

Investigation of the Insecticide Resistance Pattern in *Anopheles gambiae* s.l. Mosquitoes in Selected Local Government Areas in Ekiti State, South West, Nigeria

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Abstract

Background

Insecticide resistance among malaria vectors is an increasing challenge to malaria control in Nigeria and other tropical regions. Regular assessment of the susceptibility status of local *Anopheles* mosquito populations is essential for effective vector control. This study evaluated the efficacy of World Health Organization (WHO)-recommended insecticides against *Anopheline* mosquitoes in Ekiti State, southwestern Nigeria. Mosquito larvae were collected from breeding habitats across six Local Government Areas (LGAs) in Ekiti State using standard dipping techniques and reared to adulthood. Adult female *Anopheles* mosquitoes were exposed to WHO standard susceptibility bioassays using Deltamethrin (0.05%), DDT (4%), Bendiocarb (0.1%), Propoxur (0.1%), and Pirimiphos-methyl (0.25%). Three replicates were conducted for each insecticide. Knockdown was recorded at 10–60-minute intervals, and mortality was assessed after 24 hours.

Results

Resistance to Deltamethrin and DDT was observed in all LGAs. Susceptibility to Bendiocarb was recorded in two LGAs, while only one LGA showed susceptibility to Pirimiphos-methyl. Bendiocarb showed the fastest knockdown effect (KDT50 = 25.70 minutes), followed by Propoxur (29.33 minutes), while Deltamethrin exhibited the slowest knockdown (KDT50 = 77.67 minutes). Similar trends were observed for KDT95 values.

Conclusion

The widespread resistance of *Anopheline* mosquitoes to commonly used insecticides in Ekiti State represents a serious public health concern. These findings emphasize the need for insecticide rotation, region-specific resistance management, and integrated vector management strategies to sustain malaria control efforts.

Background

The significant level of morbidity and mortality among children, particularly under five years old, pregnant women, elderly and immunocompromised patient due malaria in sub Saharan Africa is a serious health concern [1]. Malaria is transmitted throughout Nigeria, with 97% of the population at risk, including both rural and urban communities; in the southern regions there is year-round transmission while in the north the transmission season is shorter. Persistent high-risk areas ('hotspots') also exist in peri-urban and urban Local Government Areas over many years [2]. Annually, Nigeria experiences tens of millions of malaria cases, for example, about 68 million in 2021, and over 90% of the population remains at risk [3]. The high humidity and warmth in sub-Sahara Africa play significant roles in the transmission of malaria

disease in the region. Other factors responsible for the transmission dynamics are socio- cultural and economic status such as education, housing pattern, income, social groups and water storage facilities etc. The disease is more endemic than the urban areas due to the availability of the favourable environment for the breeding of the vectors in the rural areas [4].

Despite the wide implementation of treatment, control, and prevention strategies, malaria remains a major public health challenge across Africa. The disease persists as an endemic burden, with millions of new infections recorded annually, particularly in sub-Saharan Africa [3]. Currently, the major strategy adopted towards reducing mosquito contact is the use of long lasting insecticides treated mosquito net and indoor residual spray. However, the success of this approach has been limited due to the development of insecticides resistance by the mosquitoes, the vector of malaria and the *Plasmodium* parasites, the causative organisms [5]. Several studies have shown the insecticidal resistance of *Anopheles* mosquitoes to the four classes of mosquitoes approved insecticides by World Health Organization (WHO) [6]. The four recommended insecticides are organochlorine, organophosphates, carbamates and pyrethroid out of which pyrethroid is the currently approved for the long lasting insecticide nets because of its cost effective, safety and residuality. However, the reported cases of *Anopheline* resistance to the pyrethroid and other classes of insecticides is a source which calls for continuous monitoring of the efficacy of the insecticides proper monitoring of the susceptibility status of local *Anopheles* mosquitoes in the communities. Therefore, this study aims to assess the susceptibility status of *Anopheles gambiae* to the various classes of approved insecticides in the three Local Governments Areas in Ekiti State. There have been some reports on the larval habitat and molecular study of *Anopheles gambiae* in Ekiti State [7][8], but insecticide susceptibility studies has not been reported. Recent studies on insecticide susceptibility *Anopheles gambiae* of have been carried out in other parts of the country and susceptibility patterns of *Anopheles gambiae* s.l. have been identified and recorded [9–11].

