

KENYA MEDICAL RESEARCH INSTITUTE



In Search of Better Health

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Insecticide Resistance
KEMRI

What is Insecticide Resistance?

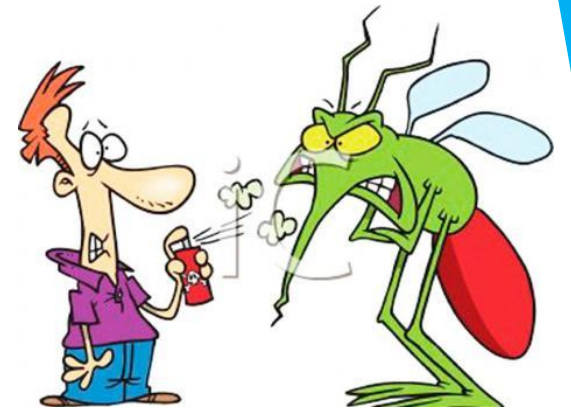
Insecticide Resistance Action Committee- IRAC

‘A heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species.’

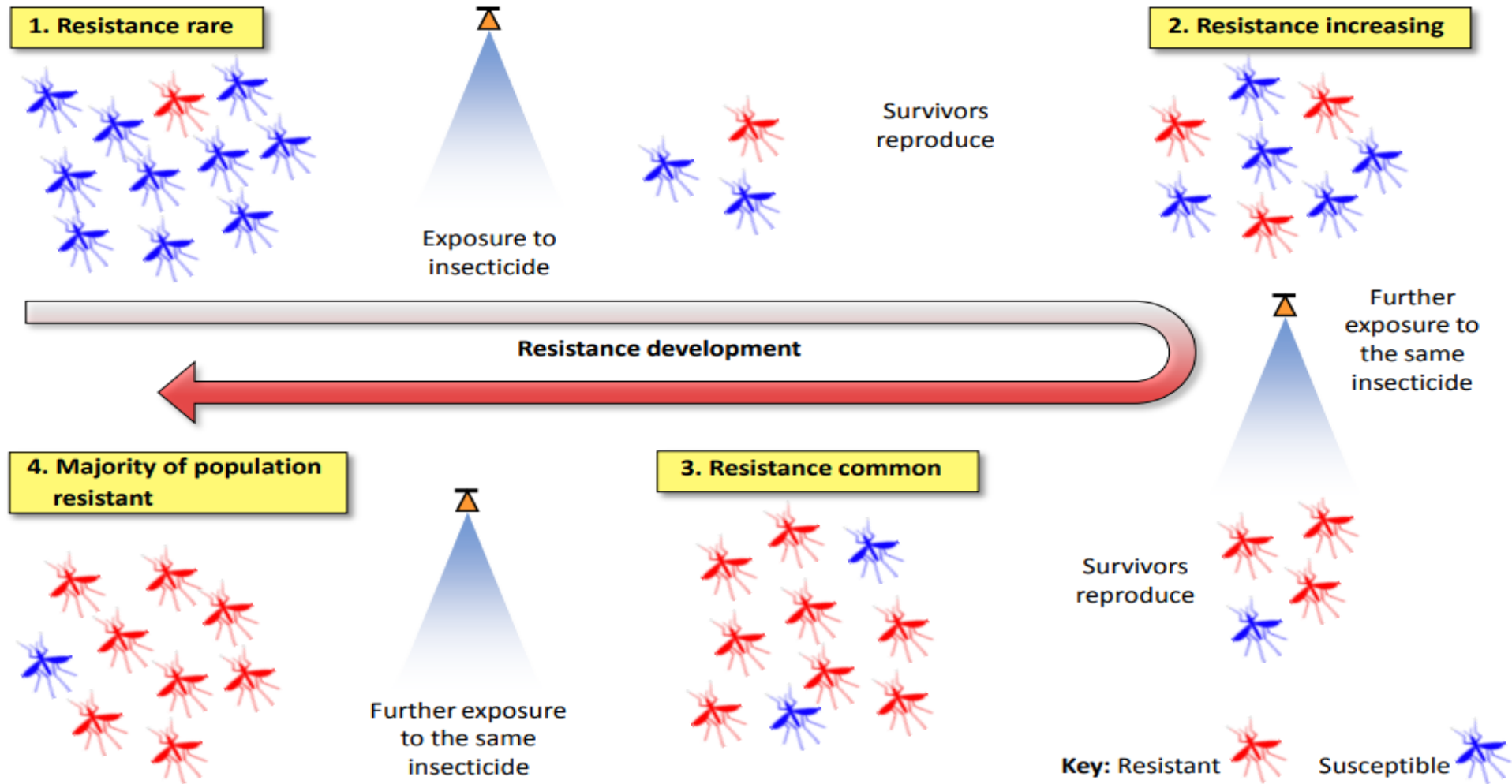
The ability of a vector to survive exposure to doses of insecticides that would normally be lethal.

