Two studies identify new strategies for insect control

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Mosquitoes spread several diseases, among them malaria and dengue virus. In 2020, about 241 million cases of malaria occurred worldwide, with a few more million cases occurring in 2021. Nearly half the world's population lives in regions where contracting dengue virus is a risk.

Insects also destroy a third of agriculture.

New research by scientists at the University of California, Riverside, shows potential for insect control through volatile repellents that could be applied on surfaces such as windowsills, eaves of huts, house entryways, backyards, outside produce storage areas, entryways of livestock shelters, and next to crops in a field.

The researchers focused on ammonia, a basic volatile compound found in insect environments. At low concentrations, such as in human sweat, ammonia is an attractant for mosquitoes and other insects. At high concentrations, however—for example, the concentrations found in household cleaners—ammonia is no longer attractive to insects. The researchers inquired into what happens to the olfactory (smell) system and gustatory (taste) system of fruit flies and mosquitoes in the presence of ammonia.

"We found the olfactory neurons seem to have a burst of activity and then they become silent for a while," said Anandasankar Ray, a professor of molecular, cell and systems biology, who led the study that appears in the journal *iScience*. "During the silent period, the neurons are not able to detect any odorants, which means insects cannot effectively find human skin odor."

When Ray's team tested the taste system of fruit flies and mosquitoes (Aedes aegypti), they found a similar response.

"Where taste is concerned, we found ammonia and 'amines'—derivatives of ammonia that make up many synthetic odorants—don't produce the flash type of activity we see in the olfactory system," Ray said. "But they do show the inhibition we found in the olfactory system. We were able to show that ammonia silences the sugar and salt response in insects."

After most insects use their smell system find a location to land on, their taste system is executed. Mosquitoes use the labella—sensory probes that aid in searching for a good place to bite—on their legs to taste food. Fine hairs (sensilla) on the labella of fruit flies enable the flies to taste potential foods without eating them.

According to Ray, the discovery could be used to make effective insect repellents in the future.

"While compounds like ammonia, which have a high pH and are basic, cannot be used on skin due to their corrosive properties, they can be used in other ways," he said. "Many biting insects fly into homes from outside. In most parts of the world, insects bite humans and pets indoors and often at night. For example, if walls, where insects land and wait, had a high pH material in them, mosquitoes would be affected. Similarly, if a high pH compound, such as an amine, were dispensed around entryways of homes and animal sheds, it could keep mosquitoes away."

Ray was joined in the study by Jonathan Trevorrow Clark, Anindya Ganguly, Jadrian Ejercito, Matthew Luy, and Anupama Dahanukar. The research paper is titled "Chemosensory detection of aversive concentrations of ammonia and basic volatile amines in insects."

It's the humidity

In a separate paper, published in the journal *Scientific Reports,* Ray's lab studied behavior modification to humidity in the Asian citrus psyllid, or ACP, which transmits citrus greening disease, and mosquitoes. Although insects can sense humidity, little research has been done on disrupting their humidity-sensing neurons.

"We found amine odorants inhibit the humidity response," Ray said.

"We identified neurons in the ACP that detect humidity and found that certain amines could inhibit their humidity sensing. We then showed this was conserved in fruit flies. This is probably the first time that researchers have shown that humidity sensing can be inhibited by odorants."

The researchers then tested humidity sensing in gravid mosquitoes (Aedes aegypti and Anopheles coluzzi) that are attracted to water bodies to lay eggs. In the lab, blood-fed mosquitoes that were ready to lay eggs were presented with two cups of water. One cup contained a small vial of odor that inhibits humidity sensing. The researchers found the mosquitoes avoided laying eggs there and preferred instead the untreated cup.

"This suggests it is possible to block the humidity sensing neurons in insects by using a volatile chemical and lower the level of egg laying," Ray said.

He also explained that ACPs appear to avoid high humidity. To test their humidity sensing, his lab used a Y shaped tube with high humidity in both arms. The ACPs preferred neither arm at first. But when the researchers introduced a humidity inhibiting odorant in one arm, the ACPs began to prefer it because they could not sense the humidity anymore.

"This means that by blocking the insects' ability to sense water using a volatile odorant, we can manipulate their humidity sensing pathway and alter their behavior in a predictable manner," Ray said. "In the future it may be possible to engineer amines to prevent insect egg laying in certain areas."

The research has implications for regions where mosquitoes spread diseases. After they take a blood meal, mosquitoes look for water in

which to lay their eggs. A single female mosquito can lay up to 300 eggs in a single night.

"Because of this extremely high reproductive potential, from spring to summer we see an explosion of mosquitoes," Ray said. "Where you have water with mosquito larvae, it is extremely difficult to control the mosquito population. This is why in tropical countries it is impossible to kill off all the mosquitoes. Even if a few mosquitoes are left over, they reproduce very fast."

More information: Jonathan Trevorrow Clark et al, Chemosensory detection of aversive concentrations of ammonia and basic volatile amines in insects, *iScience* (2022). DOI: 10.1016/j.isci.2022.105777

Iliano V. Coutinho-Abreu et al, Pentylamine inhibits humidity detection in insect vectors of human and plant borne pathogens, *Scientific Reports* (2022). DOI: 10.1038/s41598-022-20488-x

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