Methods

Study area

The study was carried out in six selected local government areas in Ekiti State, located in South-West Nigeria from April 2022 to June 2023 as shown in Fig. 1. Ekiti State is situated in the tropical region, bounded by longitudes $40^{\circ} 51''$ and $50^{\circ} 451''$ East of the Greenwich meridian and latitudes $70^{\circ} 151''$ and $80^{\circ} 51''$ North of the Equator. The state is divided into 16 local government areas (LGAs), comprising 13 rural, 2 peri-urban and 1 urban area. Figure one (1) shows the study sites which were randomly selected within each study location and their respective coordinate were taken accordingly as indicated in the map. The study areas (Fig. 1) was deliberately chosen to include Ado LGA (Latitude: 7.621111; Longitude: 5.221389) because it is home to the state capital and is the most populous local government area, Ise-Orun (Latitude: 7.232837, Longitude: 5.196718) and Ido-Osi (Latitude: 7.843093; Longitude: 5.182314).

Study Sample

Larvae surveys were carried out in three locations evenly spread across each of the selected LGA making a total of 9 locations. The global positioning system (GPS) of each location where *Anopheles* larvae were found breeding was taken. Standard dipper sampling techniques were employed to collect mosquito larvae from all types of larval habitats, including both man - made and natural sources, at each study locations. Mosquito larvae collected were carefully transported in clearly labeled plastic containers to the insectaries at the Entomology unit of the Department of Animal and Environmental Biology, Federal University Oye-Ekiti. There, they were raised to adulthood. Larvae from different breeding sites were kept separately to ensure accurate species identification. In the laboratory, larvae were placed in individual bowls labeled accordingly and maintained under controlled conditions: room temperature of 27°C and relative humidity of 82%. Adult mosquitoes were fed with yeast and the water in the bowls was regularly changed to prevent mortality from bacteria or algae growth.

Susceptibility test papers

The impregnated test papers recommended by WHO used in this study were purchased from the Vector Control Research Unit, School of Biological Sciences, Universiti Saints Malaysia 1800 Minden, Penang, Malaysia.

Susceptibility test procedure

The WHO insecticide susceptibility test-kit, as detailed by [12], was utilized to assess the susceptibility status of mosquito vectors to various insecticide classes. The kits used in this study included 7 plastic tubes, each 125mm in length and 44mm in diameter. One tube with red dot served as a control without insecticides, three tubes contained the insecticides, and three tubes with green dots served as recovery tubes for pre-test sorting and post-exposure observation. Each tube had one end fitted with a 16-mesh screen. Slide units with screw caps were used to connect the exposure tubes and the holding tubes. A glass aspirator tube with a 12mm internal diameter, along with 60cm of tubing and a mouthpiece, was used to aspirate 25 female mosquitoes into the holding tubes. After removing the slide partition, the mosquitoes were gently blown into the exposure tubes, which were lined with impregnated papers containing known insecticide concentrations of Deltamethrin (0.05%, Pyrethroids), Permethrin (0.75%, Pyrethroids), DDT (4%, Organochlorines), Bendiocarb (0.1%, Carbamates), Propoxur (0.1%, Carbamates), and Pirimiphos-methyl (0.25%, Organophosphates). The holding tubes were then temporarily detached. The exposure tubes were positioned with the screen end facing up under diffused light. Three replicates were provided for each concentration. Knockdown was recorded at 10, 15, 20, 30, 40, 50, and 60-minute intervals. Following the knockdown recordings, all mosquitoes were transferred back to the observation holding tubes and provided with 10% sucrose. Final mortality was recorded after a 24-hour post-exposure period. A mosquito is considered alive if it is able to fly, regardless of the number of legs remaining.

Data Analysis

The mortality percentage for mosquitoes exposed to each insecticide was determined by calculating the proportion that died at the diagnostic time for that specific insecticide. Since control mortality remained below 5% in all tests, adjustment using Abbott's formula was not required. The WHO guidelines for assessing insecticide resistance/susceptibility in mosquitoes were applied [12]. According to these criteria, mosquitoes are considered susceptible if the mortality rate 24 hours after exposure is between 98–100%. Mortality rates between 90–97% suggest the possibility of resistance, which should be further confirmed. Mortality rates 0–89% indicate resistance to the insecticide. Microsoft office excel, version 2024 was used to create charts, sort and clean the data. While Statistical Package for the Social Sciences (SPSS) version 23 was used to calculate the knock down rates at 95% confidence interval.

