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Press release

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Angela Overmeyer

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Hormonal teamplay in trees

In poplars, two plant hormones boost each other in defense against pathogenic fungi. Researchers from the Max Planck Institute for Chemical Ecology showed that higher levels of jasmonic acid were also detectable in poplars that had been modified to produce increased levels of salicylic acid or that had been treated with salicylic acid. Plants that had higher concentrations of both hormones were also more resistant to the rust fungus Melampspora larici-populina, with no negative effect on growth. Knowledge of the positive interaction of these hormones involved in plant resistance could help to better protect poplars and other trees against pathogens.

In contrast to previous assumptions, the defense hormones salicylic acid and jasmonic acid do not always suppress each other in regulating plant chemical defenses against pests and pathogens. In trees, the interplay of both hormones can actually increase plant resistance. This is the conclusion researchers from the Max Planck Institute for Chemical Ecology draw in a new study on poplars. The scientists showed that higher levels of jasmonic acid were also detectable in poplars that had been modified to produce increased levels of salicylic acid or that had been treated with salicylic acid. Plants that had higher concentrations of both hormones were also more resistant to the rust fungus Melamspora larici-populina, with no negative effect on growth. Knowledge of the positive interaction of these hormones involved in plant resistance could help to better protect poplars and other trees against pathogens (New Phytologist, doi: 10.1111/nph.18148).

The function of plant hormones or phytohormones is to coordinate the growth and development of plants. Moreover, they also control plant immune responses to microbial pathogens such as pathogenic fungi. Until now, there has been a broad consensus in science that the signaling pathways of the defense hormones salicylic acid and jasmonic acid act in opposite directions. Thus, if plants produce more salicylic acid, this would inhibit the production of jasmonic acidand vice versa. Scientists have repeatedly shown this negative interplay in studies of the model plant Arabidopsis thaliana (thale cress) and many other annual herbs. "Contrary to the assumption that the salicylic acid and jasmonic acid hormone signaling pathways work in an opposite manner, we had already observed in our earlier studies on poplar trees that both of these hormones increase in response to infection by pathogenic fungi. Therefore, the main research question was to determine the interaction between these two defense hormones in poplar," Chhana Ullah, first author of the publication, explains the starting point of the current study.

To study experimentally how salicylic acid levels affect the formation of jasmonic acid, the scientists genetically modified experimental plants of black poplar (Populus nigra) native to Germany so that they produced higher amounts of salicylic acid than control plants. In another experiment, they applied salicylic acid to the poplar leaves of genetically unmodified plants. "We manipulated salicylic acid levels in poplar by genetic engineering and direct chemical application, after which we conducted extensive chemical analyses of the plants with and without fungal infection. This allowed us to separate the effects of salicylic acid from other factors and show that it directly stimulates jasmonic acid production," explains Chhana Ullah.

Plants that contained high levels of salicylic acid also had higher concentrations of jasmonic acid. In addition, these plants produced more antimicrobial substances, known as flavonoids, even if there was no infection with a pathogen. Further comparative studies with plants that produced high levels of salicylic acid and control plants that had each been infected with the rust fungus Melamspora larici-populina showed that high levels of salicylic acid made poplars more resistant to fungal attack.

Surprisingly, higher fungal resistance due to increased defenses did not negatively affect plant growth, as had been observed in Arabidopsis and other annual herbs. In Arabidopsis, either salicylic acid or jasmonic acid takes control of the immune response, while the other hormone is suppressed. Salicylic acid is produced in higher amounts after attack by biotrophic pathogens that do not kill plant tissue and feed on living plant material, while jasmonic acid is increased after attack by insects or necrotrophic pathogens that feed on dead plant tissue. "The negative interplay between the defense hormones salicylic acid and jasmonic acid in plants like Arabidopsis enables the plant to prioritize protection against one kind of enemy. Small herbs like Arabidopsis may benefit from such a narrow focus because they lack the resources to defend against different kinds of enemies at once. This may also be the reason why Arabidopsis plants reduce their growth rate when in a defense mode," says Jonathan Gershenzon, head of the Department of Biochemistry where the study was conducted.

In contrast to annual herbs such as thale cress, resources are usually less limited for trees and other woody plants. Moreover, because of their long lifespan, trees are often attacked simultaneously by different enemies, such as fungal and bacterial pathogens, leaf-eating caterpillars, and wood-destroying insects. They may have evolved to use the salicylic and jasmonic acid signaling pathways together for defense. The greater availability of resources in long-living woody plants may also be the reason why high concentrations of salicylic acid do not affect plant growth in poplars.

The researchers were surprised to find that high levels of salicylic acid in poplars did not activate so-called pathogenesis-related (PR) genes, although these are established markers for the salicylic acid signaling pathway in Arabidopsis. "However, we found that the magnitude of PR gene induction was positively correlated with the susceptibility of poplar to rust. Apparently, the activation of PR genes in poplar is not regulated by salicylic acid signaling, but by a different mechanism," Chhana Ullah explains.

The team of scientists led by Chhana Ullah still has to find out exactly how the molecular mechanism of the positive interaction between salicylic acid and jasmonic acid works in poplar. They also want to know which role PR genes play in poplar and other woody plants. What is certain, however, is that a fundamental knowledge of the positive interaction between salicylic acid and jasmonic acid in poplar and other related trees could make an important contribution to better protecting these plants from pest infestation and disease. Or, as Jonathan Gershenzon notes: "Poplars are known as the trees of the people for their diversified uses by humans, hence the genus name Populus: the Latin name for people. Incredibly fast-growing, poplars are cultivated as short-rotation woody crops and are extremely important of the pulp and paper industry. They are also desirable for biofuels." Improving their protection therefore serves us all.

contact for scientific information:

Dr. Chhana Ullah, Department for Biochemistry, Project Group Counteradaptation of Plant Pathogens, Max Planck Institute for Chemical Ecology, Hans-Knöll-Str. 8, 07745 Jena, Germany, E-Mail cullah@ice.mpg.de, Tel. +49 (0)3641 57-1335

Prof. Dr. Jonathan Gershenzon, Department for Biochemistry, Max Planck Institute for Chemical Ecology, Hans-Knöll-Str. 8, 07745 Jena, Germany, E-Mail gershenzon@ice.mpg.de, Tel. +49 (0)3641 57-1300

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Rust-infected black poplar (Populus nigra).
Chhana Ullah

Max Planck Institute for Chemical Ecology

Chhana Ullah characterizing transgenic high salicylic acid poplar lines.
Anna Schroll
Max Planck Institute for Chemical Ecology