GENE DRIVE CAPABLE MOSQUITOS

A gene drive is a genetic mechanism that causes a particular gene to be inherited much more often than the normal 50% predicted by Mendelian rules, allowing it to spread rapidly through a population. Mechanisms of this kind also exist in nature (for example meiotic drive elements, selfish genetic elements, and transposons), but today they can also be engineered artificially using CRISPR.

The idea behind the Nature paper by Habtewold et a. (1) is not to eliminate mosquitoes, but to genetically modify them so that they can no longer transmit malaria, and then use a genetic mechanism to spread this trait through natural populations (gene drive).

First, the researchers engineered mosquitoes to produce two small anti-parasitic molecules. These molecules interfere with the development of the malaria parasite inside the mosquito. As a result, even if the mosquito feeds on infected blood, the parasite usually fails to reach the salivary glands, which are essential for transmission to humans. In practice, the mosquito can still bite, but it almost never becomes infectious.

Second, they use a “gene drive” system. Normally, a gene has a 50% chance of being inherited. A gene drive biases this process: using CRISPR-based molecular machinery, the modified gene is copied onto the other chromosome, so it is inherited by nearly 100% of the offspring. This allows the trait to spread very rapidly through a population, even if it provides no direct advantage to the mosquito.

In principle, the entire system (the antimalarial genes and the gene-drive machinery) could be packaged into a single genetic construct that would spread autonomously. However, for safety reasons, the researchers deliberately did not do this. Instead, the system is split into two parts. One mosquito line carries the anti-malaria genes but no drive. Another line carries the CRISPR machinery. Only when the two are crossed does the gene drive operate, forcing the anti-malaria genes to be inherited by almost all descendants. This makes the system much more controllable and safer to test.

The key advance of this study is that the system was tested using blood samples collected from malaria-infected children in Tanzania, rather than using only laboratory parasite strains. The results show that in genetically modified mosquitoes, the parasite almost never reaches the salivary glands, meaning transmission would be essentially blocked.

Artificial gene drives have never been released into the wild. Once such a system starts spreading in a natural ecosystem, nobody can reliably predict what will happen in the long term, nor how it might interact with ecology and evolution. For this reason, gene-drive systems are currently kept under strict containment.

Most researchers agree that gene drives should be considered only in extreme situations, where the potential benefit is enormous and no reasonable alternatives exist. The most often cited case is the control of devastating human diseases such as malaria, dengue, or Zika, when other methods (insecticides, drugs, vaccines, environmental control) prove insufficient.

Another widely discussed application is the control of invasive species, especially in geographically limited ecosystems such as islands, for example rats or mice that are responsible for the extinction of native birds and reptiles.

Even in these cases, it is likely that the first real-world applications will not use fully self-propagating global gene drives, but rather self-limiting or threshold-dependent systems, designed to remain local and, in principle, reversible.

Gene drive will probably be used only when the risk of not using them is clearly greater than the risk of using them. Until then, they remain one of the most powerful and carefully contained tools ever developed in evolutionary genetics.

1. https://www.ncbi.nlm.nih.gov/pubmed/41372414