Results

Based on 24-hour post-exposure mortality after WHO tube bioassays, Table 1 displays the insecticide susceptibility status of *Anopheles* mosquitoes collected from six Local Government Areas (LGAs) in Ekiti State: Oye Ekiti, Efon Alaye, Ikere-Ekiti, Ado Ekiti, Ise Orun, and Ido Osi. Mortality rates exhibited significant variability across all LGAs, contingent upon the insecticide used and the geographical location, reflecting spatial variation in insecticide resistance. Propoxur-resistant mosquitoes were found in Oye Ekiti (92.0%). Resistance was confirmed against DDT (62.7%), bendiocarb (61.3%), and pirimiphos (78.7%). Conversely, mosquitoes exhibited complete susceptibility to deltamethrin, resulting in a fatality rate of 98.7%. Resistance was observed in Efon Alaye against propoxur (85.3%), DDT (62.7%), and bendiocarb (89.3%). Resistance to pirimiphos was noted at 90.7%, whereas complete susceptibility was documented for deltamethrin at 98.7%. Mosquitoes in Ikere-Ekiti were completely susceptible to bendiocarb and propoxur, both of which caused 100% mortality. Confirmed resistance to DDT (70.7%), pirimiphos-methyl (80.0%), and deltamethrin (77.3%) was discovered, signifying diminished efficacy of these insecticides in this LGA. Bendiocarb continued to be quite successful in Ado Ekiti, where a death rate of 98.67% indicated susceptibility. In contrast, resistance was observed to propoxur (84.0%), DDT (29.33%), pirimiphos (73.33%), and deltamethrin (65.33%), with DDT showing particularly poor efficacy. Mosquitoes in Ise Orun exhibited potential resistance to pirimiphos and propoxur, both of which had 94.67% mortality rates. However, resistance was observed to DDT (38.67%), bendiocarb (82.67%), and deltamethrin (50.67%), demonstrating general reduced sensitivity in this LGA. Ido Osi showed 100% susceptibility to propoxur and 98.67% susceptibility to bendiocarb. Possible resistance was identified to pirimiphos (90.67%), while resistance was observed to DDT (69.33%) and deltamethrin (65.33%). Comparison of the effectiveness of the five insecticides across all the six study LGAs after twenty four hours is shown in Fig. 2.

Table 1
Susceptibility Patterns of *Anopheles gambiae* to Different Insecticides across different LGAs in 24 hrs.

LGA	Insecticide	Dead / Tested	Mortality (%)	WHO Status
Oye Ekiti	Propoxur (0.10%)	69 / 75	92.0	Possible resistance
	DDT (4%)	47 / 75	62.7	Resistant
	Bendiocarb (0.10%)	46 / 75	61.3	Resistant
	Pirimiphos (0.25)	59 / 75	78.7	Resistant
	Deltamethrin (0.05%)	74 / 75	98.7	Susceptible
Efon Alaye	Propoxur (0.10%)	64 / 75	85.3	Resistant
	DDT (4%)	47 / 75	62.7	Resistant
	Bendiocarb (0.10%)	67 / 75	89.3	Resistant
	Pirimiphos (0.25)	68 / 75	90.7	Possible resistance
	Deltamethrin (0.05%)	74 / 75	98.7	Susceptible
Ikere-Ekiti	Propoxur (0.10%)	75/75	100%	Susceptible
	DDT (4%)	53/75	70.7%	Resistant
	Bendiocarb (0.10%)	75/75	100%	Susceptible
	Pirimiphos-methyl (0.25%)	60/75	80.0%	Resistant
	Deltamethrin (0.05%)	58/75	77.3%	Resistant
Ado Ekiti	Propoxur (0.10%)	63/75	84.00	Resistant
	DDT (4%)	22/75	29.33	Resistant
	Bendiocarb (0.10%)	74/75	98.67	Susceptible
	Pirimiphos (0.25%)	55/75	73.33	Resistant
	Deltamethrin (0.05%)	49/75	65.33	Resistant
Ise Orun	Propoxur (0.10%)	71/75	94.67	Possible resistance
	DDT (4%)	29/75	38.67	Resistant
	Bendiocarb (0.10%)	62/75	82.667	Resistant
	Pirimiphos (0.25)	71/75	94.67	Possible resistance
	Deltamethrin (0.05%)	38/75	50.67	Resistant
Ido Osi	Propoxur (0.10%)	75/75	100.00	Susceptible

