Precision Pollination of berry crops is not a pipedream

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Blueberries (and other berry crops) depend to a greater or lesser extent on pollination by insects for good yields and high fruit quality. Many growers manage honey bee hives on their properties, but inevitably any crop flowers outdoors or in polytunnels are also visited by wild insects. These may include some wild honey bees, native bees, as well as flies, moths, butterflies and other insects.

As a grower, this may raise a number of questions that can be very hard to answer. What level of pollination do the managed honey bees provide? Are the bees you pay for pollinating the weeds on your property, or perhaps the flowering crops on your neighbour's farm? How much value do they contribute compared to the value provided by the ecosystem services of wild insects? Are your crops adequately pollinated? What gains might be had if pollination could be improved?

These are the kinds of questions my research team is investigating using new technology we have developed through discussions with growers and beekeepers. The latest project, "**Precision Pollination: Data-driven enhancements to boost crop yield",** is supported by the Australian Blueberry Growers Association (ABGA), Costa Group and the Australian Government (through the Australian Research Council Linkage program). It links these partners with researchers at Monash University, Western Sydney University, University of New England and CSIRO to provide a step-change in the way Australia's berry industry understands and addresses pollination.

The project has three main objectives:

1. **Digital pollination monitoring –** We will establish formal methods, computer vision and animal tracking software and portable video monitoring hardware to facilitate rigorous, continuous, dynamic, data-driven insect-pollinator monitoring across expansive (semi-) protected cropping infrastructure.

2. **Honey bee computer simulation & forecasting –** We will research and develop novel computer simulations of individual insect-flower interactions to suggest to growers and beekeepers environmental conditions, planting and co-planting layout, hive locations and site-specific management strategies to eliminate pollination "dead spots" and boost crop yield and quality.

3. **Site-specific management of honey bees & cropping infrastructure –** Based on monitoring and simulation output data, we will develop standardised, reusable, protected cropping interventions. These will be designed to enhance real insect pollinator behaviours that boost food security, yield and quality while maintaining bee health.

We recognise that these are ambitious goals, but we have reason to believe they can be achieved based on our previous trials conducted with the valuable assistance of Sunny Ridge berries (Boneo, Victorian site), Rijk Zwaan (Daylesford, Victorian site), Costa Group (Coffs Harbour, NSW), the ARC, AgriFutures and other partners.

Our process works in an iterative cycle to "adaptively manage" insect-plant interactions. The cycle is informed by both expertise on the ground (growers, apiarists, and researchers), digital data our researchers and technological system collects, and computer simulations (Figure 1). Here's how the process works.

Stage 1

The process begins by obtaining information through discussions with stakeholders such that site-specific features and issues can be understood collectively. If we think we can help tackle a pollination issue, only then would we proceed further with this process[1].

In Stage 1, technology is focussed on obtaining hard digital data beyond the observations of expert growers and apiarists about insect behaviour. We distribute small computers equipped with video cameras across the rows of any polytunnel of interest.

These collect extensive video footage that is analysed using Computer Vision and Artificial Intelligence software we have written to determine which species or varieties of insects are visiting the crop, how often, at which times of day, how long they spend on flowers, the directions they tend to move, and the locations within the crop that seem to be more or less densely attended to by insect pollinators.

We also work with the growers to try to acquire crop yield and quality metrics for different regions of the crop, even within a block if possible, corresponding to the areas we have monitored for insect activity.

We sometimes monitor nearby weeds and other unmanaged vegetation too to see what insects might be doing there.

Figure 1. Overview of the cyclic process we are researching to improve berry crop pollination.

1 I feel that the AgTech industry's assumption that "AgTech is the solution" is fundamentally problematic – it is going to get us (further) into trouble if we allow ourselves to be seduced by this position. I am saying this from the perspective of a person who has spent most of his life engaged with technology and who has made technology his career focus!

Stage 2

The data from stage 1 informs stage 2. The data may confirm the suspicions of the growers about issues with pollination. But not always. Sometimes it might reveal new understanding, or new issues that also could be important. To explore the situations leading to pollination issues, we tweak complex computer simulations of bee behaviour to attempt to replicate the observations from stage 1.

These simulations operate very much like computer games where the characters are all under computer control. These virtual bees (imagine the ghosts in a Pacman game) act under their own volition to move across virtual crops (imagine the Pacman maze and its "power ups" arranged like polytunnels, crop rows and flowers) that represent the current planting arrangements.

We model bee colour vision, bee decision-making, bee learning, bee memory, bee scent-marking and other parameters to build a simulation with thousands of bees. If we run this simulation thousands of times under different conditions, it can inform us about the possible reasons for the issues noted by stakeholders and supported by the digital data.

Additionally, we can alter conditions in the computer simulation to test hypothetical ways to improve the situation... What if we move the beehives? What if we add more managed honey bees? What if we change the planting layout? What if we try to attract bees to one area of the polytunnel, or reduce their access to one part of the crop? What if we better utilise wild insects by planting wildflower strips in field verges? There are many options to consider.

Stage 3

If growers and beekeepers agree that our program's suggested management strategies are worth trying, with their assistance and insight, we try them! And then, we return to stage 1 to repeat the loop.

If all goes to plan, the outcomes we target are improvements in pollination, increased yields, better quality fruit and healthy, happy bees. Through our process, and with the novel technology we are developing, we really feel that Precision Pollination is feasible. So far, some problems we have discussed with industry growers and beekeepers include:

- Bee row following behaviour makes cross-pollination difficult to achieve
- Bees don't "like" all crops equally. So, planting co-flowering crops (for instance raspberries with strawberries) in proximity can result in most bees visiting one crop (raspberry) and hardly any the other (strawberry)
- Bees are reluctant to move from outdoors to areas under polytunnels
- Bees don't disperse evenly across crops
- Bees become disoriented and confused under polytunnels
- Bees prefer to forage on my neighbour's farm!
- Bees prefer to visit nearby weeds along the access road than to visit crop flowers

Bee hives placed within the berry orchard to boost pollination. Photo credit: Jane Richter