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Two years evolution of deltamethrin, malathion and pirimiphos-methyl resistance in *Aedes aegypti* from urban in peri urban sites of Ouagadougou, Burkina Faso

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ABSTRACT

Arboviral diseases such as dengue, chikungunya, and yellow fever are major public health concerns in Africa, with *Aedes aegypti* as the primary vector. Insecticide-based interventions remain the cornerstone of vector control, but their effectiveness is increasingly compromised by the evolution of resistance. Monitoring resistance dynamics is therefore essential to guide sustainable control strategies. Adults emerged from eggs collected in urban and peri-urban sites of Ouagadougou in 2019 and 2020, were exposed to insecticide-treated papers according to WHO standard tubes protocols. Mosquitoes were exposed to 0.03% deltamethrin, 0.08% malathion, and 0.21% pirimiphos-methyl for one hour. The mortality rate was recorded 24 hours after exposure and compared across years and sites using Chi-square test. The tested populations were resistant to deltamethrin, with lower mortality rates at the urban site (20.20% in 2019 vs. 23.76% in 2020; p = 0.5434) but a significant change at the peri-urban site (70.24% vs. 24.30%; p < 0.001). The resistance to malathion was moderate with, mortality rate decreasing from 91.51% to 82.98% in the urban site (p = 0.069), and from 98.99% to 59.61% in the peri-urban site (p= 0.001). Pirimiphos-methyl mortality rates slightly drop from 80.39% to 74.72% (p=0.44) in urban site and from 93.20% to 84.69% (p=0.001). These findings reveal a worrying trend of reducing susceptibility of *Aedes aegypti* to both pyrethroids and organophosphates, particularly in peri-urban areas within in one year. The results underscore the urgent need for continuous resistance monitoring and the implementation of early resistance management strategy to sustain arbovirus prevention efforts in Burkina Faso.

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INTRODUCTION

Arboviral diseases such as dengue, chikungunya, Zika, and yellow fever are major public health concerns worldwide (WHO, 2023). Their transmission relies primarily on *Aedes aegypti*, a highly anthropophilic mosquito species, well adapted to urban and peri-urban environments (Gossner *et al.,* 2023; WHO, 2024). Globalization, rapid urbanization, and climate change have facilitated the expansion of this vector, leading to recurrent epidemics in many regions (Kolimenakis *et al.,* 2021; Ifenyinwa and Nwadiuto, 2022).

Chemical insecticides, particularly pyrethroids (deltamethrin) and organophosphates (malathion and pirimiphos-methyl), have historically been the mainstay of control programs (WHO, 2019). However, the effectiveness of these compounds is increasingly undermined by the development of insecticide resistance in *Aedes aegypti* (Moyes *et al.,* 2017).

Globally, resistance to pyrethroids has been reported across Latin America, Southeast Asia, and Africa, often linked to *kdr* mutations in the voltage-gated sodium channel genes and metabolic detoxification mechanisms (Moyes *et al.,* 2017). In Burkina Faso, dengue outbreaks have become more frequent in the past decade, and local populations of *Aedes aegypti* have shown rapid changes in susceptibility to commonly used insecticides (Badolo *et al.,* 2019; Toe *et al.,* 2022; Zongo *et al.,* 2025). This poses a serious challenge to public health authorities, who must adapt their strategies to the evolving resistance landscape.

The resistance to the common insecticide resistance classes is widely spreading in Burkina Faso (Zongo *et al.,* 2025) and seems to evolve over time as reported (Yaméogo *et al.,* 2024). However, how speed, the insecticide resistance is evolving, could depend of many factors such as the selection pressure. This study aims to provide longitudinal data on insecticide resistance in *Aedes aegypti* populations from urban and peri-urban sites of Ouagadougou. Specifically, we report a two-year evolution of susceptibility to three reference insecticides, deltamethrin, malathion, and pirimiphos-methyl, using WHO diagnostic doses (WHO, 2022).

MATERIALS AND METHODS

Study sites

The study was conducted in Ouagadougou, (12°21'58" N, 1°31'05" W), the capital and largest city of Burkina Faso. Urban and peri-urban districts of the city were selected. 1200 logements is an urban district which comprises modern concrete buildings, piped water, electricity, sanitation and waste management systems. The second site, named Tabtenga is a peri-urban district with high density of houses. It is located approximately 5km east of 1200 logements but it has no centralized water supply, no electricity and no waste management systems.