LGA	Insecticide	Dead / Tested	Mortality (%)	WHO Status
	DDT (4%)	52/75	69.33	Resistant
	Bendiocarb (0.10%)	74/75	98.67	Susceptible
	Pirimiphos (0.25%)	68/75	90.67	Possible resistance
	Deltamethrin (0.05%)	49/75	65.33	Resistant

There were significant differences in the knockdown response of *Anopheles* mosquitoes treated to WHO-recommended pesticides among the six Local Government Areas (LGAs) under investigation (Table 2). Overall, knockdown times (KDT_{50} and KDT_{95}) were shortest, and corresponding knockdown rates (KR_{50} and KR_{95}) highest, in Ido-Osi and Ikere-Ekiti LGAs, whereas Ado-Ekiti consistently recorded delayed knockdown and lower knockdown rates across major insecticide classes. In Ise-Orun LGA, pirimiphos-methyl (0.25%) induced the most rapid knockdown (KDT_{50} = 32.6 min; KDT_{95} = 65.1 min), leading to the highest knockdown rates (KR_{50} = 0.0307 min⁻¹; KR_{95} = 0.0154 min⁻¹). In contrast, DDT (4%) displayed the slowest knockdown (KDT_{50} = 76.1 min; KDT_{95} = 121.6 min) and the lowest knockdown rates (Table 2). Mosquito populations from Ido-Osi LGA demonstrated the fastest overall knockdown response. Bendiocarb (0.10%) recorded the lowest knockdown times (KDT_{50} = 25.7 min; KDT_{95} = 57.2 min) and the highest knockdown rates (KR_{50} = 0.0389 min⁻¹; KR_{95} = 0.0175 min⁻¹), followed closely by propoxur. DDT and deltamethrin displayed considerably slower knockdown responses, though still faster than those found in Ado-Ekiti. In Ado-Ekiti LGA, all insecticides produced delayed knockdown reactions. Deltamethrin (0.05%) showed the slowest action (KDT_{50} = 77.6 min; KDT_{95} = 115.3 min), with correspondingly low knockdown rates (KR_{50} = 0.0129 min⁻¹; KR_{95} = 0.0087 min⁻¹). Similarly, DDT and pirimiphos-methyl showed longer knockdown times, showing lower susceptibility in this LGA. For the remaining LGAs, Oye-Ekiti and Efon-Alaaye, (carbamates) particularly bendiocarb (0.10%) consistently achieved faster knockdown than organochlorine and pyrethroid insecticides. In Efon-Alaaye, bendiocarb attained a KDT_{50} of 31.9 min and a KR_{50} of 0.0313 min⁻¹, while DDT demonstrated the slowest knockdown response. In Oye-Ekiti, bendiocarb and pirimiphos-methyl displayed moderate to rapid knockdown compared with deltamethrin and DDT. In Ikere-Ekiti LGA, high knockdown rates were reported for bendiocarb (KR_{50} = 0.0372 min⁻¹) and propoxur (KR_{50} = 0.0338 min⁻¹), however pirimiphos-methyl and DDT showed substantially reduced knockdown efficiency. Across all LGAs, DDT and deltamethrin consistently reported longer knockdown periods and lower knockdown rates, suggesting widespread resistance to organochlorine and pyrethroid insecticides.

Table 2
Knock Down Rates for Different Insecticides during One Hour Exposure across Different LGAs.

