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Monitoring of Aedes albopictus Resistance to Common Insecticides in Futian District, Shenzhen

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Abstract

Background: This study aimed to investigate changes in the resistance of *Aedes albopictus* mosquitoes in Futian District, Shenzhen, to commonly used insecticides, providing a scientific basis for rational insecticide application and resistance management. **Methods:** Larval resistance to four commonly used insecticides was assessed using the World Health Organization (WHO)-recommended larval immersion method. Adult resistance was evaluated using the WHO-recommended adult contact tube method. **Results:** In 2025, *Aedes albopictus* larvae in Futian District, Shenzhen, exhibited high resistance to permethrin and beta-cypermethrin, with resistance ratios ranging from 224.6–239.5-fold and 88.3–118.8-fold, respectively. Low-level resistance was observed to propoxur and parathion, with resistance ratios of 3.3–3.4-fold and 4.0–4.9-fold, respectively. Adult *Aedes albopictus* mosquitoes showed resistance to permethrin and alpha-cypermethrin, with mortality rates of 8.9%–11.1% and 64.4%–72.2%, respectively. Possible resistance was detected to malathion and propoxur, with mortality rates of 87.8%–91.1% and 92.2%–94.4%, respectively. **Conclusion:** *Aedes albopictus* populations in Futian District, Shenzhen, have developed varying degrees of resistance to commonly used insecticides. Resistance to pyrethroid insecticides was markedly higher than that to carbamate and organophosphate insecticides. Insecticides should therefore be applied scientifically and rationally based on resistance surveillance results to improve control efficacy and delay the development of resistance.

Keywords Aedes albopictus; insecticide resistance; insecticides

1 Background

The Asian tiger mosquito, also known as the *Aedes albopictus*, is a vector for multiple insect-borne diseases. It transmits illnesses such as dengue fever, chikungunya fever, and Zika virus disease[1], posing a serious threat to human health[2]. Originating in the forested regions of Southeast Asia, *Aedes albopictus* has spread rapidly. Driven by human migration and climate change, it has now expanded to every continent except Antarctica[3]. Its distribution in China is extensive, reaching as far north as Heilongjiang Province, east to the Shandong Peninsula, south to Yunnan Province, and west to Xinjiang Province[4].

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Guangdong Province is one of China's major dengue fever hotspots[5]. In 2025, chikungunya fever experienced its first large-scale outbreak in Guangdong, with a cumulative number of locally acquired cases exceeding 20,000[6], posing a significant threat to public health. Currently, there are no effective vaccines or specific antiviral drugs available for dengue fever and chikungunya fever[7]. Among prevention strategies for these diseases, vector control stands as one of the most effective methods.

Chemical control aims to eliminate mosquitoes through the use of insecticides. Its advantages include convenience and rapid effectiveness, making it one of the most commonly employed vector control techniques, particularly during large-scale outbreaks and epidemics of mosquito-borne diseases. However, with the widespread adoption of chemical control strategies, mosquitoes have increasingly developed resistance to commonly used insecticides, leading to a significant decline in control efficacy and posing new challenges to public health[8]. Currently, *Aedes albopictus* mosquitoes in multiple regions of China exhibit varying degrees of resistance to commonly used pyrethroids, organophosphates, and carbamates, as public health insecticides[9].

To Investigate the pesticide resistance status of *Aedes albopictus* in Futian District, Shenzhen, resistance monitoring was conducted in 2025 to provide a scientific basis for rational pesticide use and resistance management.

2 Methods

2.1 Mosquitoes

The sensitive test mosquito strain was collected in 1980 from the mountainous regions of northern Guangdong by the Guangdong Provincial Center for Disease Control and Prevention and has been maintained in the laboratory since then. Wild mosquitoes were collected from May to July 2025 in several areas of Futian District, including Xiangmihu Subdistrict, Yuanling Subdistrict, Meilin Subdistrict, Futian Subdistrict, Lianhua Subdistrict, and Fubao Subdistrict. After 1–2 generations of laboratory rearing, late third-instar to early fourth-instar larvae were selected for testing.