Significance: A major threat to the effectiveness of vector control interventions, such as:

- Insecticide Treated Nets (ITNS)
- Indoor Residual Spraying (IRS)



Resistance Development



Resistance Mechanisms

Key Mechanisms:

- **Metabolic Resistance**

Increased activity of detoxification enzymes (e.g., P450s, esterases, GSTs).

- **Target-Site Resistance**

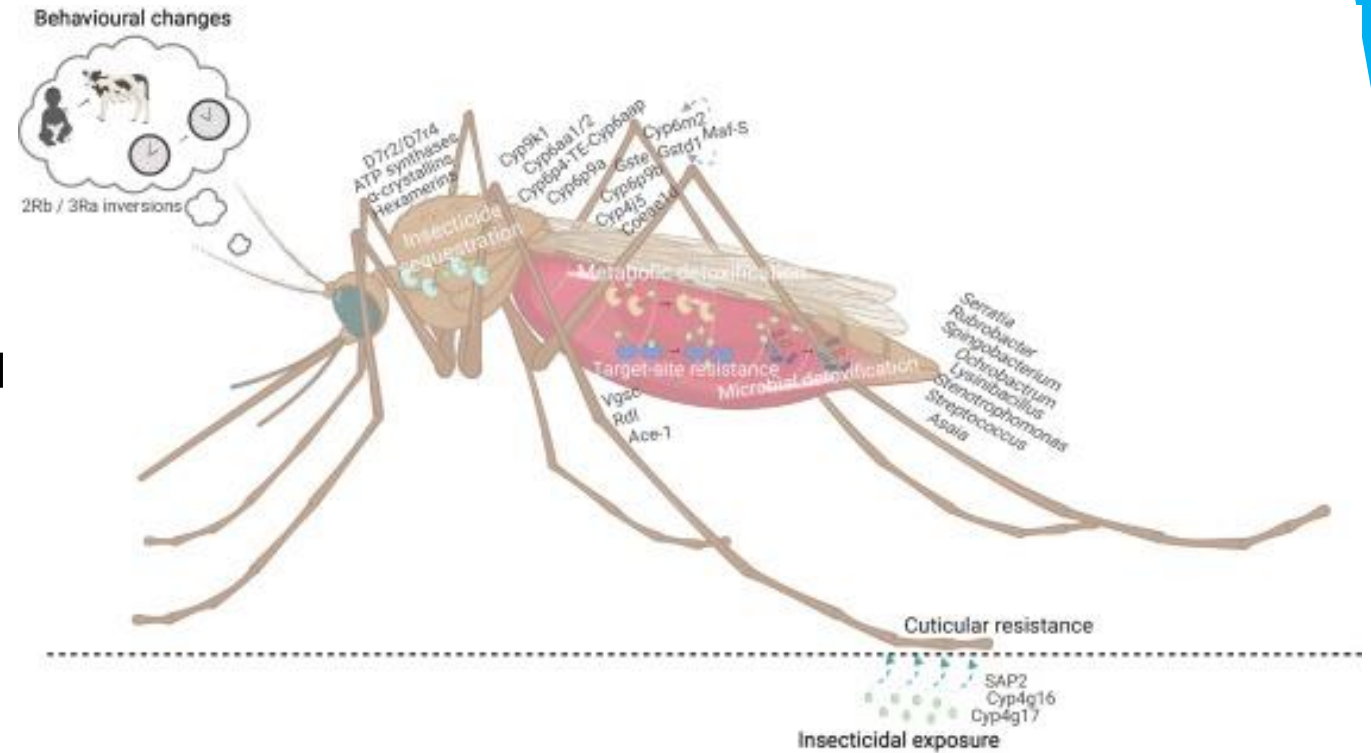
Example: kdr mutations in voltage-gated sodium channels.

