Great potential in regulating plant greenhouse gas emissions

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The Blue Mountains in Australia are named after the blue haze that can be seen on hot days over the forest. This haze is caused by isoprenoids that are emitted by these forests in large quantities. Isoprenoids can, when reacting with pollutants in the atmosphere, increase greenhouse gas formation. Credit: DAVID ILIFF. License: CC BY-SA 3.0, Wikicommons.

You cannot see them with the naked eye, but most plants emit volatile gases—isoprenoids—into the atmosphere when they breathe and grow. Some plants emit close to nothing; others emit kilograms annually.

Why are plant isoprenoid emissions interesting? Well, isoprenoids contribute immensely to the amounts of hydrocarbons released into the atmosphere, where they can be converted into potent greenhouse gases, affecting climate change. Actually, it has been estimated that short-chain isoprenoids account for more than 80% of all volatile organic compounds emitted from all living organisms, totaling about 650 million tons of carbon per year.

"We discovered a new way that plants regulate how much volatile isoprenoids they emit into the atmosphere, which had long been unknown. Some plants emit a lot, while very similar species don't emit them at all. This is interesting from a basic research point of view to better understand these emissions and how growing different plants might affect carbon cycling and impact greenhouse gases," says first-author behind a new study recently published in *eLife*, Senior Researcher Mareike Bongers from The Novo Nordisk Foundation Center for Biosustainability and Australian Institute for Bioengineering and Nanotechnology, The University of Queensland.

Crops that emit a lot of isoprene are, for example, palm oil trees; spruce, which is grown for timber; and aspen trees, which are grown for timber and biofuel. With this knowledge, farmers could in principle optimise forest land and farming area by planting fewer high-emitter-plants and more zero-emitters.

"It should be said, though, that we do not know for sure that all effects of these emissions are bad, more research is needed on that. But what is clear is that many of the harmful effects of isoprenoid emissions happen when they react with common air pollutants, which affects greenhouse gas formation and air quality. Therefore, large plantations with high emissions are particularly troublesome in the vicinity of industrial or municipal air pollution. So, reducing pollution is another way to address the problem," says Mareike Bongers.

The researchers behind this study are now looking into the possibility of using this new knowledge in applied biotech. The researchers actually discovered the new regulatory mechanism, because they tried to engineer the bacterium E. coli to produce sought-after isoprenoids, which could replace many fossil fuel chemicals if they could be produced more cheaply.

So, while engineering plant genes into E. coli to improve isoprenoid production, the researchers became aware of the plant-based regulation mechanism. When E. coli was engineered with plant genes for an enzyme known as HDR, they produced two important chemicals in different ratios, and this influenced how much isoprene could be produced.

This revelation is very useful in applied biotech, because isoprenoids can be turned into products like rubber. GoodYear has already produced car tires made from bio-produced isoprene. Furthermore, the findings could also improve the production of monoterpene isoprenoids, which are excellent jet fuels because they are very energy dense.

"This is particularly interesting from a sustainability perspective, because it is not anticipated that airplanes can be fuelled from anything else than liquid fuels, as opposed to ground transportation, which could be electric," she says.

Finally, isoprenoids are also used as flavours and fragrances in perfumes and cosmetics, and they are very important as active compound in some drugs, for instance the anti-malarial drug artemisinin or taxadiene, from which the cancer drug Taxol is made.

Today, most labs and biotech companies that make isoprenoids use a pathway from yeast, since the achieved yields have been much higher than with E.coli. But the pathway used by E. coli and plants has a higher theoretical yield, meaning that more isoprenoids could theoretically be made from the same amounts of sugar in E.coli than in yeast. Therefore, trying to optimise E.coli for isoprenoid production makes good sense commercially.

The team compared eight different plant HDR genes and one cyanobacterial HDR gene in E.coli. The best result was obtained with genes from peach, poplar and castor bean. Since this was a proof of concept, the team only produced 2 mg isoprene per litre of cell broth. But with further engineering and fermentation optimization efforts, the researchers expect to improve isoprene production in E. coli using this system.

"We saw that choosing the right plant enzyme made a big difference for isoprene production in E. coli. So, our 'learning from nature' approach on how some plants became so good at emitting isoprenoids really helped us to design more efficient cell factories," she concludes.

More information: Mareike Bongers et al, Adaptation of hydroxymethylbutenyl diphosphate reductase enables volatile isoprenoid production, *eLife* (2020). DOI: 10.7554/eLife.48685

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