ScienceWatch-Signing Your Own Death Warrant

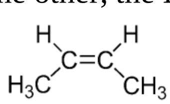
“Why would a caterpillar do this to itself?” – I. Baldwin

Plants can’t run away when they are attacked by plant-eating insects so they have evolved a variety of defense mechanisms. For example, when oak tree (*Quercus spp*.) leaves are eaten by gypsy moth caterpillars (*Lymantria dispar*) the concentration of leaf tannin rises. The bitter tannin not only makes the leaves less palatable, but also interferes with caterpillar growth by making leaf proteins less available. Plants can also produce bitter-tasting terpenes in response to leaf damage by caterpillars. Familiar terpenes are camphor, menthol and limonene.

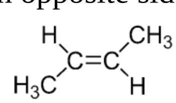
Other terpenes released by herbivore-damaged plants function as signaling molecules, “phytodistress” signals, which act as an indirect defense, attracting predators that eat the plant-eating insects. These terpenes belong to a group known as herbivore-induced plant volatiles (HIPV’s). They are synthesized in response to insect chewing, but not mechanical damage. Somehow saliva from insect herbivores, secreted as they graze on leaves, tells the plant to produce terpenes from both damaged and undamaged leaves. For example, tobacco plants (*Nicotiana attenuata*) manufacture HIPV’s in response to browsing by the tobacco hornworm (*Manduca sexta*). The volatile terpene bouquet attracts the big-eyed bug (*Geocoris pallens*), a natural caterpillar predator, which consumes both eggs and caterpillars - see *ScienceWatch, Stand and Fight* (May 2001).

Another group of compounds is known as green-leaf volatiles (GLV’s). Responsible for the smell of a fresh-cut lawn, they are also released by plants in response to injury. However, unlike terpenes, which can take up to a day to be produced, GLV’s waft into the air from injured sites immediately. In laboratory studies GLV’s have been shown to act as rapid phytodistress calls. But they are produced by both mechanical damage and insect chewing, so how they attracted insect predators was a mystery. Now a study in the August 27, 2010 issue of *Science* shows that, surprisingly, GLV attractiveness to predators is enhanced by caterpillar saliva.

Ian Baldwin and his graduate student Silke Allman, molecular ecologists at the Max Planck Institute, Jena, Germany, found that caterpillar saliva changes the composition of the GLV molecules. These molecules exist in two forms that are composed of the same chemical groups, but the groups are arranged differently in space. The two forms, known as isomers, cannot be superimposed on each other. As an example, the GLV molecule butene is shown below in its two forms. In the Z form the chemical groups are one side of the molecule. In the other, the E form, they are on opposite sides.



Z-BUTENE



E-BUTENE

Allman and Baldwin looked at the isomer composition of GLV molecules released by tobacco plants and found that mechanically injured plants release nine times more Z-GLV than E-GLV. By contrast, plants chewed on by tobacco hornworm caterpillars release both forms in equal amounts. They looked for chemical reactions performed by the plant that could convert one form to the other, but found none. However, equal amounts of both forms could be produced by adding caterpillar saliva to mechanically injured plants, and that activity was destroyed by heat. This meant that an enzyme in the caterpillar saliva was converting Z-GLV's to E-GLV's.

Next they glued caterpillar eggs to tobacco plants growing naturally in the Great Basin desert in Utah and dabbed on a lanolin paste containing different GLV mixtures. Within hours big-eyed bugs showed up to eat the eggs, but eggs baited with E-GLV's were three times more likely to be eaten than those baited with Z-GLV's. In other words the caterpillars were producing the GLV form that was more attractive to the predator bugs.

Why would caterpillars produce E-GLV's and make it more likely they will be devoured? Allman and Baldwin note that the most common E-GLV, (E)-hex-2-enal, is a powerful antimicrobial that could kill bacteria growing on plants. The caterpillar seems to be engaged in a balancing act that reduces infection at the cost of betraying its location to its enemies.

Perhaps the caterpillars will find a better way in the future, but they right now they seem to be participating in their own demise.

Fig. 1 A big-eyed bug attacking a young hornworm caterpillar

Saul Scheinbach