



Research Article

Insecticide Resistance Profile of *Aedes aegypti* from the Northern Part of Katsina, Katsina State

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ABSTRACT

Aedes mosquitoes are the primary vector of various relevant arthropod-borne viral infectious diseases worldwide. Insecticide resistance in *Aedes* mosquitoes has emerged as a major public health challenge due to its impact on the effectiveness of mosquito control efforts. *Aedes* mosquitoes, particularly *Aedes aegypti*, serve as vectors for diseases including yellow fever, dengue fever, Chikungunya, and Zika virus. This study aims to evaluate the resistance mechanisms in *Aedes* mosquitoes exposed to four different insecticides, namely: Dichlorodiphenyltrichloroethane (DDT 4%), pirimiphos-methyl (0.25%), Bendiocarb (0.1%), and Permethrin (0.75%). *Aedes* mosquito larvae were collected from five LGAs, namely Batagarawa, Daura, Kaita, Katsina, and Mashi. The collected larvae were transported to the Insectary Laboratory, Department of Biology, UMYU, Katsina. The knockdown results obtained revealed that the knockdown rate (KDR) at 30 minutes showed that pirimiphos-methyl had the highest KDR of 39%, while permethrin had the least (1%). At 60 minutes, the KDR was highest (77%) in *Aedes* mosquitoes collected from Daura and tested with pirimiphos-methyl, while the least (3%) was in mosquitoes tested with permethrin from Kaita LGA. After twenty-four hours of exposure, the results obtained showed complete susceptibility (100%) to pirimiphos-methyl in all the selected LGAs, possible resistance (82% mortality) to Bendiocarb, and resistance to permethrin and DDT. Findings of this study indicated that *Aedes* mosquitoes from the study areas were susceptible to pirimiphos-methyl; these findings highlight the urgent need for integrated vector management strategies and the rotation of insecticides to mitigate resistance development in mosquito populations in Nigeria.

Keywords: *Aedes aegypti*; *Aedes albopictus*; Insecticide; Katsina State; Mosquitoes; Resistance; Susceptibility

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INTRODUCTION

Nigeria is regarded as one of the most vulnerable countries to mosquito-borne diseases, particularly yellow fever, with major urban centers experiencing significant epidemiological threats (WHO, 2007; 2010). These disease outbreaks have disrupted socioeconomic activities and posed serious public health concerns. Vaccinating the urban population alone would require immunizing approximately 100 million people (WHO, 2015). Mosquitoes, belonging to the family *Culicidae*, comprise over 3,600 species. While male mosquitoes feed on nectar, female

mosquitoes require blood meals for egg development. They are highly efficient disease vectors, locating hosts through body heat, scent, and carbon dioxide emission. Their ability to transmit a wide array of pathogens makes them the deadliest animal group, responsible for over 700,000 deaths annually (Higgs, 2008; Bates, 2016).

Among the mosquito genera, *Anopheles*, *Culex*, and *Aedes* are the most significant in terms of disease transmission: *Anopheles* mosquitoes are vectors of *Plasmodium* parasites, which cause malaria, *Culex* species transmit arboviruses such as West Nile virus

and filariasis. *Aedes* mosquitoes, particularly *Aedes aegypti*, are responsible for transmitting several arboviral diseases including yellow fever, dengue, Zika, and Chikungunya (Roger, 2019). *Aedes aegypti* has adapted to urban environments, breeding in artificial containers and exhibiting aggressive daytime biting behavior. The control of *Aedes* and other mosquito species heavily depends on chemical insecticides, primarily pyrethroids, organochlorines, carbamates, and organophosphates, due to their high efficacy and relative safety for human use (Al-Amin *et al.*, 2020).

However, the continuous and widespread use of these insecticides has led to the emergence of insecticide resistance. Resistance in *Aedes* species was first documented in the 1950s and has since been reported in over 50 countries, posing a major challenge to vector control programs (Fox *et al.*, 1960; WHO, 2012). Resistance is defined as the heritable ability of a mosquito population to survive exposure to doses of insecticides that would normally be lethal to a susceptible population (Scott *et al.*, 2021; Isabelle, 2019).

In addition to public health use, insecticides are extensively employed in agriculture, especially in regions of intensive farming. Approximately 90% of insecticides are used for agricultural purposes, which inadvertently contributes to resistance development in disease vectors exposed to the same chemical agents (Overgaard, 2006). Therefore, addressing insecticide resistance requires an integrated approach that considers both public health and agricultural contributions to the problem. This study thus focuses on understanding the mechanisms and prevalence of insecticide resistance in mosquito populations, with a particular emphasis on *Aedes aegypti*, in order to inform sustainable vector control strategies.

