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'Chemical warfare' in the redwood forests

The visitor to the redwood forest enters more than a world of majestic trees. It is also a world of invisible influences and chemical warfare.

The spicy and pungent fragrances wafting through the damp air are volatile chemicals being emitted by the leaves of redwoods trees, bay trees and other plants, believes UC-Santa Cruz plant ecologist Jean Langenheim. The compounds, known as terpenoids, can serve as natural pesticides for the plants that manufacture them and may also be partially responsible for regulating nitrogen in the forest ecosystem.

Terpenoids are not unique to redwood forests, however. Plants all over the world synthesize these compounds, which are distant cousins of common oils. Humans have long exploited terpenoids in a myriad ways. They tickle the taste buds as the flavor-enhancers of spices and herbs and sweeten the air as lemon and pine scents in consumer products. They form rubber and the viscous tree resins traditionally tapped for medicines, turpentine, adhesives, and varnish products. The versatile chemicals also led to recently introduced substitutes for ozone-depleting chlorofluorocarbons.

It was amber, the fossilized resin of tropical and semitropical trees, that drew Langenheim to study terpenoids in tropical forests throughout the world. The encasement of perfectly preserved, ancient insects in amber provided researchers with early clues about the possible role of resins and other terpenoids in plant life. The greatest diversity of trees that produce copious amounts of resins grow in the tropics and subtropics, where countless insects, fungi and other pests thrive. Increasing evidence shows not only that plants use resins and other terpenoid compounds to stave off pest assaults but, in a kind of evolutionary one-upmanship, that the pests in some cases have adapted to tolerate the chemicals and even use them in different ways.

Over time some trees have evolved an ability to vary the proportions of pest-repelling terpenoids in their leaves. "We think this is so very important in the trees' abilities to inhibit herbivores and disease-producing pathogens, and therefore it is essential to take this chemical variability into account in managing these forests," Langenheim says.

UCSC's redwood-forest setting provides the perfect natural laboratory to find out what the terpenoids do for local plants and how they affect the environment.

For instance, early work showed that in the Yerba Buena plant, a kind of mint, certain proportions of the lead terpenoids fend off hungry banana slugs. Now, in the attempt to explain why deer habitually devour the leaves of some bay trees and avoid others, the researchers are comparing the terpenoid compositions of bay trees in different locations.

Workers in Langenheim's lab have found that redwoods appear to have escalated the chemical battle to another level by harboring various toxin-producing fungi in their leaves. Terpenoids prevent some fungi from producing disease, whereas others remain dormant until the leaves are attacked and then produce toxins that provide the tree with an "acquired chemical defense." In similar work elsewhere, researchers are studying crop plans in an effort to arm them with beneficial fungi.

Her research team is now proceeding step-by-step to track the environmental effect of redwood terpenoids that accumulate in the soil from redwood leaves washed by rain and from forest litter decomposed by bacteria. The researchers suspect that the terpenoids may chemically interfere with the process of nitrate formation by soil bacteria, thus preventing the leaching of nitrates from the soil into water supplies, where it can fertilize unwanted plant growth.

The first step was to determine the amount of terpenoids going into the soil. Now they can study how the chemical compounds move through the soil by adding the chemicals to different soil components and monitoring chemical changes.

—Bob Smith