LGA	Insecticide (WHO dose)	KDT₅₀ (min)	KDT₉₅ (min)	KR₅₀ (min⁻¹)	KR₉₅ (min⁻¹)
Ise-Orun	Propoxur (0.10%)	38.9	73.2	0.0257	0.0137
	DDT (4%)	76.1	121.6	0.0131	0.0082
	Bendiocarb (0.10%)	47.0	94.4	0.0213	0.0106
	Pirimiphos-methyl (0.25%)	32.6	65.1	0.0307	0.0154
	Deltamethrin (0.05%)	62.6	98.0	0.0160	0.0102
Ido-Osi	Propoxur (0.10%)	29.8	57.6	0.0336	0.0174
	DDT (4%)	48.0	82.0	0.0208	0.0122
	Bendiocarb (0.10%)	25.7	57.2	0.0389	0.0175
	Pirimiphos-methyl (0.25%)	33.4	62.1	0.0299	0.0161
	Deltamethrin (0.05%)	48.5	76.7	0.0206	0.0130
Ado-Ekiti	Propoxur (0.10%)	48.0	85.0	0.0208	0.0118
	DDT (4%)	70.2	98.7	0.0142	0.0101
	Bendiocarb (0.10%)	53.0	84.3	0.0189	0.0119
	Pirimiphos-methyl (0.25%)	73.5	109.9	0.0136	0.0091
	Deltamethrin (0.05%)	77.6	115.3	0.0129	0.0087
Oye-Ekiti	Propoxur (0.10%)	41.8	88.6	0.0239	0.0113
	DDT (4%)	66.4	128.9	0.0151	0.0078
	Bendiocarb (0.10%)	35.6	79.4	0.0281	0.0126
	Pirimiphos-methyl (0.25%)	38.2	84.1	0.0262	0.0119
	Deltamethrin (0.05%)	47.9	96.7	0.0209	0.0103
Efon-Alaaye	Propoxur (0.10%)	44.6	90.8	0.0224	0.0110
	DDT (4%)	61.2	121.5	0.0163	0.0082
	Bendiocarb (0.10%)	31.9	69.8	0.0313	0.0143

LGA	Insecticide (WHO dose)	KDT ₅₀ (min)	KDT ₉₅ (min)	KR ₅₀ (min ⁻¹)	KR ₉₅ (min ⁻¹)
	Pirimiphos-methyl (0.25%)	33.4	71.6	0.0299	0.0140
	Deltamethrin (0.05%)	46.1	93.2	0.0217	0.0107
Ikere-Ekiti	Propoxur (0.10%)	29.6	61.7	0.0338	0.0162
	DDT (4%)	42.8	91.4	0.0234	0.0109
	Bendiocarb (0.10%)	26.9	58.2	0.0372	0.0172
	Pirimiphos-methyl (0.25%)	48.3	97.6	0.0207	0.0102
	Deltamethrin (0.05%)	39.5	82.1	0.0253	0.0122

Discussion

Results from the susceptibility test of *A. gambiae* to DDT (organochloride) and deltamethrin (pyrethroid) in the six Local Governments Areas in Ekiti State showed widespread and strong resistance to both insecticides. However, greater susceptibility to Bendicarb and Propoxur was observed in the current study with local mosquitoes susceptible to Bendicarb and Propoxur in the two out of the three LGAs studied while only one LGA recorded resistance. This result is in accordance with the similar study conducted by [13] in the neighbouring State of Osun, South Western part of Nigeria which also revealed a general resistance to both insecticides. These findings are somewhat aligned with [14], where a wild population of *An. gambiae s.l.* was highly susceptible to bendiocarb (mortality rate of 100%) and DDT (mortality rate of 99.2%) but showed resistance to permethrin (mortality rate of 89.68%) and deltamethrin (mortality rate of 69.96%). Similarly, researches on the susceptibility status of *Anopheles gambiae s.l.* in Auyo, Jigawa state reported resistance to DDT (9%-16%) and permethrin (25%-35%) but susceptibility to bendiocarb (81%-94%) as observed by [15]. Also, the results corroborate other similar findings in other parts of Africa which revealed widespread insecticidal resistance to organochloride and pyrethroid [16]. *Anopheles* mosquitoes across the study LGAs exhibited the highest resistance to DDT, Pirimiphos – methyl and Deltamethrin in all breeding habitats. This resistance also extends to widely used insecticides like deltamethrin, echoing similar trends observed in other countries. Joseph *and group* conducted a study where they observed reduced mortality rates (< 90%), indicating resistance to deltamethrin (0.05%) in both *An. gambiae s.s.* and *An. arabiensis* in specific regions [17]. In contrast to findings by [18], *Anopheles gambiae s.l.* exhibited the highest resistance to Permethrin (49%) ($p = 0.04$, $p < 0.05$), while Pirimiphos-methyl showed the highest susceptibility (69%) with the lowest resistance recorded against Permethrin (16%) ($P = 0.002$; $p < 0.05$). In contrast, [6] reported varying levels of susceptibility and possible resistance in pirimiphos-methyl-treated *An. gambiae s.l.* The discrepancy in findings may be attributed to the historical use of insecticides in the respective regions. Over time, extensive use of specific insecticides could lead to the development of resistance among mosquitoes,