MATERIALS AND METHODS

Study Area

The study was carried out in some Local Government Areas (LGAs) of Northern Katsina State, Nigeria. The selected LGAs include Batagarawa, Daura, Kaita, Katsina and Mashi (Figure 1). Table 1 presents the list of the collection sites and their coordinates.

The collected larvae were transported to the insectary of Umaru Musa Yar'adua University, Katsina (UMYUK) for adult rearing and susceptibility tests. The containers were covered with muslin cloth to allow proper gaseous exchange for the larvae and pupae when transporting to the Insectary. The larvae were fed twice daily, with tetramine.

The larval containers were checked daily for emerged adults which were removed and placed into adult cages. The adults were fed with 10% sugar soaked into cotton wool and placed at the top of the cages. This was checked regularly to ensure availability of food at all times

Morphological identification of mosquitoes tested

Rued (2004) pictorial keys for the identification of mosquitoes (Diptera: Culicidae). The morphological identification of different species of male and female mosquitoes were carried out by studying the pattern of the antennae, the scales and color of the palps at the head region, the patterns of spots on the wings, thorax, terminal abdominal segments, scales of the legs, presence or absence of speckling in the hind tarsi and striations on the body using both compound and dissecting microscope following the taxonomic keys.

The identified mosquitoes were then carefully placed in well-labelled Eppendorf's tube containing silica gel using forceps without damaging any part of the body have been packed in zip – lock bag and sent to the Department of Biochemistry, Bayero University, Kano (BUK), Nigeria for further identification through molecular and biochemical analysis to identify the sibling species and observed the resistant and susceptible ones to understand the resistant mechanism from the mosquito population tested.