Mosquito sampling and WHO susceptibility bioassays

Aedes mosquitos were collected as eggs using oviposition traps. Mosquitoes were reared to adults for use in laboratory tests, under controlled conditions of temperature (27 ± 2°C) and relative humidity (75± 10%). The samples were collected during the wet season (July-September) in 2019 and 2020. For each bioassay one hundred mosquitoes (four replicates of 25 mosquitoes) of 3 to 5 days old, non-blood fed female mosquitoes were exposed to the insecticide treated paper at *Aedes* diagnostic dose for one hour following the WHO tube bioassay procedure (WHO, 2016). The following insecticides and concentrations were tested: deltamethrin 0.03% (pyrethroid class insecticide), 0.8% malathion and 0.21% pirimiphos methyl (organophosphates insecticides class). The susceptibility profile was determined per insecticide based on the mortality rate recorded 24 hours after exposure to the insecticide treated paper, and classified as resistant, probable resistant, or susceptible following WHO criteria (WHO, 2016). After the test, dead and alive mosquitoes were stored over silica gel in 1.5 ml tubes for each insecticide and the control.

Statistical analyses

The susceptibility status of an *Ae. aegypti* mosquito population was determined according to the WHO criteria (WHO, 2016) which is based on the 24 hours mortality rate. Abbot's correction was not required as the mortality rate in the controls was below 5%. The mortality rates between sites and years were compared by Fisher's exact test using R software.

RESULTS

A total of 475, 351, and 348 adults of *Aedes aegypti* mosquitoes from the study sites were subjected to WHO bioassays to evaluate their susceptibility to three insecticide diagnostic doses: 0.03% deltamethrin, 0.08% malathion, and 0.21% pirimiphos-methyl respectively. These assays provide an overview of the evolution of resistance status between 2019 and 2020 to pyrethroid and organophosphate insecticide classes.

Deltamethrin resistance and its evolution

The mosquito populations in both sites showed mortality under 90% suggesting resistance to deltamethrin. Mortality rates of *Aedes aegypti* exposed to deltamethrin varied between 2019 and 2020. In the urban site, mortality increased slightly from 20.20% in 2019 to 23.76% in 2020 (Fig. 1). Statistical analysis did not reveal a significant difference between the two years (Chi-square= 0.369, p = 0.543). However, in the peri-urban site, mortality decreased significantly from 70.24% in 2019 to 24.30% in 2020 (X^2 = 55.304, p < 0.001) (Fig. 1).

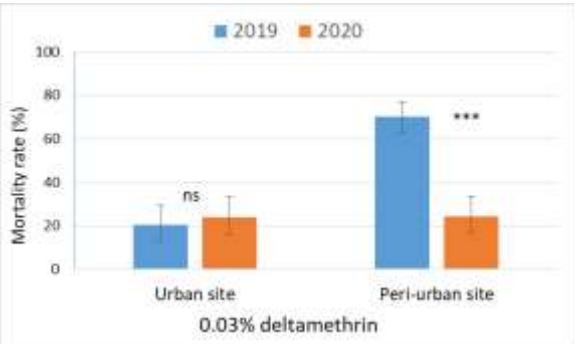

Fig. 1. Mortality rate to deltamethrin 0.03% in 2019 and 2020 in *Aedes aegypti* from urban and peri-urban sites of Ouagadougou (ns: non-significant, ***: p< 0.001)

Malathion resistance and its evolution

Mortality rates of *Aedes aegypti* exposed to 0.8% malathion varied between 2019 and 2020. In the urban site, mortality rate trend to decrease, but this not significant (X^2 = 3.315, p = 0.0687). Indeed a mortality rate of 91.51% and 82.98% were observed respectively in 2019 and 2020 (Fig. 2). In the peri-urban site, mortality significantly dropped from 98.99% in 2019 to 59.61% in 2020 (X^2 = 13.026, p = 0.0003) (Fig. 2).

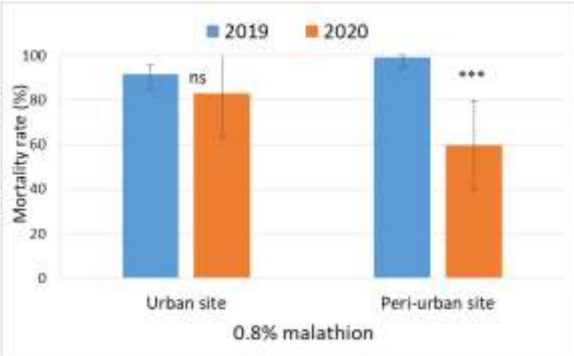

Fig. 2. Mortality rate to malathion 0.8 % in 2019 and 2020 in *Aedes aegypti* from urban and peri-urban sites of Ouagadougou (ns: non-significant, ***: p< 0.0001)

