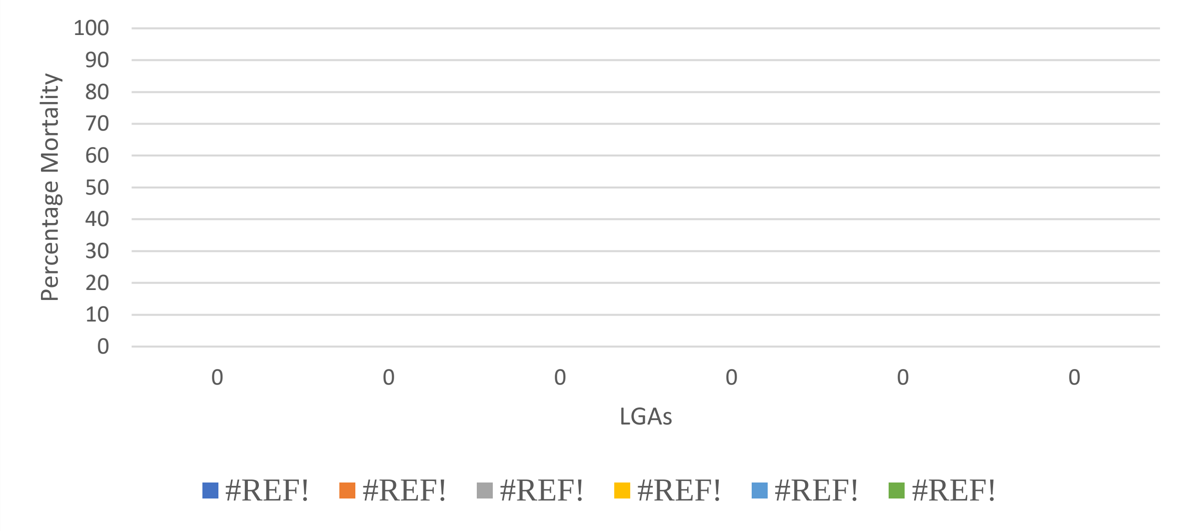

Figure 2: Susceptibility status of various insecticides to in area

Discussion

The susceptibility status of Anopheles mosquitoes in our study revealed that propoxur, bendiocarb, and pirimiphos-methyl were susceptible across all LGAs, confirming their efficacy. The efficacy of propoxur, bendiocarb, and pirimiphos-methyl suggests they could be alternative insecticides for malaria vector control. They can be incorporated into vector control strategies rarely used in Nigeria e.g., for Indoor Residual Spray (IRS). However, it's important to consider other factors such as cost, and environmental impact, when selecting insecticides for vector control. In contrast, permethrin, deltamethrin, and DDT showed resistance across the LGAs. The apparent resistance of Anopheles mosquitoes to permethrin, deltamethrin, and DDT in these areas suggests that reliance on these insecticides may be less effective for vector control. This might be due to the intense use of insecticide-based strategies for vector control i.e., Long Lasting Insecticide Treated Nets (LLIN). DDT and deltamethrin resistance have also been previously reported in Muchala and Bachure of Adamawa State (Wahedi *et al*., 2021). Also, permethrin, deltamethrin, and DDT resistance in *Anopheles gambiae* s.l were reported in a study conducted in Lagos (Omotayo *et al*., 2021), in Gombe (Philemon *et al*., 2016; Oduola *et al*., 2019), in Kano (Abdu *et al*., 2017; Ibrahim *et al*., 2019), in Benin (Djouaka *et al*., 2008; Yadouleton *et al*., 2010), in Gambia (Opondo *et al*., 2016, in Liberia by Temu *et al*., 2012), in Niger (Soumaila *et al*., 2017) and in Ghana (Baffour-Awuah *et al*., 2016). However, in our study, Anopheles mosquitoes were susceptible to bendiocarb, which was at variance to earlier reports from Adamawa State where suspected resistance to bendiocarb was reported in *Anopheles gambiae* s.l in a study carried out by Wahedi *et al*., 2021. These findings have important implications for vector control strategies in Adamawa State.

CONCLUSION

The observed trends in mortality percentages indicated the efficacy of propoxur, bendiocarb, and pirimiphos-methyl, suggesting that these insecticides should be prioritized. Alternative strategies are required for permethrin, deltamethrin, and DDT which showed significant resistance among the Anopheles mosquito populations. These findings emphasize the importance of continuous surveillance, resistance management, and the development of context-specific vector control strategies to combat malaria effectively in Adamawa State.

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