From Honey to High-Tech Adhesives: A Sticky Alternative to Pesticides

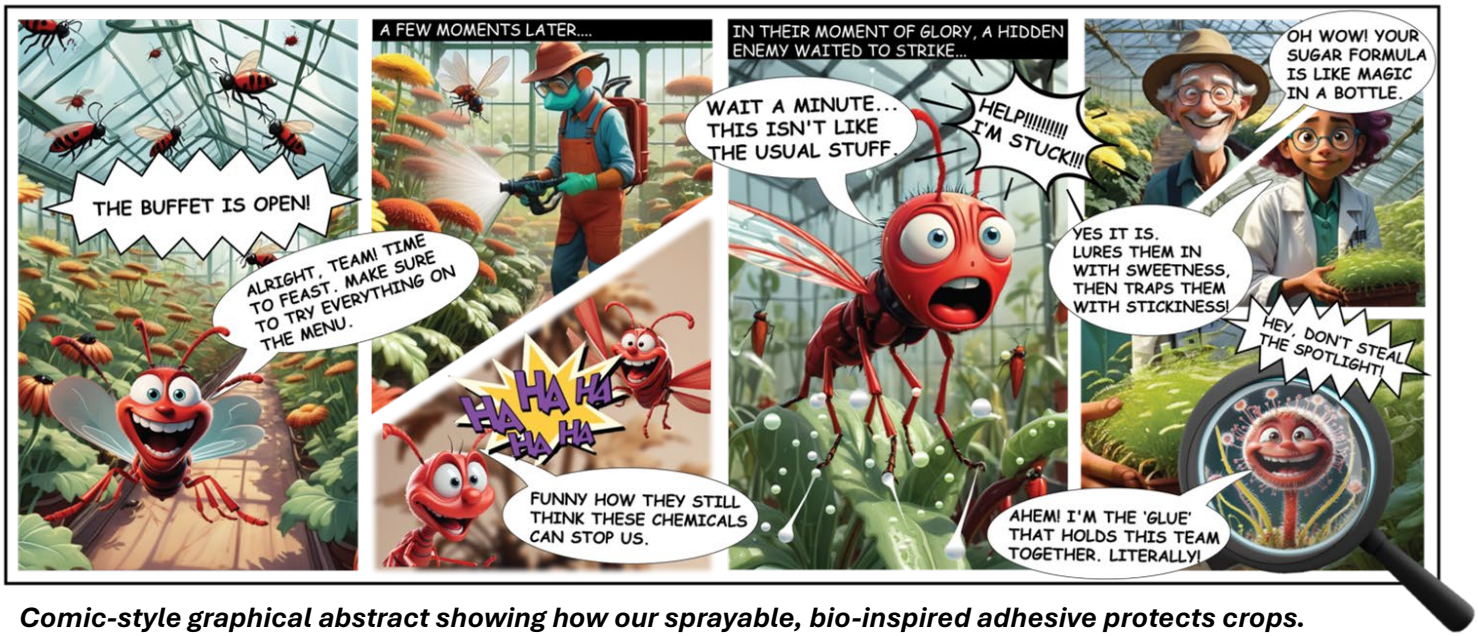
Chemical pesticides have long protected crops, but their drawbacks have also been long ignored: resistant pests, environmental contamination, biodiversity loss, and risks to human health. In greenhouses, where pesticides are applied repeatedly, much of the spray is lost when droplets bounce off leaves or drip to the ground. This not only reduces the effectiveness of crop protection, requiring more frequent applications, but also contaminates the surrounding environment and increases exposure risks to humans and non-target organisms. Could we protect crops more effectively without relying on toxic chemicals?

One day in the lab, I got honey on my hands and realized that even the tiniest particles could not escape its grip: sticky enough to ruin my keyboard, but perfect enough for trapping pests! I thought I was a genius but realized nature had already known this solution at a more sophisticated level. Carnivorous plants such as *Drosera* capture insects using sticky exudates from their surface hairs called trichomes that are highly effective and biodegradable. These secretions are hypothesized to be natural deep eutectic solvents (NaDES) which are mixtures of sugars, acids, polysaccharides, and water that form strong hydrogen-bonded liquids. Inspired by this principle, I developed a sprayable, bio-inspired adhesive for crop protection, essentially just a glue trap sprayed directly on plants.

My colleagues at Leiden University and Aeres University of Applied Sciences tested our formulations on plants and insects in greenhouse experiments, and validated the effectiveness of the adhesive traps while remaining safe for crops. As a materials scientist, I designed formulations blending NaDES with the natural biopolymer hyaluronic acid (HA). In this system, NaDES provides tackiness and spreads evenly, similar to honey, while HA adds elasticity, allowing filaments to form and resist breaking. The resulting material physically traps and starves western flower thrips, a major greenhouse pest, without using chemical toxins.

Application strategy for this formulation was crucial. Like natural trichomes, the adhesive had to be sprayed in tiny droplets, and multiple contacts were necessary for full effectiveness. We further optimized the formulation: citric acid reinforced hydrogen bonds, improving cohesion, while mixing long and short polymer chains balanced mechanical strength and sprayability. Because preparation requires only simple mixing of food-grade components and the material is compatible with readily available spraying equipment, the adhesive is not only tunable, flexible, and biodegradable, but also shows promising potential for scalable use in commercial greenhouses.

By starting with the familiar stickiness of honey and building toward advanced bio-adhesives, my research shows how biomimicry and green chemistry can offer a practical, safe, and sustainable solution for crop protection. This work points to a future where fewer chemical pesticides are needed, yet crops remain well protected, and greenhouse agriculture becomes safer for people and the environment.



Comic-style graphical abstract showing how our sprayable, bio-inspired adhesive protects crops.

Associated Publications

1. Arunachalam, A., Oosterhoff, T., Breet, I., Dijkstra, P., Mohamed Yunus, R.A., Parisi, D., Knegt, B., Macel, M. and Kamperman, M., (2025). Harnessing the bio-adhesive power of natural deep eutectic solvents for trichome-inspired pest control. *Communications Materials*, 6(1), p.101.

2. Arunachalam, A., Perraki, M., Knegt, B., Macel, M., Voigt, D. and Kamperman, M., (2025). Turning over a new leaf: innovative pest control from a materials science perspective. *Chemical Society Reviews*, 54(13), p.6525.

3. Arunachalam, A., Le Cornec, E., Es Sayed, J. and Kamperman, M., (2025). Bioinspired Pressure Sensitive Adhesives Based on Natural Deep Eutectic Solvents. *Macromolecules*, 58(16).

4. Arunachalam, A.,* van der Molen, A.,* Knegt, B., Macel, M. and Kamperman, M., From sticky to sprayable: Optimizing trichome-inspired pest control for high-humidity environments. (*In preparation*)

5. Arunachalam, A.,* Lasorsa, A.,* Kamperman, M. and van der Wel, P. Strengthening the Hydrogen-Bond Network in Sugar-Based Natural Deep Eutectic Solvents Probed by Solid-State NMR. (*In preparation*)

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