Female moths use olfactory signals to choose the best egg-laying sites

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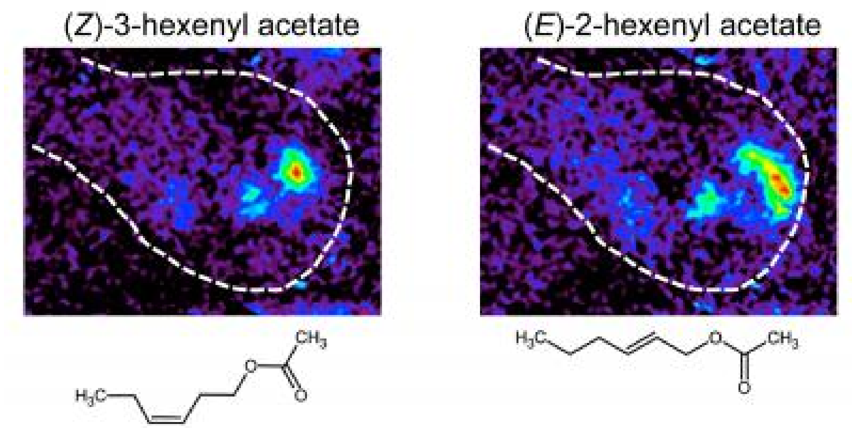

Functional calcium imaging in the antennal lobes of a female *Manduca sexta* moth: Different activation patterns (red spots) can be observed depending on whether the moths respond to (Z)-3-hexenyl acetate or (E)-2-hexenyl acetate. The odor of a (Z)-3-isomer or a (Z)-3 / (E)-2 ratio in favor of a (Z)-3-isomer -- according to the odor bouquet of an unattacked plant -- guides ovipositing *Manduca* females to plants that have yet been spared by herbivorous caterpillars. Copyright: Anna Späthe, Max Planck Institute for Chemical Ecology

Researchers at the Max Planck Institute for Chemical Ecology, Jena, Germany, discovered that the ability of *Manduca sexta* moths to recognize changes in the profile of volatile compounds released by plants being attacked by *Manduca* caterpillars allows them to lay their eggs on plants that are less likely to be attacked by insects and other predators, and to avoid competing against other caterpillars of the same species for resources. The results of field experiments and neurobiological studies were now published in the open access online journal *eLIFE*.

"Green" leaf odors

Plants have developed many different strategies to defend themselves against herbivorous animals, particularly insects. In addition to mechanical defenses such as thorns and spines, plants also produce compounds that keep insects and other herbivores at bay by acting as repellents or toxins. Some of these metabolites are produced on a continuous basis by plants, whereas others – notably compounds called green-leaf volatiles – are mainly produced once the plant has been wounded or attacked. Green-leaf volatiles – which are also responsible for the smell of freshly cut grass – have been observed to provide plants with both direct protection, by inhibiting or repelling herbivores, and indirect protection, by attracting predators of the herbivores themselves.

Attracting the enemies of the herbivores

The hawkmoth *Manduca sexta* lays its eggs on various plants, including tobacco and Sacred Datura plants (*Datura wrightii*). Once the eggs have hatched into caterpillars, they start eating the leaves of their host plant, and if present in large numbers, these caterpillars can quickly defoliate and destroy the plant. In an effort to defend itself, the host plant releases green-leaf volatiles to attract various species of *Geocoris*, predatory bugs that eat insect eggs and tiny larvae.

One of these green-leaf volatiles released by tobacco plants is known as (Z)-3-hexenyl acetate, but enzymes released by *M. sexta* caterpillars' spit change some of these molecules into (E)-2-hexenyl acetate, which has the same chemical composition but a different structure. The resulting changes in the volatile profile alerts *Geocoris* bugs to the presence of *M.*

sexta caterpillars on the plant – their potential prey.

This is a *Manduca sexta* moth. Copyright: Linda Kübler, Max Planck Institute for Chemical Ecology

Ideal conditions for *Manduca* offspring

Now the scientists from the Max Planck Institute for Chemical Ecology show another interesting effect of the chemical "odor conversion": Just like *Geocoris* bugs, adult female *M. sexta* moths are able to detect the changes in the green volatile profile emitted by Sacred Datura plants that have been damaged by *M. sexta* caterpillars. This alerts the moths to the fact that *Geocoris* bugs are likely to predate eggs and caterpillars on the plant, and as a consequence the moths lay their eggs on unattacked plants. Hereby they minimize the risk of newly laid eggs being eaten by the predators. Another positive effect is that the competition for resources with larvae that already feed on a plant is reduced.

Interdisciplinary Research: Ecology and Neurobiology

The researchers also identified the neural mechanism that allows moths to detect the slightest changes in the volatile profile of plants that have already been attacked by caterpillars. Neurobiological studies of the moth brain revealed that E- and Z- odors lead to different activation patterns. The two isomers of hexenyl acetate activated different regions in the antennal lobe of the moth (see images above). "This suggests that the female moths have isomer-specific receptors and neurons on their antennae," says Bill Hansson, director of the institute. The combination of such neurological experiments and ecological field studies are very promising and may provide further insights into odor-guided behavior of insects in nature and agriculture.

New plant protection strategies

A similar behavioral pattern is known from potato beetles (*Leptinotarsa decemlineata*). An artificial application of (Z)-3- or (E)-2-hexenol, (E)-2-hexanal or 1-hexanol to potato plants lead to a disoriented behavior observed in egg-laying potato beetles. On the basis of these results, plant protection strategies seem possible which utilize artificial odor application in order to deter ovipositing insects from field crops and thereby reduce insect infestation. [McLennan /AO/JWK]

More information: Allmann, S., Späthe, A., Bisch-Knaden, S., Kallenbach, M., Reinecke, A., Sachse, S., Baldwin, I. T., Hansson, B.S. (2013). Feeding-induced rearrangement of green leaf volatiles reduces moth oviposition. *eLife* 2:e00421. DOI: 10.7554/eLife.00421

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