The specimens were grouped into three sets: 1. Xiangmihu Subdistrict formed a separate group due to its high number of locally acquired dengue fever cases in 2024. 2. Yuanling Subdistrict was grouped separately because the Shenzhen Sports Center hosted the 15th National Games there. 3. The larvae from Meilin Subdistrict, Futian Subdistrict, Lianhua Subdistrict, and Fubao Subdistrict were combined into one group.

2.2 Insecticide

Larvicides: permethrin, beta-cypermethrin, propoxur, parathion. **Adulticide Film:** 0.4% Permethrin, 1.4% alpha-cypermethrin, 0.05% malathion, 0.5% propoxur. Shenzhen Center provided all test chemicals and films for the Disease Control and Prevention.

2.3 Larval Resistance Assay

The larval immersion method, recommended by the WHO[10-11], was employed to assess the larval resistance of *Aedes albopictus*. Test chemicals were diluted with acetone to achieve concentrations ranging from 5 to 7, with the concentration range determined through preliminary experiments to ensure that larval mortality was less than 20% at the lowest concentration and greater than 80% at the highest concentration. One milliliter of the prepared pesticide solution was pipetted onto the water surface and stirred with a glass rod. Thirty larvae pre-selected from another container were then transferred into the beaker along with 50 mL of water, resulting in a total volume of 200 mL.

The entire experiment was conducted in a greenhouse maintained at 25°C ± 1°C with a relative humidity range of 60% to 80%. Larval mortality was assessed after 24 hours, with each concentration repeated three times. Gently touch the larva's head and tail with a pipette. If the larva shows no response, fails to float to the surface, or sinks to the bottom, it is considered dead. If the control group mortality rate is ≤20%, the experimental group mortality rate is corrected using the Abbott formula. If the control group mortality rate exceeds 20%, the experiment is invalid and must be repeated.

2.4 Adult Mosquito Resistance Testing

The WHO-recommended adult mosquito exposure tube method[10-11] was used to determine the resistance of *Aedes albopictus* adults. A clean, standard A4 white paper sheet matching the size of the impregnated paper was placed inside the exposure tube. The impregnated paper was rolled into the tube and secured with a spring clip, followed by installation of the partition. Twenty-five healthy female mosquitoes, 3–5 days post-eclosion, were transferred into recovery tubes using mosquito pipettes and placed in parallel.

After 0.5 h of recovery, damaged, injured, or dead test insects were removed from the tubes. Test insects from recovery tubes were blown into exposure tubes, exposed to the pesticide film for one hour, then blown back into recovery tubes. Exposure tubes were removed, and recovery tubes were placed upright with the partition facing downward. Place a cotton ball soaked in a 10% glucose solution on the gauze mesh. Maintain the entire experiment in a greenhouse at 25°C ± 1°C and 60–80% relative humidity. After 24 hours, count the number of dead mosquitoes. Repeat the procedure three times per group.

2.5 Criteria for Determining Resistance

Larvae: Sensitive: RR < 3; Low-Level resistant: 3 ≤ RR < 10; Moderate resistant: 10 ≤ RR < 40; High-Level resistant: RR ≥ 40.

Adult mosquitoes: At diagnostic dose, Sensitive: Mortality rate ≥ 98%; Possible resistance: 80% ≤ Mortality rate < 98%; Resistant: Mortality rate < 80%.

2.6 Statistical Analysis

Statistical analysis was performed using SPSS 24.0 software to calculate the LC50 and 95% confidence interval (CI) for insecticides against *Aedes albopictus* larvae, along with toxicity regression equations. Excel 2016 software was used to calculate the mortality rate of adult female *Aedes albopictus* mosquitoes 24 hours after exposure to the insecticide-impregnated film.

3 Results

3.1 Monitoring Results of Larval Resistance in *Aedes albopictus*

The results of resistance testing for four insecticides against *Aedes albopictus* larvae in the Futian District of Shenzhen are presented in Table 1. The relative resistance (RR) levels observed were as follows: to permethrin, the RR ranged from 224.6 to 239.5 times; to beta-cypermethrin, from 88.3 to 118.8 times; to propoxur, from 3.3 to 3.4 times; and to parathion, from 4.0 to 4.9 times.