driven by genetic mutations or metabolic adaptations [19][20]. The widespread and strong resistance to pyrethroid and Organochloride as well as moderate resistance to other insecticides used in the current study showed that there is a rapid evolution of insecticide resistance malaria vector in the study areas. This could be attributed to the over reliance on the domestic use of insecticides, herbicides and pesticides by the farmers in the agricultural pruned study areas. Results from several studies had shown that mosquito larvae exposed to lethal dose of pesticides, herbicides or other pollutants on the cultivated vegetables in the urban areas commonly develop insecticide resistance through increased activities of insecticides detoxifying enzymes [21][22]. Similarly, the use of carbamates, pyrethroid and Organochloride in the rural areas to protect the cocoa, coffee and agricultural crops could be linked to the factors that triggered the selection pressure that influence evolution of insecticide resistance local mosquitoes in the three study LGAs. In the current study, *A. gambiae* was knocked down at different rates based on the types of insecticides used and locations of the capture flies. The fastest knocked down rate was recorded in Ido-Osi while the slowest was in Ado-Ekiti. The variation of knocked down rate in the study sites is in line with the similar study conducted in other parts of Africa which recorded differences in the knocked down rates of *A. gambiae* against insecticides types and study areas [6][23]. The differences observed could be attributed to the variation in insecticides used and the susceptibility status of *A. gambiae*. The findings from this study showed that deltamethrin had slowest knocked down time 77.6 minutes. This is in accordance with the similar study in other parts of Africa which revealed KDT50 of deltamethrin was greater than 60 minutes in all the three study areas. However, in this study only two study areas were greater than 60 minutes. Also KDT95 of all three tested areas were greater than 60 minutes which is similar to other studies. Similarly, bendiocarb had the fastest knocked down time of 25.7 min at KDT50. Also, the current study showed that KDT50 was below 60 minutes whereas KDT95 was above 60 min in all the three study areas. These results are in agreement with a similar study that can be found in the reference [24]. The outcomes of this research provide valuable insights for making informed decisions in designing effective vector control strategies and contribute significantly to the ongoing efforts aimed at combating malaria in Nigeria.

The insecticide resistance pattern observed in Ekiti State is also in agreement with results from neighbouring Osun State [4][25][26], where widespread resistance to DDT and deltamethrin was recorded. Similarly, studies in Kaduna [15][27] showed very low mortality rates for DDT (9–16%) and moderate resistance to pyrethroids, corroborating the high levels of resistance observed in Ekiti. However, susceptibility to bendiocarb in two of the three LGAs studied mirrors patterns in northern Nigeria, where *Anopheles gambiae* populations exhibited mortality rates between 81–94% to carbamates. The emerging resistance to Pirimiphos-methyl in Ado-Ekiti contrasts with reports from some other regions where organophosphates remain largely effective [18]. A recent work [28] has reported increasing resistance to Pirimiphos-methyl in West Africa. This indicates localized selective pressures, likely due to domestic and agricultural chemical usage, which may differ between states.

Conclusion

The occurrence of insecticide resistance in population of *A. gambiae* in the study areas is a major threat to the vector control operation in Nigeria. The observed resistance to pyrethroid which is commonly used in the control of malaria as well as bendiocarb in some parts of the study areas is a sign that their efficacies are threatened. As a result, this study suggests combining two insecticides with different modes of action as a resistance management method on the resistant vectors. In addition, using different insecticides in rotation manners, different regions and integrated vector management should be employed as part of resistance management method.