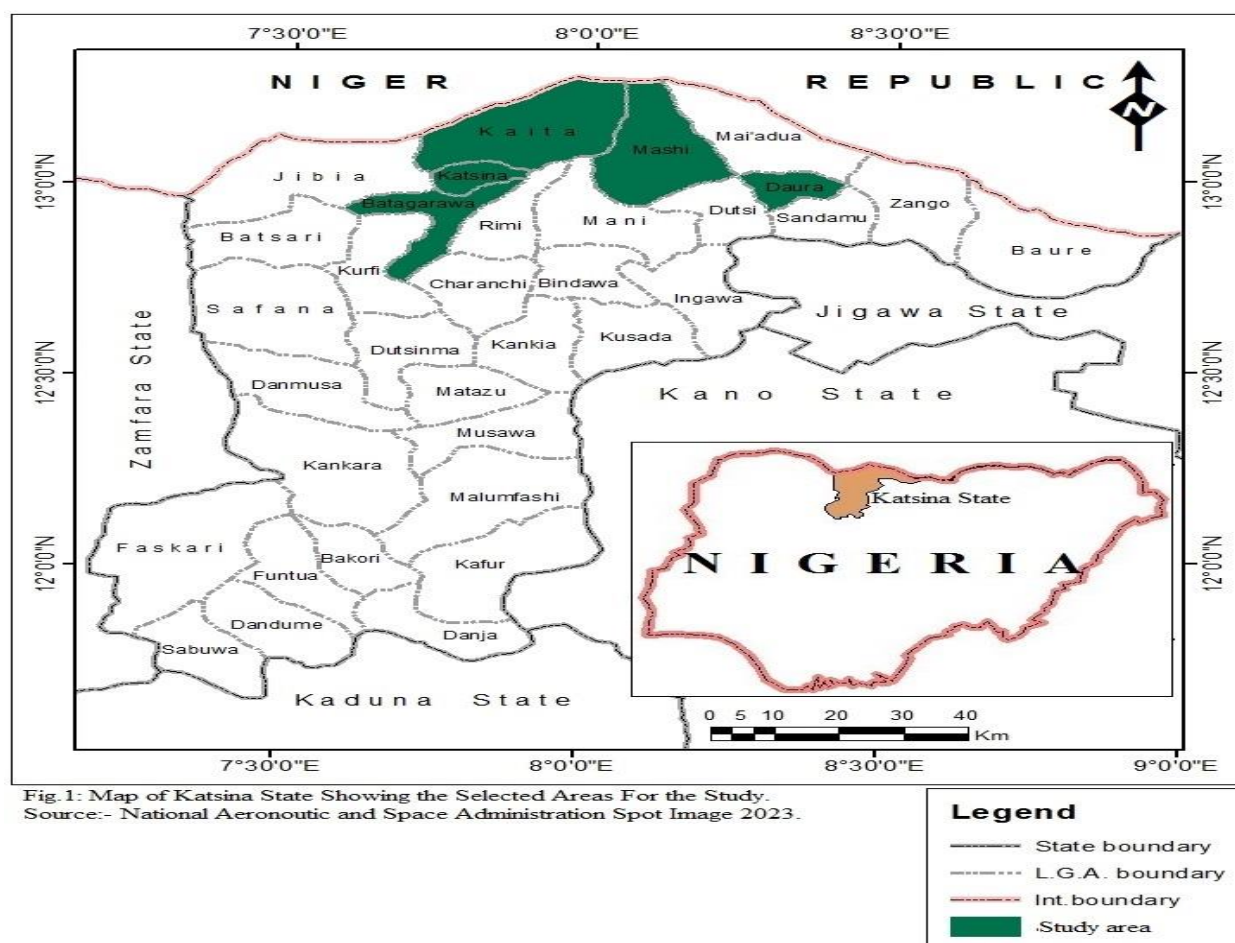


Figure 1: Map of Katsina State Showing Selected LGAs for Collection of *Aedes* Mosquitoes Collection and Rearing of Mosquito Larvae and pupae

Source; National Aeronautics and space Administration, 2023

Table 1: Collection Sites of *Aedes* Mosquitoes from Selected LGAs of Northern Katsina State

LGAs	Locality	Latitude	Longitude
Batagarawa	Tafkin Bello Jah	12.902422	7.611040
	Ungwar Yamma, Kauyen Malamai	12.899818	7.632578
	Batagarawa Town B, Kofar Arewa	12.906913	7.607660
	Sabuwar Tasha	12.970415	7.601265
	Ungwar Madina Tafkin Tsame	13.030397	8.314150
Daura	Tudun Wada	13.031447	8.322212
	Ungwar Tawalala (Tafkin Malga)	13.049774	8.318585
	Central behind Abiola masjid	13.019947	8.329657
	Rahamawa (Gangaren Masara)	12.964802	7.580246
Katsina	Kwakwachi (Tudun Matawalle)	12.956040	7.616048
	Turai Maternal and Child Hospital	12.970058	7.6334
	Unwala Quarters	12.983010	7.600792
	Falala Modoji	13.024583	7.642458
Kaita	Tafkin Shinkafi	13.037171	7.650672
	Tafkin Birji	13.080008	7.734612
	Mashi Motor Park	12.980645	7.967563
Mashi	Abu Halawa	12.971478	7.967338
	Tudun Dam	12.972275	7.946065

Determination of Resistance and Susceptibility of *Aedes* Mosquitoes to Different Insecticides Using WHO Tube Assay

This test was carried out according to WHO Global Malaria Programme (2016). Papers already impregnated with insecticide at the appropriate diagnostic concentrations were provided by the Katsina State Malaria Vector Sentinel Site located at the Department of Biology of UMYUK. The papers are prepared on behalf of WHO by the Universiti Sains Malaysia. The papers were impregnated with insecticides namely bendiocarb (0.1%), DDT (4%), permethrin (0.75%) and pirimiphos-methyl (0.25%). The 12 tubes include four marked with a red dot are use as exposure tubes, i.e. for exposing mosquitoes to insecticide-impregnated papers; two marked with a yellow dot are use as control tubes, six marked with a green dot are used as holding tubes for pre-test sorting and post-exposure observation.

Six holding tubes (with the green dot), One hundred and twenty-five (125) active *Aedes* mosquitoes were aspirated from a mosquito cage into five green-dotted holding tubes through the filling hole in the slide, to give five replicate samples of 25 mosquitoes per tube, the slide unit is closed and the holding tubes set in an upright position for 1 hour. At the end of this time, any moribund mosquitoes and dead mosquitoes were removed. One oil-treated paper (the control) was inserted into the yellow-dotted tube,

Four exposure tubes with red dots were prepared in much the same way as the yellow-dotted tubes. Each of the four red-dotted exposure tubes was lined with a sheet of insecticide-impregnated paper such that print label was visible on the outside. Each paper was then fastened into exposure tubes. The empty exposure tubes were attached to the vacant position on the slides and, with the slide unit opened, the mosquitoes were blown gently into the exposure tubes.

Mosquitoes were kept in the exposure tubes, which are set in a vertical position with the mesh-screen end uppermost, for a period of 1 hour. During this period, the number of knocked down mosquitoes was recorded at 0, 10, 15, 20, 30, 40, 50 and 60 minutes. At the end of the 1-hour exposure period, the mosquitoes were transferred back to the holding tubes by reversing the procedure outlined above. A pad of a cotton wool soaked in 10% sugar water was placed on the mesh-screen end of the holding tubes. Mosquitoes were maintained in the holding tubes for 24 hours, the holding tubes were kept on laboratory desk in a shady, sheltered place at $27 \pm 2^\circ\text{C}$

temperature and $75 \pm 10\%$ relative humidity. At the end of recovery period. An adult mosquito was considered to be alive if it was able to fly, regardless of the number of legs remaining. Any knocked down mosquitoes, whether or not they had lost legs or wings, were considered moribund and were counted as dead. A mosquito was classified as dead or knocked down if it was immobile or unable to stand or take off.

