

1 **IN BRIEF**2 **Secrets of the Forest: Volatiles First Discovered in Pine Trees Propagate Defense**
3 **Signals Within and Between Plants**

4
5 Systemic acquired resistance (SAR)—a plant-wide heightened state of defense following
6 localized exposure to a pathogen—is characterized by increased salicylic acid (SA) and ROS
7 levels and elevated expression of pathogenesis-related genes. SAR depends on ENHANCED
8 DISEASE SUSCEPTIBILITY1 (EDS1), which both generates the SAR signal at the primary infection
9 site and perceives it in distal, uninfected tissues (Breitenbach et al., 2014). Various vascular
10 mobile signals function within SAR, including methyl salicylate (Park et al., 2007), the non-
11 proteogenic amino acid pipecolic acid (Návarová et al., 2012), and the dicarboxylic acid azelaic
12 acid (Jung et al., 2009).

13
14 In a new study, Riedlmeier et al. (2017) examined the role of volatile organic compounds (VOCs)
15 in SAR. Using gas chromatography/mass spectrometry, they compared the emissions released
16 by wild-type *Arabidopsis* plants and SAR-deficient *eds1-2* mutants several hours after induction
17 of SAR. Whereas the wild-type plants released substantial amounts of the bicyclic
18 monoterpenes α -pinene and β -pinene—volatiles best known for giving pine forests their
19 enchanting scent—the mutants with compromised SAR released almost undetectable levels of
20 these VOCs.

21
22 Based on these findings, the authors hypothesized that α -pinene and β -pinene induce SAR. To
23 test this possibility, they exposed wild-type plants to a mixture of α -pinene and β -pinene or to
24 the VOC solvent control for 3 days and then challenged the plants with the pathogenic
25 bacterium *Pseudomonas syringae* pv tomato strain DC3000 (*Pst*). They found that bacterial
26 growth was ~10-fold less in the leaves of plants that had been exposed to the monoterpenes,
27 and that the effect depended on pinene concentration. Bacterial growth was not limited in the
28 *non-expressor of PR genes1-1* (*npr1-1*) mutant, which has defects in signaling downstream of
29 SA, or in the *sa induction deficient2-1* (*sid2-1*) mutant, which has defects in SA biosynthesis,
30 after 3 days of monoterpene exposure. Furthermore, ROS $O_2^{\bullet-}$ accumulated in the leaves of
31 plants treated with pinenes, but not in those of control plants. Microarray analysis showed that
32 pinene treatment directly influenced key regulatory genes in SA biosynthesis and SAR (e.g., the
33 gene encoding the lipid transfer protein AZELAIC ACID INDUCED1). Therefore, pinenes appear
34 to induce SAR, in a manner that depends on SA signaling.

35
36 As monoterpenes are highly volatile, the authors directly tested whether these VOCs could
37 function as mobile plant-to-plant defense signals. Wild-type receiver plants enclosed in a
38 vacuum dessicator for three days with SAR-induced (i.e., monoterpene-emitting) sender plants
39 were indeed more resistant to *Pst* infection than were receiver plants enclosed with control
40 plants.

41

42 Thus, in addition to functioning in SAR signaling within the plant, α -pinene and β -pinene act as
43 airborne signals that prime neighboring plants for impending danger (see figure). This exciting
44 finding suggests that the aroma of a pine forest has an important function.