- **Behavioral Resistance**

Avoidance of treated surfaces.

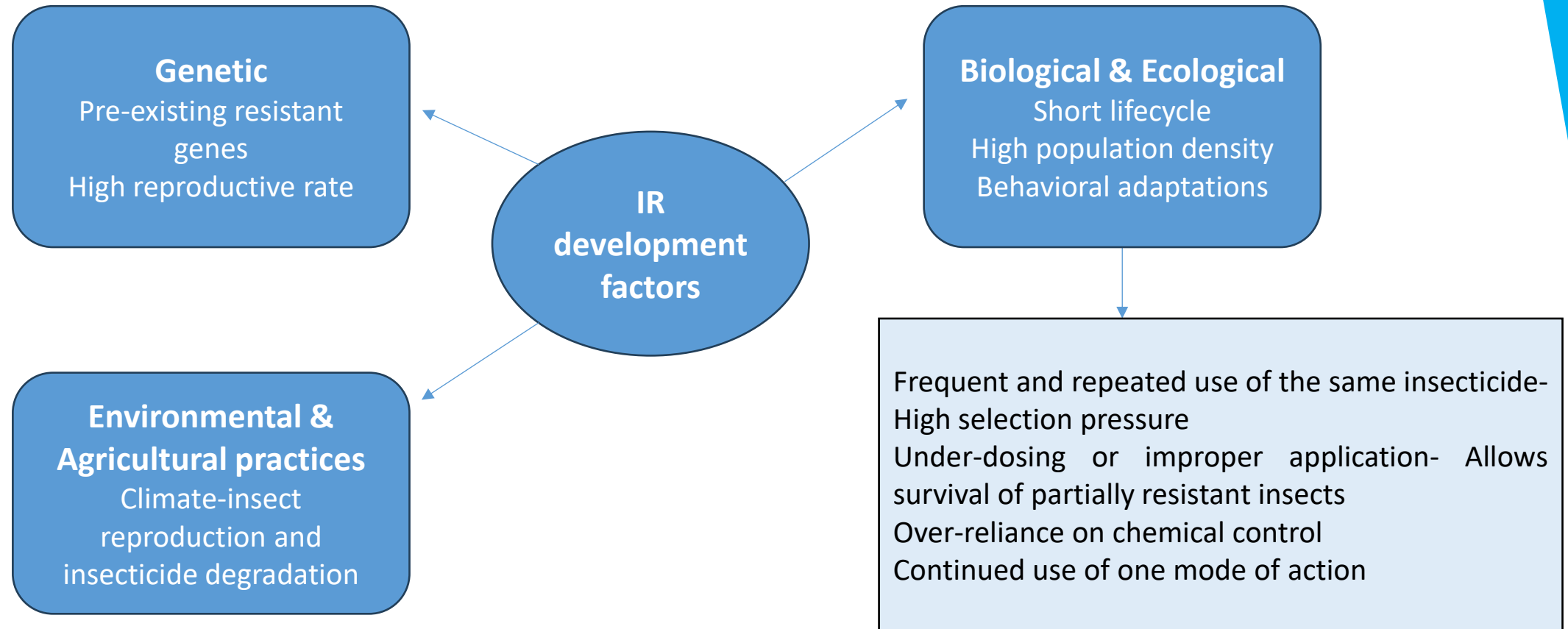
- **Cuticular Resistance**

Thickened exoskeleton reducing insecticide penetration.



