How do pesticides protect crops?

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Credit: University of Manchester

New research published today could lead to the fine-tuning of pesticide formulations to further increase crop yield. The findings also show a way to develop advanced performance formulations which will interact reversibly with plant surfaces and will leave their protective cuticles unharmed.

Scientists from the University of Manchester have created a model of a leaf's wax surface similar to those found in wheat crops, in a project supported by the agrochemical company, Syngenta. They are now using the model at the Science and Technology Facilities Council's ISIS Neutron and Muon Source research facility to study how surfactants, a key component in pesticide formulations, interact with the leaf surface to get into the plant and take effect.

This is the first time anyone has used extracted waxes to recreate the wax shield plants use for protection against pests and water loss. The new tool enables scientists to study how pesticides cross the wax barrier on the leaves of crops such as wheat and barley. The breakthrough is another step towards fine-tuning the chemicals used in agriculture to optimise crop yields without damaging the plants, in an attempt to meet the demand of feeding an ever growing global population.

The results, titled 'Structural Features of Reconstituted Wheat Wax Films' have been published in the Royal Society journal *Interface*.

Waxy cuticles are essential for the well-being of all plants. The cuticle, made up of a thin coating of wax on plant leaves, acts as a protective shield against attack from pests, prevents the loss of nutrients and water from the plant and is involved in transporting water and nutrients across the plant surface for plant growth.

To add an additional layer of protection against pests, farmers use pesticides on their crops in an attempt to maximise their yields.

Julian Gold, Farm Manager of the Hendred Estate in Oxfordshire said: "Farmers are harvesters of sunshine and the growing of crops aims to turn as much of the sun's energy as possible into food via photosynthesis. Pesticides play a vital role in ensuring plants can maintain the maximum area possible of green leaf for photosynthesis rather than losing surface area to pests and diseases."

"We are currently facing multiple challenges on the pesticide front as there are increasing levels of resistance developing in weeds, pests and diseases as well as a reducing pesticide armoury due to tighter conditions being imposed for registration of products. Any research that can improve the efficacy of products through a better understanding of the way that diseases and pesticides penetrate the waxy layer on leaf surfaces should be incredibly useful".

However, the structure of wax cuticles and the way pesticides modify the barrier to get inside and protect the plant are not fully understood.

Lead author of the study, Elias Pambou from the University of Manchester said: "By understanding how surfactants in pesticides interact with the plant you can fine-tune the ingredients of the pesticide to not only further increase crop yield but take away some potential negative side effects, including the removal of some of the waxes which leaves the plant susceptible to other sorts of diseases and attack from bacteria and microbes. This opens the door to crop-safe formulations which will reversibly interact with the plant waxes."

"We're finding out important information about how plants operate which is something we previously did not have the tools to study".

To make the model of the leaf surface, scientists first extracted real plant wax from barley and wheat leaves. This was made possible by a new technique called supercritical carbon dioxide extraction, where scientists dissolve the wax off the surface of the leaf using a carbon dioxide solvent under its supercritical condition at a very high temperature and pressure. When the pressure and temperature is reduced, the carbon dioxide evaporates, leaving behind the wax. This technique was developed in the Green Chemistry Department at the

University of York.

The team from the University of Manchester then took the extracted wax and spin coated it onto a flat a silicon support in order to model the leaf surface. Imaging techniques allowed the team to see that the wax model was very similar to the structure of the wax on a real leaf, meaning the model could be used to realistically study how pesticides cross the wax barrier to get into the plant.

In a technique known as neutron reflectometry, the team used ISIS instrument, INTER to bounce neutrons off the surface of the wax model. They found that the wax was made up of a thin underlying film covered by large crystalline structures.

Professor Robert McGreevy, Director of the STFC ISIS Facility said: "Neutrons offer a unique tool for seeing deep into all sorts of materials. The Manchester team used the INTER instrument here at ISIS to see what the wax film was made up of and how water crossed the barrier at the molecular level. But we can also use the same technique to study new magnetic materials for computer data storage."

Elias Pambou added: "Neutron reflectometry is so effective because not only can we look at the thickness of the wax films but also the change in density over the thickness range. We're able to look at the amount of water penetrating into the leaf at the surface of the wax compared to the bottom of the wax closest to the epicuticular plant cells. That could give us a lot of information regarding how the water is diffusing through the plant."

The project is being supported by the agrochemical company, Syngenta. Dr Gordon Bell, a senior scientist at Syngenta said: "This research has furthered our understanding of the kinetics of plant uptake. It has shown that water can penetrate into leaf wax. This simple observation explains a lot of the basic science behind pesticide uptake into plants."

More information: Elias Pambou et al. Structural features of reconstituted wheat wax films, *Journal of The Royal Society Interface* (2016). DOI: 10.1098/rsif.2016.0396

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