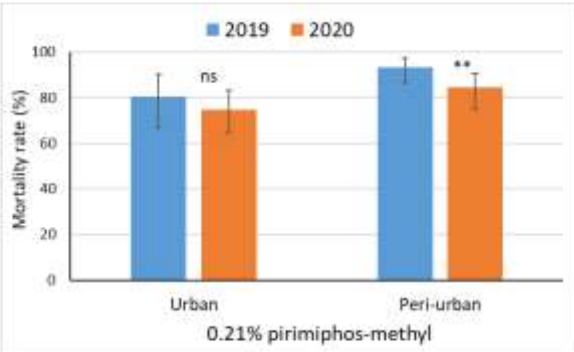

Fig. 3. Mortality rate to pirimiphos-methyl 0.21% in 2019 and 2020 in *Aedes aegypti* from urban and peri-urban sites of Ouagadougou (ns: non-significant, **: p< 0.0001 to **: p< 0.001

Pirimiphos-methyl resistance and its evolution

Aedes aegypti population showed moderate level of resistance to pirimiphos-methyl with overall mortality ranged from 74.7 to 93.2%. Mortality rates showed moderate variation between 2019 and 2020. Indeed, in the urban site, mortality decreased from 80.39% in 2019 to 74.72% in 2020 (X^2 = 0.588, p = 0.443) (Fig. 3). In the peri-urban site, mortality dropped significantly from 93.20% in 2019 to 84.69% in 2020 (Fig. 2) ($X^2 = 13.026$, $p = 0.0003$).

DISCUSSION

In 2023, Burkina Faso experienced one of its most severe dengue outbreaks, affecting all regions of the country with the capital city of Ouagadougou being the most affected (MSHP, 2024). The use of insecticide is the first strategy to respond to dengue outbreak in order to quickly drop down the vector densities. However, the effectiveness of this strategy could be undermined by the insecticide resistance level of local mosquito populations. The present study reported resistance to pyrethroids and organophosphate in *Ae. aegypti* populations from urban and peri-urban sites of Ouagadougou.

Resistance to pyrethroid is widespread in *Ae. aegypti* from all regions of Burkina (Zongo *et al.,* 2025) as well in Ouagadougou where many studies were performed (Badolo *et al.,* 2019; Sombie *et al.,* 2019). The pyrethroid resistance in Burkina Faso is mainly associated to the kdr mutations (Toe *et al.,* 2022; Sombie *et al.,* 2023). Resistance to organophosphates is sparse as only reported in some localities (Badolo *et al.,* 2019; Namountougou *et al.,* 2020; Toe *et al.,* 2022; Zongo *et al.,* 2025). The source of insecticide selection in *Aedes* is poorly investigated in Burkina Faso as it is for *Anopheles gambiae* where agriculture is playing an important role (Hien *et al.,* 2017). In *Aedes* mosquitoes the resistance is more likely to be associated the household uses of the insecticide products (Martins *et al.,* 2025).

The study reported overall a significant decreasing in mortality within a year suggesting, a rapid escalation of insecticide resistance in both sites. This increasing of the resistance is particularly pronounced in peri-urban compared to urban sites. Indeed the resistance level was overall high in the urban sites compared to peri-urban. This may make the increasing in the urban sites less perceptible. Similar patterns of evolution of resistance has been observed previously in Ouagadougou specifically for deltamethrin and permethrin from 2016-2018. This evolution of pyrethroids resistance was accompanied by of the 1534C, 1016I and 410L kdr alleles (Yaméogo *et al.,* 2024). As this resistance is till evolved in Ouagadougou, suggests the presence of the source of selection. The selection can come from both adults and larval stages. A recent study in Ouagadougou suggested that the type of *Aedes* water-holding containers may affect the susceptibility to pyrethroid insecticides. This study suggested that adults from larvae collected in domestic containers were more resistance compared to whose coming from tires (Toe *et al.,* 2025). Further investigation of the patterns of the evolution of insecticide resistance and its underlying mechanisms will provide valuable information. Although the current study focused on the evolution of the resistance over a short period of time, highlights the need for continual monitoring of insecticide resistance. As this study only assessed the resistance over the years can be a limitation.

CONCLUSION

This study demonstrates that *Aedes aegypti* populations from Ouagadougou exhibit resistance to both pyrethroid and organophosphate insecticides. The declines in mortality rates following exposure suggest the intensification of the resistance particularly in peri-urban settings. Further investigation on the mechanisms sustaining the rapid evolution of the insecticide resistance may be required. Also continuous monitoring according to the level of urbanization, coupled with integrated approaches beyond chemical reliance, will be essential to sustain arbovirus.

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