Trends in Parasitology

Factors that lead to the development of insecticide resistance



Insecticide mode of action

Mode of Action

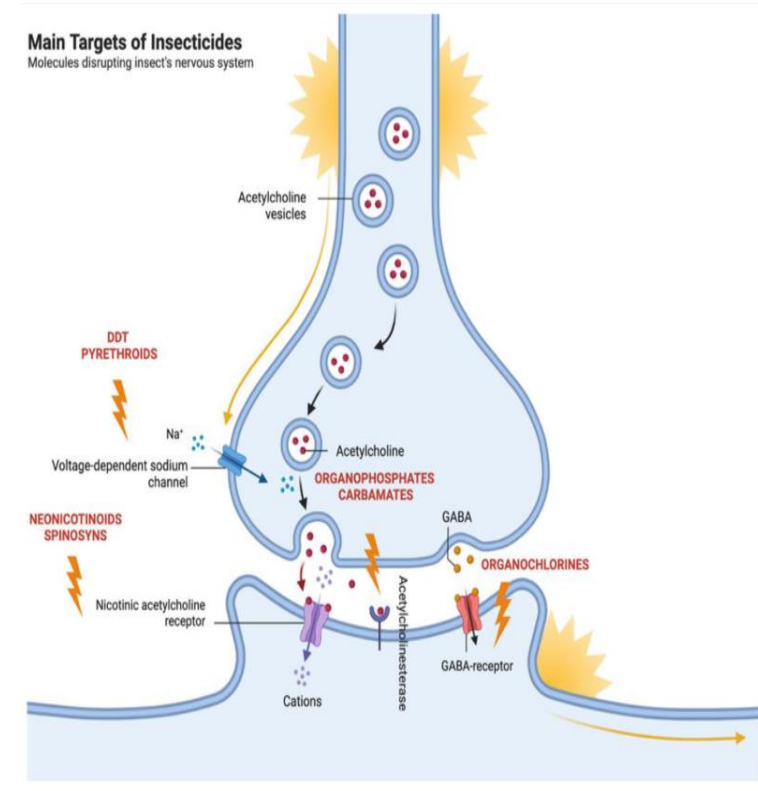
Classification based on site of action.

Different insecticides can have the same target site within the insect. Insecticides from the same chemical class, e.g., pyrethroids, will have the same MoA.

There may be many different commercial products based on insecticides from the same chemical class.

The IRAC MoA Classification allocates each insecticide to a numbered group based on their target site.

Chemical subgroups are identified with a letter; for example, pyrethroids are given the IRAC MoA classification 3A



Araújo et al., 2023

Insecticide mode of action-adult

Nerve and Muscle Targets

- Group 1: Acetylcholinesterase (AChE) inhibitors 1A Carbamates, 1B Organophosphates
- Group 3: Sodium channel modulators 3A Pyrethrins, Pyrethroids, 3B DDT

IRAC classification for mode of action

Primary Target Site of Action	Group	Sub-group	Chemical subgroup	Examples
Acetylcholinesterase (AChE) inhibitors	1	A	carbamates	bendiocarb, propoxur
		B	organophosphates ²	fenitrothion, pirimiphos-methyl, malathion, temephos
Sodium channel modulators	3	A	pyrethroids and pyrethrins	allethrin, bifenthrin, <i>lambda</i> -cyhalothrin, <i>alpha</i> -cypermethrin, deltamethrin, cyfluthrin, permethrin, etofenprox, phenothrin, transfluthrin
		B	DDT	DDT

Insecticide mode of action-larvae

Nerve and Muscle Targets

- Group 1: Acetylcholinesterase (AChE) inhibitors, 1B Organophosphates
- Group 5: Nicotinic acetylcholine receptor (nAChR) allosteric modulators, Spinosyns