Synergist Bioassays Using the WHO Method

Synergist bioassays are conducted to determine whether metabolic detoxification enzymes are responsible for insecticides resistance in mosquito population tested. The Piperonyl Butoxide (PBO), which inhibits the activity of cytochrome P450 monooxygenases, while using WHO method, synergist test comprises four bioassay exposures: PBO only, insecticide only, PBO followed by insecticide, and solvent control. Standard WHO test tubes were used for the bioassays. The procedure was as follows:

Four sheets of clean white paper (12×15 cm), rolled into a cylinder shape, were inserted into four holding tubes with green dots (one per tube) and fastened into position with a steel spring-wire clip. The tubes were attached to slides. Ensure that all tubes were appropriately labelled.

Five exposure tubes (four with red dots and one with a yellow dot) were prepared in much the same way. Two red-dotted exposure tubes are each lined with a sheet of permethrin impregnated paper (0.75%); the other two red-dotted tubes are each lined with 4% PBO-impregnated papers. The yellow-dotted control exposure tube was lined with oil-impregnated paper. Each paper was fastened into position with a copper spring-wire clip.

Four sets of 25 mosquitoes from each of the 6 LGAs, each of which was then aspirated into one of the four holding tubes.

The "PBO only" and "PBO followed by insecticide" test mosquitoes were transferred to the two 4% PBO exposure tubes for 1 hour. Mortality was recorded after 1 hour of exposure. The other samples ("insecticide only" and "solvent control") were left in their respective holding tubes.

The "PBO only" test mosquitoes were transferred back to their holding tube.

The "insecticide only" and "PBO followed by insecticide" test mosquitoes were simultaneously transferred to the two insecticide exposure tubes and exposed for 1 hour. At the same time, the "solvent control" test mosquitoes were transferred to the oil-impregnated paper control tube and exposed for 1 hour.

After the 1hour exposure, the remaining three test mosquito samples ("insecticide only", "PBO followed by insecticide" and "solvent control") were transferred back to their respective holding tubes and knock down/mortality was recorded. A pad of cotton wool soaked in sugar water was placed on the mesh-screen end of each of the four holding tubes.

Mosquitoes were maintained in the holding tubes for 24 hours (the recovery period). Temperature and humidity were recorded during the recovery period.

At the end of the recovery period, the number of dead mosquitoes in each tube was counted and recorded.

RESULT

Species composition of *Aedes* Mosquitoes in Some LGAs of Northern Katsina State

Two species of *Aedes* were identified from the selected LGAs of Katsina State namely *Ae. aegypti* and *Ae. albopictus*. Out of the 2000 individuals collected, the morphological identification showed that *Ae.*

aegypti had the highest number of one thousand, eight hundred and twenty-one (1,821) while *Ae. albopictus* had the least number with one hundred and seventy-nine (179) (Table 4.1). The population of *Ae. aegypti* among the selected LGAs was in the following order: Daura > Mashi > Katsina > Batagarawa > Kaita, while *Ae. albopictus* was more populated in Batagarawa and Kaita than in the rest of the LGAs where Daura had the least.

Following morphological identification, the species were further identified and authenticated using molecular identification technique. Internal transcribed spacer 1(ITS1) regions was used for the identification using universal primer for identification of *Aedes* mosquitoes. The PCR product amplified using the universal primers indicated that there was amplification which confirmed that the species belongs to *Aedes* mosquitoes

Figure 1: *Aedes* mosquito species Identified from the study area. (a) *Aedes aegypti* (b) *Aedes albopictus*

Table 2: Species Composition of and Number of *Aedes* Mosquitoes from the Selected LGAs

LGAs	Number of Collected Mosquitoes	
	<i>Aedes aegypti</i>	<i>Aedes albopictus</i>
Batagarawa	344	56
Daura	388	12
Kaita	344	56
Katsina	365	35
Mashi	380	20
TOTAL	1,821	179

Key: LGAs = Local Government Areas

Susceptibility Status of *Aedes* Mosquitoes to Some Insecticides in Some LGAs of Northern Katsina State

The population of mosquitoes exposed to different insecticides showed a great variation, after 24 hours of exposure where in bendiocarb the highest mortality (82%) was found in Daura, followed by Kaita and Mashi with 80% each, 70% in Katsina and 69% was found in Batagarawa (Table 4.4). Analysis of variance shows that there was a significant difference (ANOVA: $F = 2.01$; $p = 0.20$) in the susceptibility of

Aedes mosquitoes caused by bendiocarb from the selected LGAs.