Declarations

Ethical Approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

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Author Contribution

A.A.A. was responsible for conceptualization, methodology, investigation, data acquisition, provision of resources, and writing of the original manuscript. A.A.D. was responsible for data analysis, writing, review, and editing. O.H.I. was responsible for project supervision and validation. S.I.O. was responsible for reviewing the manuscript.

Data Availability

The raw data generated and analysed during this study are currently available from the corresponding author upon reasonable request and have not been deposited in a public repository.

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Figures

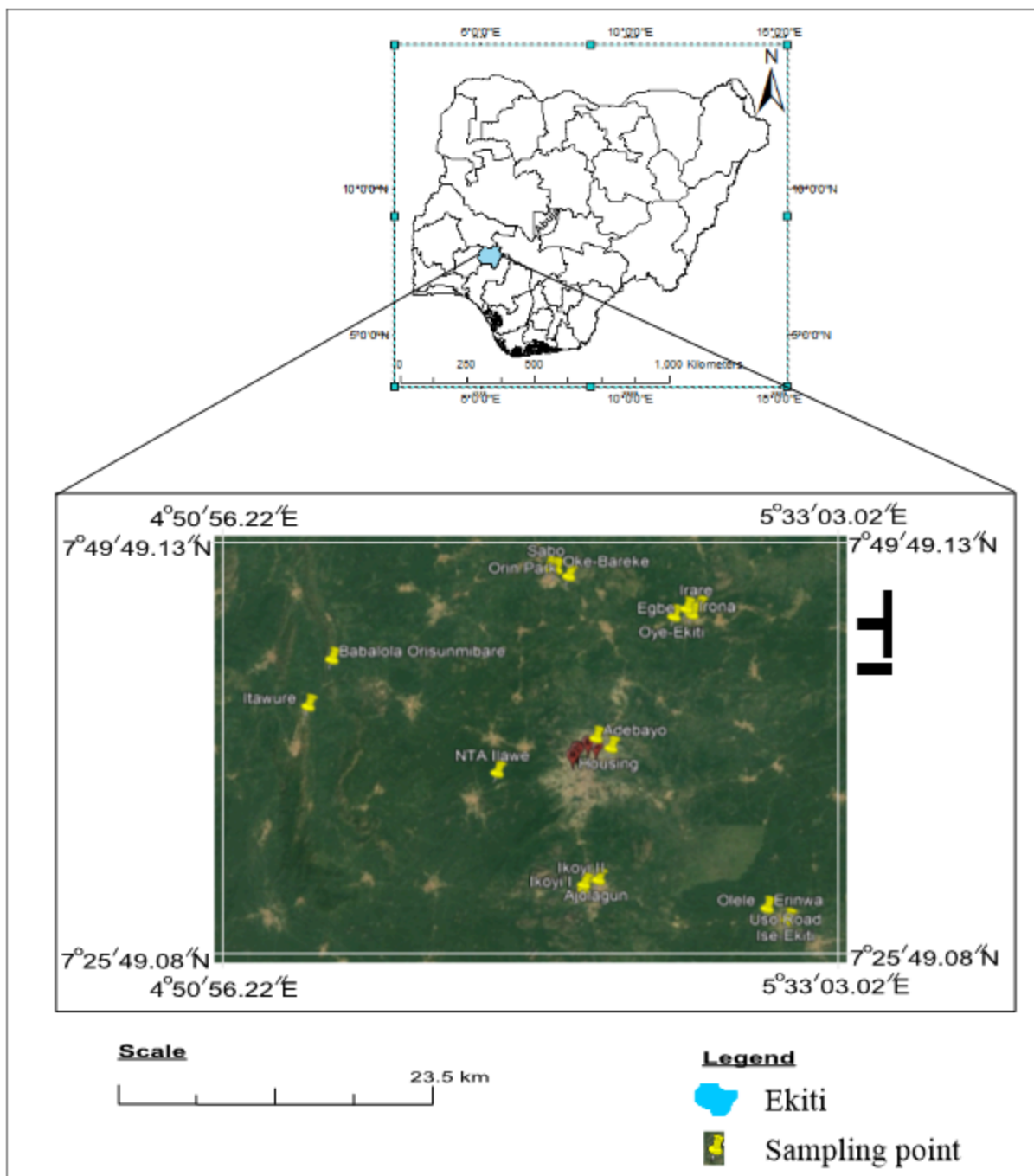


Figure 1

Map of Ekiti State highlighting the study local government areas (LGAs).