In Xiangmihu Subdistrict, *Aedes albopictus* larvae displayed high resistance to both permethrin (RR: 235.1-fold) and beta-cypermethrin (RR: 88.3-fold), alongside low resistance to propoxur (RR: 3.4-fold) and parathion (RR: 4.9-fold). Similarly, larvae from Yuanling Subdistrict showed high resistance to permethrin (RR: 224.6-fold) and beta-cypermethrin (RR: 99.3-fold), with low resistance to propoxur (RR: 3.4-fold) and parathion (RR: 4.0-fold). *Aedes albopictus* larvae from other subdistricts also exhibited high resistance to permethrin (RR: 239.5-fold) and beta-cypermethrin (RR: 118.8-fold), as well as low resistance to propoxur (RR: 3.3-fold) and parathion (RR: 4.6-fold).

Table 1: Results of Resistance Testing for Four Common Insecticides in *Aedes albopictus* Larvae from Futian District, Shenzhen

Insecticide	Sources of mosquitoes	LC_{50} (95% CI)	Regression equation	Resistance multiplier	Resistance level
Permethrin	Xiangmihu Subdistrict	1.881 (1.542–2.226)	$Y = -0.535 + 1.948x$	235.1	High-level resistant
	Yuanling Subdistrict	1.797 (1.460–2.138)	$Y = -0.486 + 1.911x$	224.6	High-level resistant
	Other streets	1.916 (1.598–2.240)	$Y = -0.597 + 2.113x$	239.5	High-level resistant
Beta-cypermethrin	Xiangmihu Subdistrict	0.362 (0.327–0.398)	$Y = 1.351 + 3.065x$	88.3	High-level resistant
	Yuanling Subdistrict	0.407 (0.370–0.445)	$Y = 1.246 + 3.190x$	99.3	High-level resistant
	Other streets	0.487 (0.386–0.606)	$Y = 1.079 + 3.023x$	118.8	High-level resistant
Propoxur	Xiangmihu Subdistrict	2.572 (2.448–2.700)	$Y = -2.318 + 5.648x$	3.4	Low-level resistant
	Yuanling Subdistrict	2.567 (2.445–2.692)	$Y = -2.337 + 5.805x$	3.4	Low-level resistant
	Other streets	2.494 (2.365–2.625)	$Y = -2.106 + 5.305x$	3.3	Low-level resistant
Parathion	Xiangmihu Subdistrict	0.016 (0.011–0.033)	$Y = 3.427 + 1.904x$	4.9	Low-level resistant
	Yuanling Subdistrict	0.013 (0.010–0.019)	$Y = 4.332 + 2.313x$	4.0	Low-level resistant
	Other streets	0.015 (0.009–0.059)	$Y = 3.558 + 1.945x$	4.6	Low-level resistant

3.2 Monitoring Results of Insecticide Resistance in Adult *Aedes albopictus* Mosquitoes

The results of resistance testing for four insecticides on adult *Aedes albopictus* mosquitoes in the Futian District of Shenzhen are summarized in Table 2. The mortality rates for each insecticide were as follows: 8.9% to 11.1% for permethrin, 64.4% to 72.2% for alpha-cypermethrin, 87.8% to 91.1% for malathion, and 92.2% to 94.4% for propoxur.

Within the Xiangmihu Subdistrict, adult *Aedes albopictus* mosquitoes demonstrated resistance to permethrin and alpha-cypermethrin, as well as possible resistance to malathion and propoxur, with mortality rates of 10%, 72.2%, 91.1%, and 94.4%, respectively. In the Yuanling Subdistrict, these mosquitoes exhibited resistance to permethrin and alpha-cypermethrin, possible resistance to malathion, and potential resistance to propoxur, resulting in mortality rates of 11.1%, 71.1%, 87.8%, and 92.2%. For the other subdistricts, adult *Aedes albopictus* mosquitoes showed resistance, possible resistance, and potential resistance to permethrin, alpha-cypermethrin, malathion, and propoxur, with corresponding mortality rates of 8.9%, 64.4%, 91.1%, and 93.3%, respectively.