In DDT (4%), the highest mortality was observed in Batagarawa with 28%, followed by 25% in Mashi, 22% in Daura and the least mortality (16%) was in Kaita and Katsina (Table 3). There was significant difference (ANOVA: $F = 0.23$; $p = 0.001$) in the mortality of *Aedes* mosquitoes caused by DDT among the five LGAs chosen.

Table 3; Susceptibility Status of *Aedes* Mosquitoes to Some Insecticides in Northern Katsina State

LGAs	Adult Mortality (% $\pm$ SEM) of <i>Aedes</i> Mosquitoes after 24 hours of Exposure			
	Bendiocarb	DDT	Permethrin	Pirimiphos-Methyl
Batagarawa	69 $\pm$ 3.00	28 $\pm$ 2.00	10 $\pm$ 2.00	99 $\pm$ 1.50
Daura	82 $\pm$ 4.00	22 $\pm$ 2.00	12 $\pm$ 2.00	98 $\pm$ 3.00
Kaita	80 $\pm$ 0.00	16 $\pm$ 2.00	4 $\pm$ 2.00	100 $\pm$ 0.00
Katsina	70 $\pm$ 4.00	16 $\pm$ 2.00	18 $\pm$ 2.00	98 $\pm$ 3.00
Mashi	80 $\pm$ 2.00	25 $\pm$ 5.00	4 $\pm$ 0.00	99 $\pm$ 1.50

Key: LGAs = Local Government Areas

In permethrin, the highest mortality (18%) was observed in Katsina, while the least (4%) was seen in Kaita and Mashi LGAs. *Aedes* mosquitoes collected from Daura and Batagarawa had their mortality as 12 and 10%, respectively (Table 4.4). Statistical result obtained showed that there was significant difference (ANOVA: $F = 0.10$; $p = 0.003$) in the susceptibility of *Aedes* mosquitoes to permethrin in the five selected LGAs.

Pirimiphos-methyl caused 100% mortality of *Aedes* mosquitoes in Kaita followed by 99% in Batagarawa and Mashi and then 98% was recorded in each of Daura and Katsina LGAs (Table 4.4). There was a significant difference (ANOVA: $F = 3.05$; $p = 0.003$) in

adult mortality of *Aedes* mosquitoes in the selected five LGAs caused by pirimiphos-methyl.

Resistance Mechanism of *Aedes* Mosquitoes Using WHO Tube Bioassay

The mosquitoes were observed resistant to the pyrethroid (permethrin), synergist (Permethrin + PBO) test was employed to study the resistance mechanism in the *Aedes* mosquitoes. The results obtained indicated that mosquitoes from Daura, Kaita, Katsina and Mashi LGAs had 98 – 100% mortality, exhibiting metabolic resistance mechanism while those from Batagarawa with 96% mortality showed multiple/metabolic and other mechanisms (Figure 4.1). This was confirmed by the results obtained from PCR analysis (Plate VI).