Growth and Development Targets

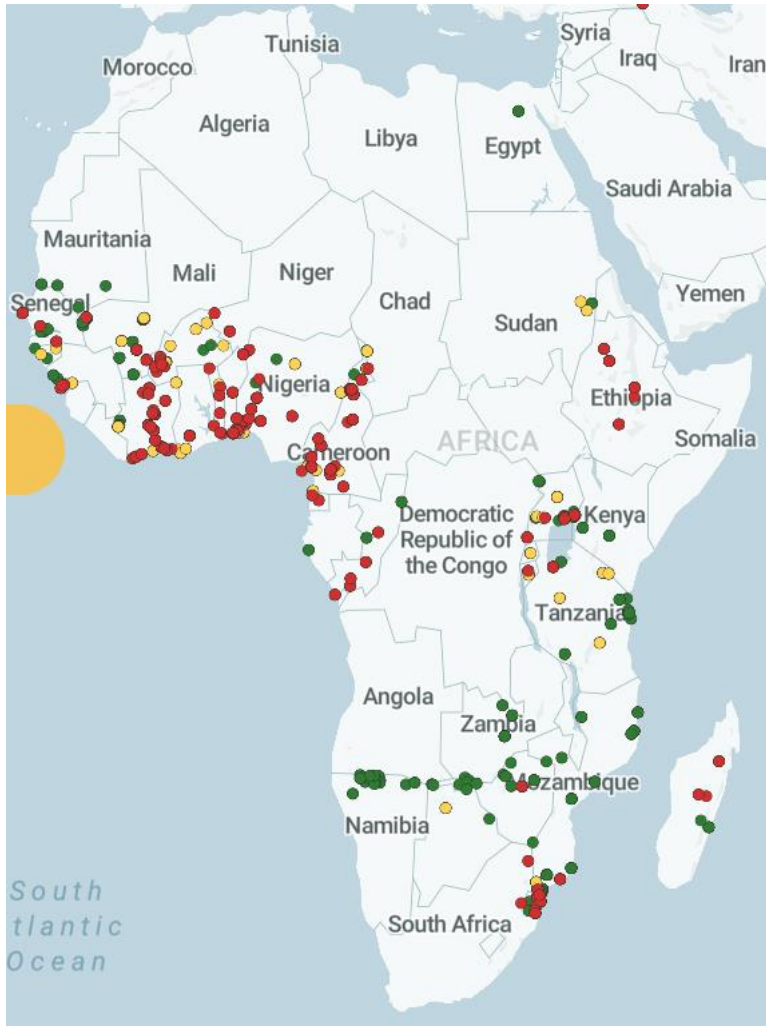
- Group 7: 7A Juvenile hormone mimics, 7C Pyriproxyfen
- Group 15: Inhibitors of chitin biosynthesis Type 0, Benzoylureas