45

46

47 **Kathleen L. Farquharson**

48 **Science Editor**

49 kfarquharson@aspb.org

50 <http://orcid.org/0000-0002-8032-0041>

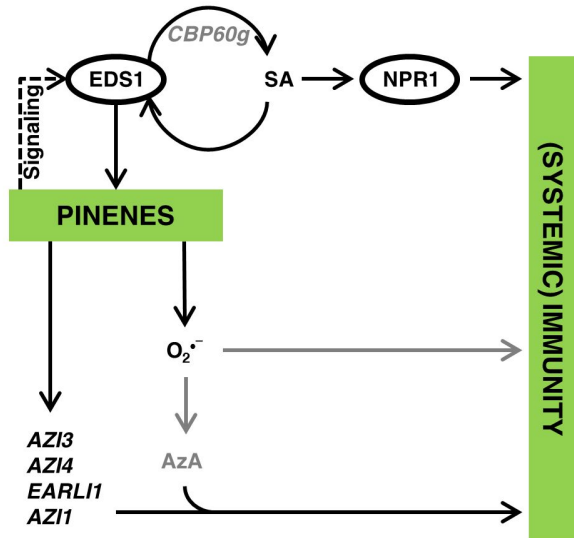
51

52

53 **Figure legend:**

54

55 Model explaining the contribution of α -pinene and β -pinene to systemic immunity. Pinenes
56 induce immunity via EDS1, SA biosynthesis (possibly via *CBP60g*), and NPR1, and upregulate the
57 expression of AZI1. In addition, pinenes trigger the production of ROS, which in turn cause SAR-
58 promoting AZA to accumulate [*Adapted from Riedlmeier et al. (2017), Figure 11.*]



Parsed Citations

Breitenbach, H.H., Wenig, M., Witek, F., Jordá, L., Maldonado-Alconada, A.M., Sarioglu, H., Colby, T., Knappe, C., Bichlmeier, M., Pabst, E., Mackey, D., Parker, J.E., and Vlot, A.C. (2014). Contrasting roles of apoplastic aspartyl protease AED1 and legume lectin-like protein LLP1 in Arabidopsis systemic acquired resistance. *Plant Physiol.* 165:791-809.

Pubmed: [Author and Title](#)

CrossRef: [Author and Title](#)

Google Scholar: [Author Only](#) [Title Only](#) [Author and Title](#)

Jung, H.W., Tschaplinski, T.J., Wang, L., Glazebrook, J., and Greenberg, J.T. (2009). Priming in systemic plant immunity. *Science* 324:89-91.

Pubmed: [Author and Title](#)

CrossRef: [Author and Title](#)

Google Scholar: [Author Only](#) [Title Only](#) [Author and Title](#)

Návarová, H., Bernsdorff, F., Döring, A.C., and Zeier, J. (2012). Pipecolic acid, an endogenous mediator of defense amplification and priming, is a critical regulator of inducible plant immunity. *Plant Cell* 24: 5123-5141.

Pubmed: [Author and Title](#)

CrossRef: [Author and Title](#)

Google Scholar: [Author Only](#) [Title Only](#) [Author and Title](#)

Park, S.W., Kaimoyo, E., Kumar, D., Mosher, S., and Klessig, D.F. (2007). Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. *Science* 318:113-116.

Pubmed: [Author and Title](#)

CrossRef: [Author and Title](#)

Google Scholar: [Author Only](#) [Title Only](#) [Author and Title](#)

Riedlmeier, M., Ghirardo, A., Wenig, M., Knappe, C., Koch, K., Georgii, E., Dey, S., Parker, J.E., Schnitzler, J.-P., and Vlot, A.C. **Monoterpenes Support Systemic Acquired Resistance Within and Between Plants.** *Plant Cell* 10.1105/tpc.16.00898.

Pubmed: [Author and Title](#)

CrossRef: [Author and Title](#)

Google Scholar: [Author Only](#) [Title Only](#) [Author and Title](#)

Secrets of the Forest: Volatiles First Discovered in Pine Trees Propagate Defense Signals Within and Between Plants

Kathleen L Farquharson

Plant Cell; originally published online June 13, 2017;

DOI 10.1105/tpc.17.00462

This information is current as of October 23, 2017

Supplemental Data	/content/suppl/2017/07/11/tpc.17.00462.DC1.html
Permissions	https://www.copyright.com/ccc/openurl.do?sid=pd_hw1532298X&issn=1532298X&WT.mc_id=pd_hw1532298X
eTOCs	Sign up for eTOCs at: http://www.plantcell.org/cgi/alerts/ctmain
CiteTrack Alerts	Sign up for CiteTrack Alerts at: http://www.plantcell.org/cgi/alerts/ctmain
Subscription Information	Subscription Information for <i>The Plant Cell</i> and <i>Plant Physiology</i> is available at: http://www.aspb.org/publications/subscriptions.cfm