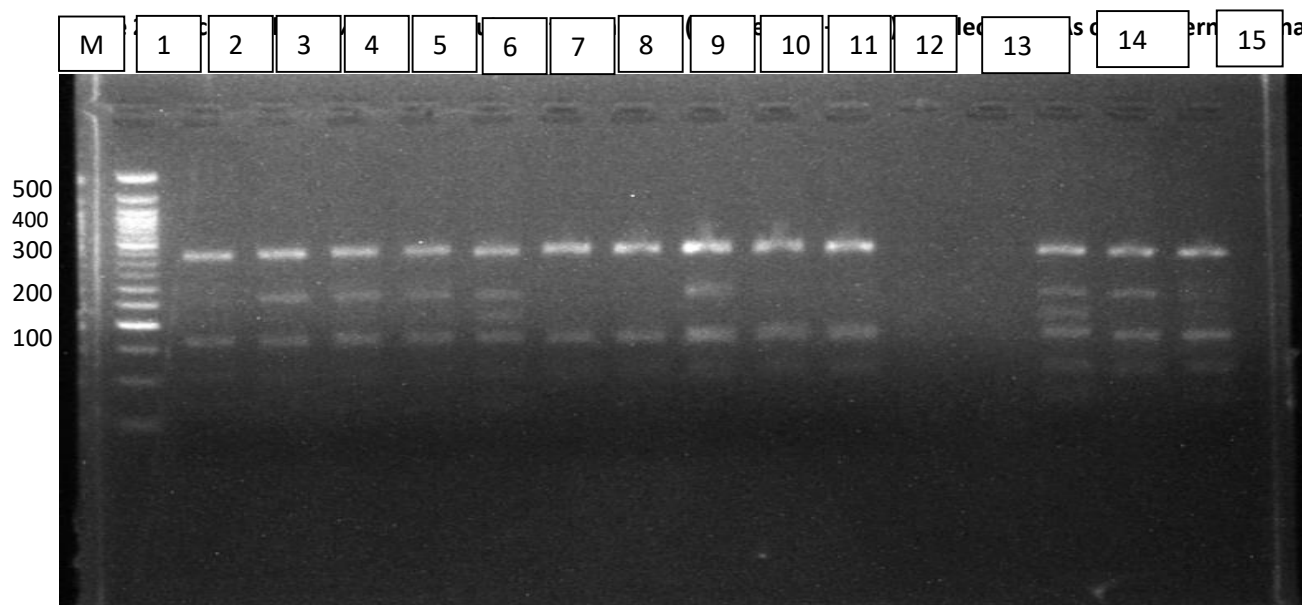
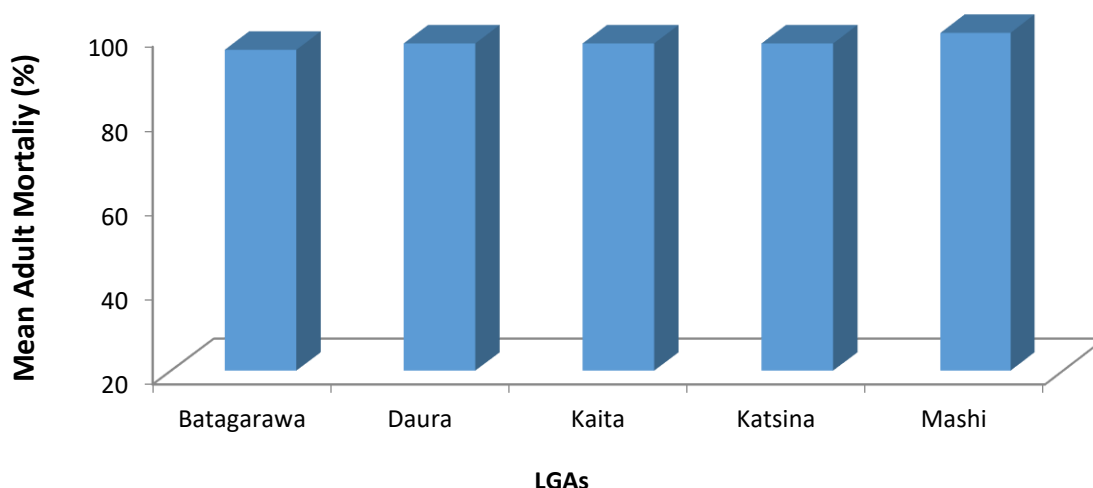


Plate 2: Resistance and Susceptibility Status of *Aedes* mosquitoes

From the number of mosquitoes exposed to the different kinds of insecticide, three were selected from each local government for the detection of resistance gene, making twelve and three individuals from the susceptible. The PCR using the primers that can amplify F1534C sequences showed amplification in the mosquitoes exposed to bendiocarb, DDT and permethrin while no amplification observed in two mosquitoes exposed to pirimiphos methyl (Plate VI). This is further interpreted as follows:

Lane 1 to 4 shows presence of resistance gene in the mosquitoes exposed to permethrin (0.75%).

Lane 5 to 8 shows presence of resistance gene in the mosquitoes exposed to DDT (4%).

Lane 9 to 12 shows presence possible resistance gene in the mosquitoes exposed to Bendiocarb (1%).

Lane 13 to 15 shows susceptibility in the absent amplification in the mosquitoes exposed to pirimiphos-methyl (0.25%).

DISCUSSION

This study provides information on susceptibility status of *Aedes* mosquitoes to four different classes of insecticides. *Aedes* mosquitoes, like other species, require a suitable, pleasing and conducive atmosphere and environment for their breeding and reproduction, the breeding site include disposable and used containers like tins of milk, soft drinks cans, disposable rubbers, spoiled cars, vans, etc. are the most productive and breeding site for *Aedes* species. *Aedes aegypti* and *Ae. albopictus* were the two species of *Aedes* mosquitoes recovered in the selected LGAs. The dominance of *Ae. aegypti* in the study area is in line with some previous findings where it was reported as the major *Aedes* species found in some parts of Nigeria such as Sokoto, Kano and Jigawa (Mahe *et al.*, 2022; Yahaya *et al.*, 2022). Similar findings were also reported in some southern states of the country (Nwankwa *et al.*, 2019; Busari *et al.*, 2023). Other researchers reported *Ae. aegypti* as the dominant species within the cities and in the sub-urban areas of African and Asia (Kamgang *et al.*, 2013; 2018; Abilio *et al.*, 2018).