Midgut

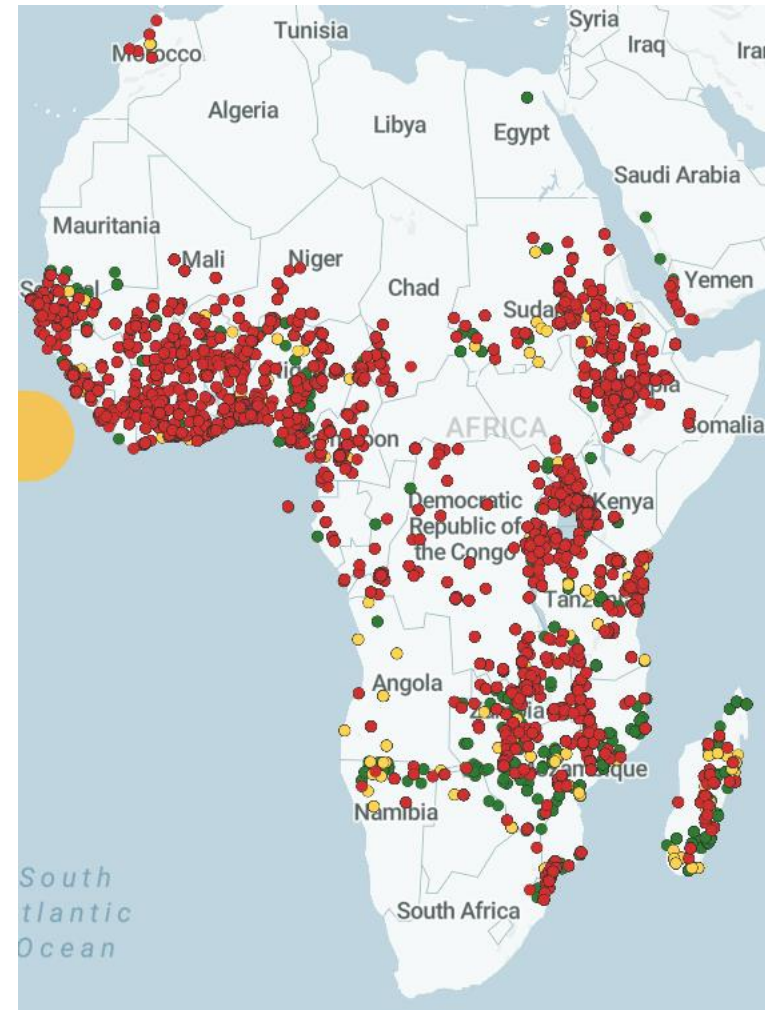
- Group 11: Microbial disruptors of insect midgut membranes, 11A *B. thuringiensis* var. *israeliensis*, 11B *B. sphaericus*

MoA	Class	Insecticide or Product
1B	Organophosphate	Temephos, Chlorpyrifos, Pirimiphos-methyl, Fenthion
5	Spinosyns	Spinosad
7A	Juvenile Hormone Mimics	Methoprene, Hydroprene
7C	Pyriproxyfen	Pyriproxyfen
15	Benzoylureas	Diflubenzuron, Novaluron
11A	Bacterial Larvicide	<i>Bt var. israeliensis</i>
11B	Bacterial Larvicide	<i>Bacillus sphaericus</i>

Current status of insecticide resistance



2000-2005



2000-2025

IR Mapper 2nd Sep
2025

Monitoring of insecticide resistance

Why monitor insecticide resistance?

- **Early Detection:** Identifies emerging resistance before it spreads widely.
- **Guides Policy:** Informs decision-makers for evidence-based vector control strategies.
- **Protects Public Health Investments:** Ensures continued efficacy of control tools.

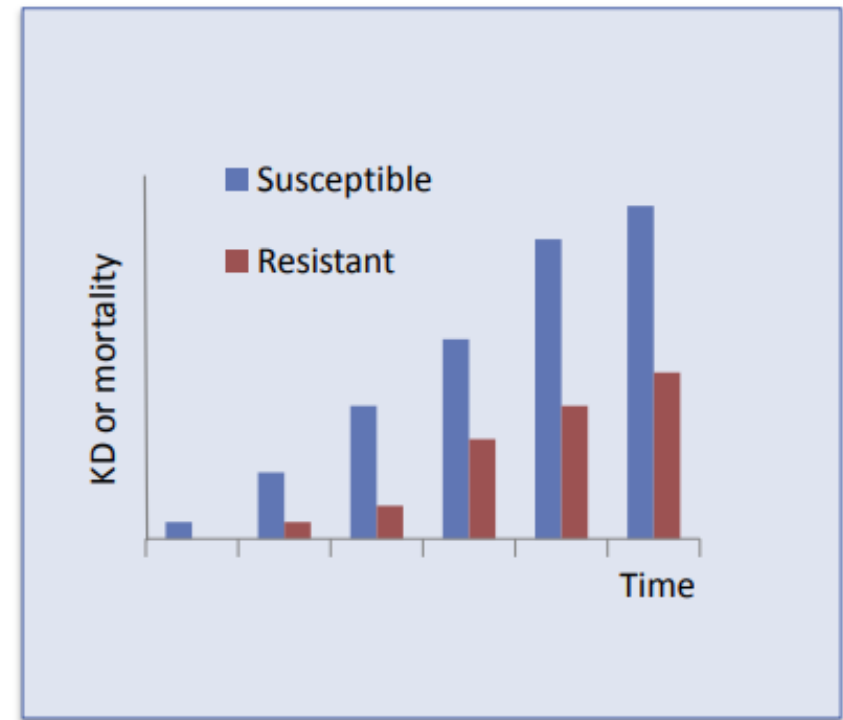
Monitoring objectives

Baseline data collection: Conducted prior to the start of a control programme in order to provide baseline data to inform planning and insecticide choice.