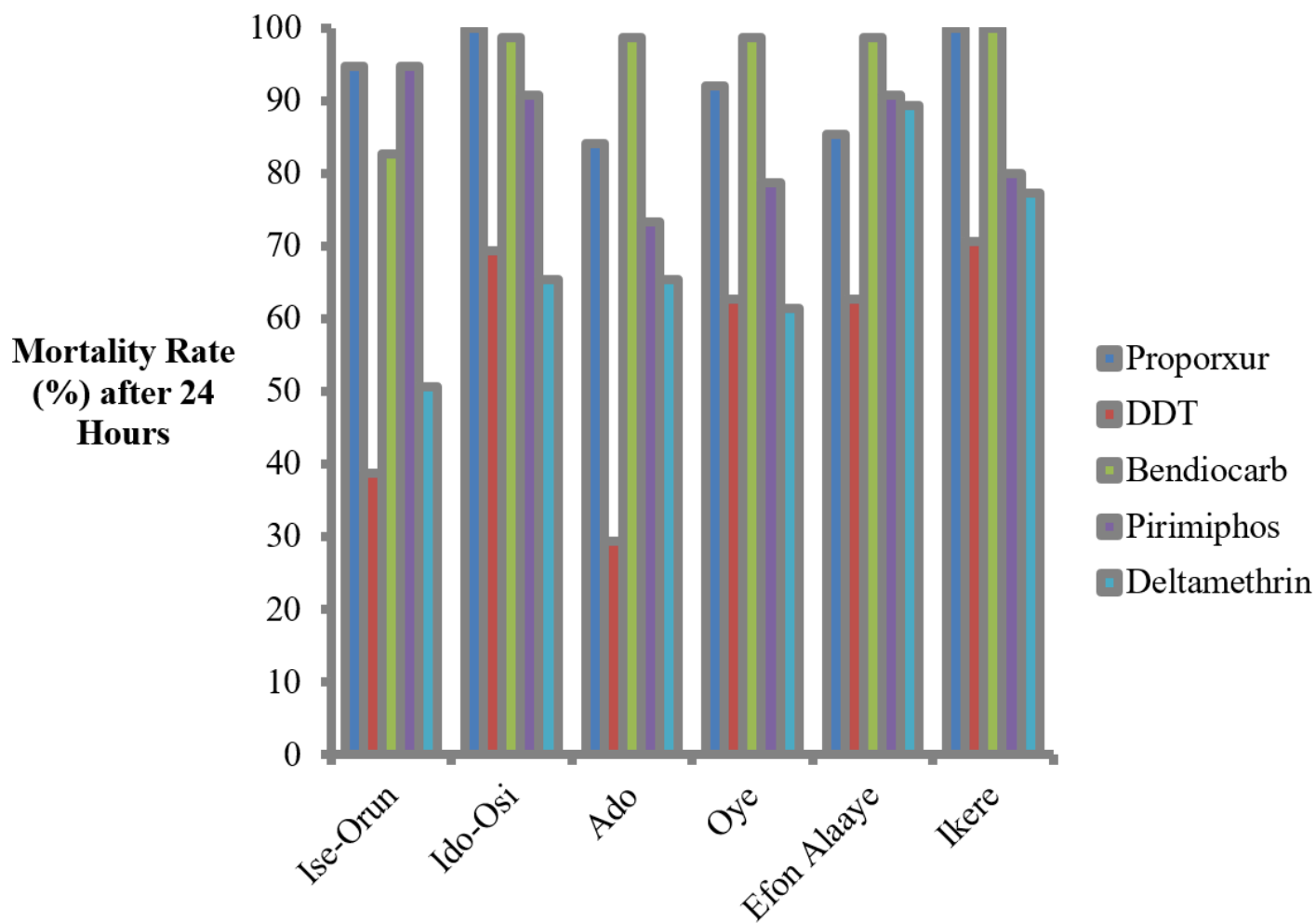


Figure 2

Comparison of the effectiveness of the five insecticides across all the six study LGAs after twenty four hours.