Tripet *et al.* (2011) reported that, the association of *Ae. aegypti* and *Ae. albopictus* in the same micro environmental conditions makes them to share the same ecological niches that makes them to compete in the available resources leading to segregation of habitat. Another finding shows form of mating processes is called Satyrization was observed where the two species are able to mate in nature and that *Ae. albopictus* male effectively sterilized *Ae. aegypti* female (Tripet *et al.*, 2011; Bargiclow *et al.*, 2013).

Findings of this study have revealed high resistance in *Aedes* mosquitoes exposed to two Permethrin and DDT, possible resistance in bendiocarb and susceptibility in pirimiphos-methyl in all the selected LGAs. This is in line with some previous reports where *Aedes* mosquitoes shows higher level of resistance to DDT and Permethrin even at 24 hours mortality ranging from 20% to 46% and 29% to 70%, respectively (Fagbohun *et al.*, 2020). Fagbohun *et al.* (2020) also observed possible resistances in Bendiocarb which is line with this study. Another study by Ukpai and Ekedo (2018) reported resistance of *Aedes* mosquitoes in DDT and Permethrin in southern part of Nigeria.

Recent studies conducted in Cameroon (Kamgang *et al.*, 2017), Burkina Faso (Badolo *et al.*, 2019), Malaysia (Ishak *et al.*, 2017), Benin (Alphonse *et al.*, 2023) reported resistance of *Aedes* mosquitoes in pyrethroid and DDT. Resistance to DDT and Permethrin by *Aedes* mosquitoes has been suggested to have been resulted due to the increasing activities of Glutathione S-transferase (GST) enzymes and P450s (Bregue *et al.*, 2003; Ishak *et al.*, 2016; Li *et al.*, 2018; Leong *et al.*, 2019). The level to which insecticides resistance increased as recorded in this study may be due to frequent use of these insecticides on both agricultural and medical insects.

In this study, results have revealed high level of susceptibility to pirimiphos-methyl (organophosphate) with 100% mortality after 24 hours of exposure, in all the selected LGAs. The effectiveness of pirimiphos methyl was since from the taking reading of knocked down at 30 minutes and at 60 minutes with high range of kdr. The effectiveness of pirimiphos-methyl observed in this study was the same with the findings of Becker *et al.* (2010) who recorded 100% susceptibility of *Aedes* mosquitoes to pirimiphos-methyl. Another study carried out by Hadura *et al.* (2015) reported 100% susceptibility of *Aedes aegypti* and *Ae. albopictus* to pirimiphos-methyl. This finding is also in line with the study carried out in Abia State in south-eastern Nigeria by Ekedo *et al.* (2018) where *Aedes* populations tested were susceptible to pirimiphos-methyl. Further, a similar trend to the findings of this study was reported by (Nwankwo *et al.* 2019).

In this study the results show possible resistance in bendiocarb which is in line with the findings of Hamid *et al.* (2018) who recorded possible resistance to bendiocarb. Another finding states that *Aedes* population was found to be resistance to the insecticide. Resistance to Bendiocarb was reported in

Nigeria, Pakistan, Malaysia, Mexico, China and Saudi Arabia (Minu *et al.*, 2021).

It has been reported that the F1534C and V1016C mutations in the voltage sodium channel (VGSC) are the target site of developing resistance in *Aedes* mosquitoes to pyrethroid and DDT. The highest knocked down rate (kdr) of 5% was shown in Batagarawa and Katsina LGAs, followed by 4% in Daura, 3% in Kaita and then the lowest kdr (1%) was in Mashi. These channels had been commonly found to be associated with insecticide resistance worldwide (Moyes *et al.*, 2017).

CONCLUSION

The result of the study provides an insight of the current status of susceptibility of *Aedes* mosquitoes to four different insecticides used in northern Katsina State. The study revealed the presence of *Aedes aegypti* and *Aedes albopictus* as the species recovered in the selected LGAs. The study revealed that *Aedes* mosquito populations display a varying degrees of insecticides resistance, which may compromise the effectiveness of current vector control interventions. The resistance patterns indicate the involvement of both metabolic and target-site resistance mechanisms. These results highlight the need for continuous insecticides resistance surveillance and the implementation of evidence-based insecticides resistance management strategies to preserve the effectiveness of available control interventions, also routine monitoring should be integrated into vector control programmes to guide insecticides selection and reduce the risk of further resistance development.