Table 2: Results of Resistance Testing for Four Common Insecticides in Adult *Aedes albopictus* Mosquitoes from Futian District, Shenzhen

Insecticide	Sources	Tested (n)	Deaths (n)	Mortality (%)	Resistance level
Permethrin	Xiangmihu Subdistrict	90	9	10.0	Resistance
	Yuanling Subdistrict	90	10	11.1	Resistance
	Other streets	90	8	8.9	Resistance
Alpha-cypermethrin	Xiangmihu Subdistrict	90	65	72.2	Resistance
	Yuanling Subdistrict	90	64	71.1	Resistance
	Other streets	90	58	64.4	Resistance
Malathion	Xiangmihu Subdistrict	90	82	91.1	Possible resistance
	Yuanling Subdistrict	90	79	87.8	Possible resistance
	Other streets	90	82	91.1	Possible resistance
Propoxur	Xiangmihu Subdistrict	90	85	94.4	Possible resistance
	Yuanling Subdistrict	90	83	92.2	Possible resistance
	Other streets	90	84	93.3	Possible resistance

4 Discussion

In current mosquito vector control practices, the use of chemical insecticides is the most widely adopted strategy. This primarily includes pyrethroids, organophosphates, and carbamates. Among these, pyrethroid insecticides are the most commonly used pesticides worldwide. They are favored because of their low toxicity to mammals, rapid environmental breakdown, and quick knockdown effect on insects. Common application methods for pyrethroids include indoor residual spraying, hedge treatment, and space spraying[12].

However, the improper use and widespread application of these chemical insecticides have led to well-documented resistance to pyrethroids in *Aedes albopictus* mosquitoes. Monitoring results indicate that by 2025, adult *Aedes albopictus* mosquitoes in Futian District, Shenzhen, exhibited varying degrees of resistance to commonly used insecticides. They demonstrated resistance to pyrethroid insecticides (permethrin, alpha-cypermethrin), consistent with findings from other cities in Guangdong Province[13-14]. Potential resistance was observed to organophosphate (malathion) and carbamate (Propoxur) insecticides. Compared with monitoring results from 2019 in this district[15], adult *Aedes albopictus* exhibited an increasing trend in resistance to malathion.

In 2025, *Aedes albopictus* larvae exhibited high resistance to pyrethroid insecticides (deltamethrin and Beta-Cypermethrin) and low resistance to organophosphate (Propoxur) and carbamate (Parathion) insecticides, consistent with monitoring results from most regions in Guangdong Province[16-17]. Overall, *Aedes albopictus* in Futian District exhibited an increasing trend in resistance to chemical insecticides in 2025 compared to the 2019 monitoring results. This may be attributed to the frequent use of pyrethroid insecticides during routine prevention and emergency control measures, coupled with the absence of a scientific insecticide rotation strategy. In practice, insufficient dosages and overly short application intervals may have allowed resistant strains to persist and spread, creating sustained selective pressure that promotes the development of resistance genes in *Aedes albopictus*[18-19].

Therefore, based on the mosquito resistance monitoring results in Futian District, routine mosquito vector control efforts will prioritize environmental management and the elimination of breeding sites as foundational measures. This involves reducing mosquito breeding grounds at their source by clearing stagnant water containers, unclogging drainage ditches, and addressing sanitation blind spots[20]. Simultaneously, insecticide categories should be rotated to avoid continuous use of the same type. Employing multiple categories of insecticides in alternation reduces selective pressure on mosquitoes while rationally controlling application frequency and dosage. Monitor data should guide timely adjustments to insecticide quantities and application intervals, preventing overreliance on high-frequency, high-dose treatments. Strict adherence to operational protocols during application ensures uniform coverage and maximizes the efficacy of mosquito elimination, thereby delaying the emergence of insecticide resistance[21].

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