Sustainability

Seeing the light: innovation in powdery mildew treatment

As growers look to reduce synthetic inputs in the vineyard, two recent developments in science and technology offer alternatives for combating powdery mildew, as **Simone Madden-Grey** writes.

David Markel, research and development manager at Willamette Valley Vineyards in Oregon

Autonomous UV light treatment

UV light treatment for powdery mildew has documented success in scientific research and an automated application has been trialled by Saga Robotics, Norway. After successfully working with strawberry polytunnels where light treatment removed the need to spray for powdery mildew, the company is now working with vineyards.

Ellen Altenborg Saga Robotics CCO, says the light treatment would be delivered by Thorvald, an autonomous robot navigating the vineyard using

GPS coordinates. To accommodate the often varied terrain of vineyards, Altenborg says that the first pass would be completed manually, mapping the vineyard using robot sensors. After that, she says it is expected Thorvald would navigate the site autonomously and it is through autonomous operation that UV light exposure is minimised. If a manual pass is necessary, safety gear is required for operator health and safety.

Ultimately, Markel sees the autonomous delivery of UV light treatment for powdery mildew as an elegant solution and he is positive about the progress made to date.

The multi-functional Thorvald is modular in design like a Lego set where operators can assemble it as required. Altenborg says the height and width is adjustable depending on light housing dimensions, a 4- or 6-wheel option is available and the robot weight is positioned close to the ground for stability. Trials are scheduled to continue later this year.

The main challenge with autonomous robots in vineyards is stability across varying elevations and this is something David Markel, research and development manager at Willamette Valley Vineyards, has been working on. Speaking to me from his office in Oregon, Markel says he first came across the concept of germicidal UV light treatment when implementing the technology as part of the winery COVID-safe programme. Shortly afterwards, owner Jim Bernau asked Markel to actualise UV light treatment in the vineyard for powdery mildew. Researching this brought Markel into contact with Dr David Gadoury, Senior Research Associate, Cornell AgriTech, Dr Walt Mahaffee USDA/Oregon State University and Saga Robotics. As a result of these discussions, Willamette Valley Vineyards purchased a robot from Saga Robotics and Markel's background in computer programming and technology means he is able to maintain and adjust the robot as necessary.

Markel says he sees numerous opportunities for innovation and technology in the vineyard and he is happy to help bridge the technology-to-field gap. Highlighting that Thorvald has been built for a 5° gradient, Markel says that vineyard elevations and site specific conditions, such as muddy soil common in the wet climate of Oregon, mean additional refinement is required. Moving the robot to one of the flatter sites on the estate allowed Markel to manually map the vineyard, and now he says the robot runs well on that site.

In Oregon, this year's field trials will be run by Willamette Valley Vineyards under the guidance of Dr Walt Mahaffee with support from Saga Robotics. Markel says the focus will be on determining correct light dosage, creating software for data capture and defining the criteria for data capture, in addition to the practicalities of running the Thorvald robot across different elevations.