REFERENCES

Al-Amin H.M, Fatema T.Y Johara. Seth. R. Irish, Muhammad Riadul Haque Parasite Vectors 2020 free articles 2020 Dec, 14; 13 (1): 622 doi;10.1186/s13071-020-04503-6. <https://doi.org/10.1186/s13071-04503-6>.

Bregue, C., (2003). Role of glutathione S-transferases in insecticide resistance of *Aedes* mosquitoes. *Journal of Medical Entomology*, 40(3), 227–236.

Fox, D. J., (1960). Early documentation of insecticide resistance in *Aedes* mosquitoes. *Journal of Economic Entomology*, 53(5), 810–815.

Higgs, S. (2008). Mosquitoes: The deadliest animal group. *Emerging Infectious Diseases*, 14(8), 1291–1293.

Invasive species specialist group; global invasive species database. *Aedes* mosquitoes 20009.

<http://www.issg.org/database/species/ecology.asp?si=109&fr=1&sts=sss&lang=EN>.

Isabelle, R. (2019). Defining insecticide resistance in disease vectors. *Parasitology Today*, 35(4), 273–279.

Kamgang B, Ngoagouuni C, Manirakiza A, Nakoune E, Paupy C, Kazanji M, Temporal patterns of abundance of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) and mitochondrial DNA analysis of *Ae. albopictus* in the Central African Republic. *PLoS Negl Trop Dis*. 2013;7(12): e2590.

Kamgang B., Yougang A.P., Tchoupo M., Riveron J.M., & Wondji C. Temporal Distribution and insecticide resistance profile of two major arbovirus vectors *Aedes aegypti* and *Aedes albopictus* in Yaounde, the capital city of Cameroon. *Parasites Vectors* 2017; 10:469. doi:10.1186/s13071-017-2408-x <https://doi.org/10.1186/s13071-017-2408-x>.

Li, C. X. (2018). P450 enzymes contributing to insecticide resistance in *Aedes*. *Pesticide Biochemistry and Physiology*, 147, 67–75.

Mahe, S. (2022). Species composition of *Aedes* mosquitoes in Sokoto, Nigeria. *Vector-Borne and Zoonotic Diseases*, 22(3), 150–158.

Moyes CL, Vontas J, Martins A.J, Ng L.C, Koou S.Y, Dufour I, Contemporary Status of Insecticide in the Major *Aedes* Vectors Arbovirus Infecting Humans, Sinnis P, Editor. *PloS Negl Trop Dis*. 2017; 11: e0005625. <https://doi.org/10.1371/journal.pntd.0005625>. PMID: 28727779.

Nwankwo EN, Ononye I.P, Ogbonna C.U, Ezihe E.K, Onwude C.O, and Nwanwu U.C. insecticide susceptibility status of *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) in Akwa south local government Area Anambra State Nigeria. *Research Article-(2019) volume 8, issue3. Entomol. orn. Thol. Hepatol*; 8:2019; DOI: 10.35248/2161-0983.19.8.220

Roger, L. (2019). Arboviral transmission by *Aedes aegypti*. *Annual Review of Virology*, 6, 189–210.

Scott M.L., Lawrence J.H, Andrea L.L and Janet C.M, Characterization of Pyrethroid Resistance Mechanism in *Aedes aegypti* from Florida Keys. *Am J Trop Med Hyg*. 2021 Mar; 104(3): 1111-1122 Published online 2021 Jan 11, doi; 10.4269/ajtmh.19-0602. PMID: PMC7941856 | PMID: 33432904.

WHO. (2007). Yellow fever in Africa and the Americas, 2005–2006. Geneva: World Health Organization.

WHO. (2010). Test procedures for insecticide resistance monitoring in malaria vector mosquitoes. Geneva: World Health Organization.

WHO. (2012). Global plan for insecticide resistance management in malaria vectors (GPIRM). Geneva: World Health Organization.

WHO. (2015). Vaccination coverage needed to control yellow fever in urban Nigeria. *Weekly Epidemiological Record*, 90(20), 261–276.

WHO *Global Malaria Programme*. (2016). Test procedures: Shell vial assay. Geneva: World Health Organization.

Umar SA, Dhakar R, Usman HS, Sulaiman M, Sa'idu M, Yahaya, MS, Shitu AS, Usman HM. (2024). Morphological identification of mosquito species in Takur Adu'a and yakasai, Dutse local Government Area, Jigawa State, Nigeria. *intl journ Bonorowo wetlands* 14;57-65.