Monitoring of susceptibility over time: To evaluate the proportion of susceptible mosquitoes in the population over time, comparing it with the pre-intervention baseline.

Detection of resistance: To detect resistant individuals when they are at a low frequency in the population, so that resistance management can be effectively introduced.

Changes in susceptibility over time



Methods of Monitoring

1. Bioassays

- WHO tube tests
- CDC bottle assays

2. Molecular Assays

- Detection of resistance genes (e.g., PCR for kdr mutations).
- Genomic assays- sequencing

3. Biochemical Assays

- Enzyme activity tests (e.g., P450s, GSTs).



WHO Tube Assay

- Principle is exposure of adult mosquitoes for a given time in a plastic tube lined with a treated filter paper
- Mosquitoes are generally exposed for one hour, and mortality is assessed after 24 hours

Results

Treatment mortality (%) = (Number of treated female mosquitoes dead / Total number of treated female mosquitoes) x 100

Interpretation

Confirmed resistance: <90%

Possible resistance: ≥90% but <98%

Susceptibility: ≥98%



CDC Bottle Assay

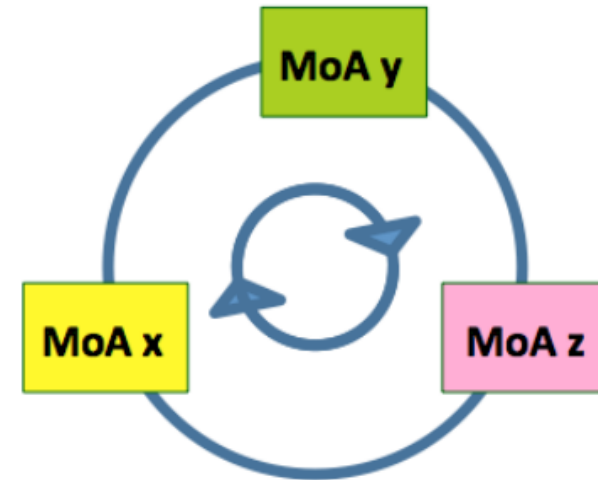
- Principle is exposure of adult mosquitoes for a given time in a 250 ml glass bottle coated with insecticide.
- The internal surfaces are coated with the insecticide diluted in acetone or ethanol. Once the solvent has evaporated, ~25 adult mosquitoes are added.
- Assessments of knockdown/mortality are made at 10-minute intervals and plotted against time. Changes in the slope of this graph over time are indicative of changes in the susceptibility of the mosquito population.



Resistance Management

Rotation:

- Strategy based on the rotation over time of two or more insecticide classes with different Modes of Action (MoA).
- This approach assumes that if resistance to each insecticide is rare, then multiple resistance will be extremely rare.



Resistance Management

Mixtures:

- A single formulation containing two or more insecticides, or different insecticide formulations being applied in the same spray tank, or an ITN treated with two or more insecticides with different MoA.
- It can also include the combination of an ITN with an IRS application in the same dwelling. This approach assumes that if a mosquito survives one insecticidal MoA, it will be killed by the other, and that if resistance to one is rare, resistance to both will be extremely rare.

Resistance Management

Fine-scale Mosaic

- Spatially separated applications of different MoA insecticides against the same mosquito population. e.g., using two different MoA insecticides in different dwellings within the same village.
- Mosquitoes are therefore likely to come into contact with a second insecticide during their lifetime, if they survive exposure to the first. This reduces the selection pressure for both insecticides.

Thank you