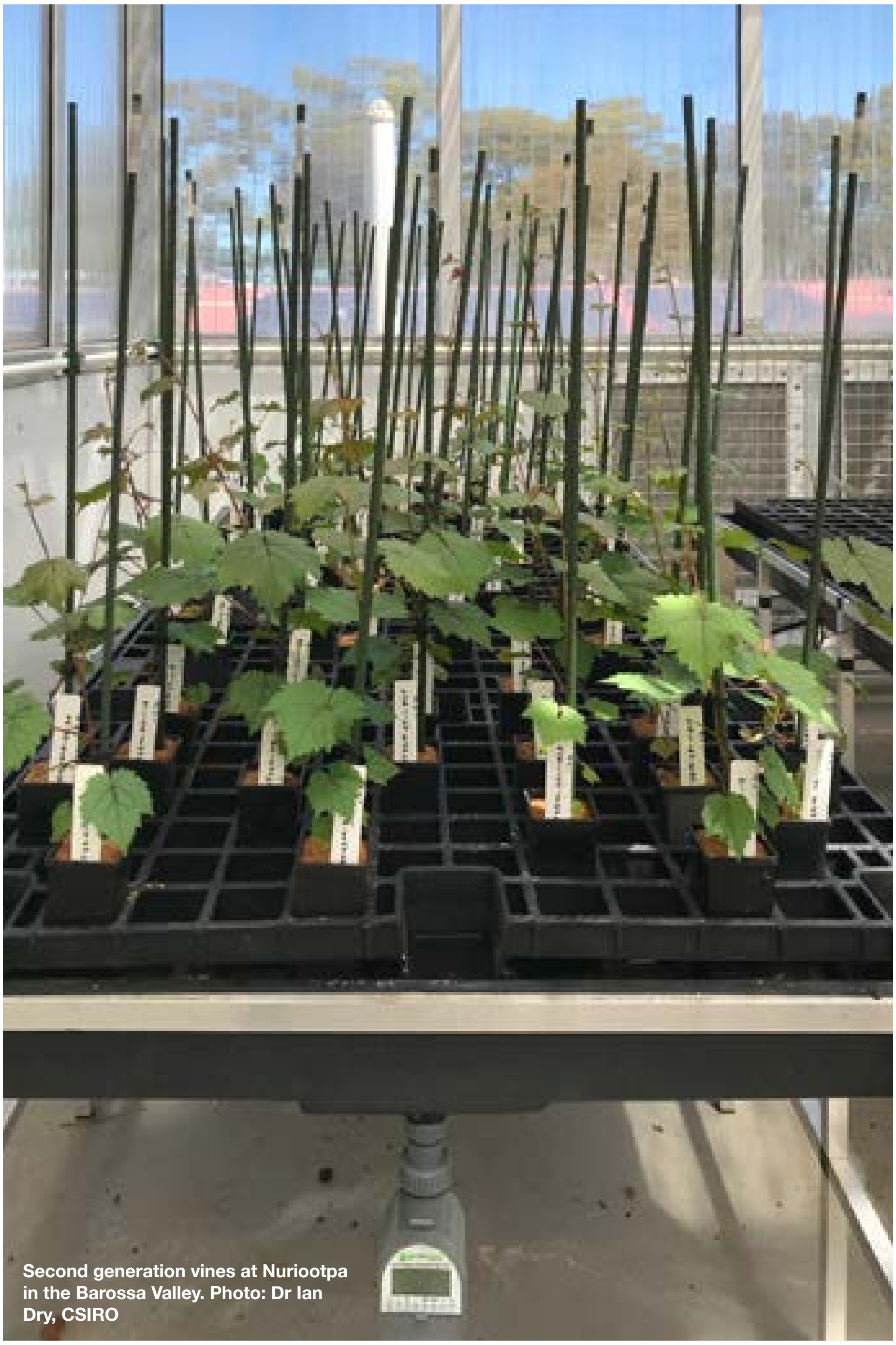
Ultimately, Markel sees the autonomous delivery of UV light treatment for powdery mildew as an elegant solution and he is positive about the progress made to date, saying he hopes the technology will be field ready within 3-5 years.

Cross-breeding mildew resistance

Closer to home, the CSIRO has developed grape varieties with resistance to powdery and downy mildew through a cross breeding programme. Vines with specific resistance conferring genes are crossed with *Vitis vinifera* to achieve this.

In the late-twentieth century a crossing by French breeder Alain Bouquet, of the American vine *Vitis rotundifolia* with *V. vinifera* resulted in the identification of a group of genes that conferred powdery and downy mildew resistance. That dominant group of genes, or locus, was named *Run1/Rpv1*, with powdery mildew resistance conferred by *Run1* and downy mildew resistance conferred by *Rpv1*.

For the CSIRO project, a team lead by Dr Ian Dry began by breeding first generation vines with the *Run1/Rpv1* locus before moving on to improving durability by addressing possible pathogen mutation in the field. A mutation could cause resistance mechanism failure, thereby



Second generation vines at Nuriootpa in the Barossa Valley. Photo: Dr Ian Dry, CSIRO

rendering the grape susceptible to infection. Durability could be increased by combining first generation plants with mildew resistance genes from another source. Fortunately at that time a team of researchers at the USDA had just identified a new powdery mildew resistance mechanism in a Chinese grape variety, *Vitis romanetii*. This provided the additional genetic material the CSIRO team was looking for.

Cross-breeding is a tool that allows researchers to isolate a desirable trait in a particular variety, and through successive crossings retain that trait while breeding out negative traits that might, for example contribute to poor quality wine. The process works by crossing an elite grape variety with a grape species possessing the desired genetic trait, such as powdery mildew resistance. Each time a crossing occurs the percentage of elite grape variety genetic material in the newly created variety increases, the desired genetic trait from the non-elite variety remains, and negative traits from the non-elite variety decrease. For example, what may begin as a 50/50 representation of *V. vinifera* and *V. romanetii* will, after successive crosses, result in a variety with 97% *V. vinifera* and 3% *V. romanetii*. Contained within the 3% of *V. romanetti* is the desired gene for mildew resistance, known in this example as *Ren4*.

Two things make the discovery of *V. romanetii* exciting. The *Ren4* gene shows very strong resistance to powdery mildew and the resistance mechanism in *Ren4* is different to the powdery mildew resistance mechanism (*Run1*) in the *Run1/Rpv1* locus. To demonstrate this, the CSIRO team attempted to break the *Ren4* mechanism using a powdery mildew isolate already known to break *Run1*. The *Ren4* gene withstood the test, proving its resistance and confirming the difference in resistance mechanism.

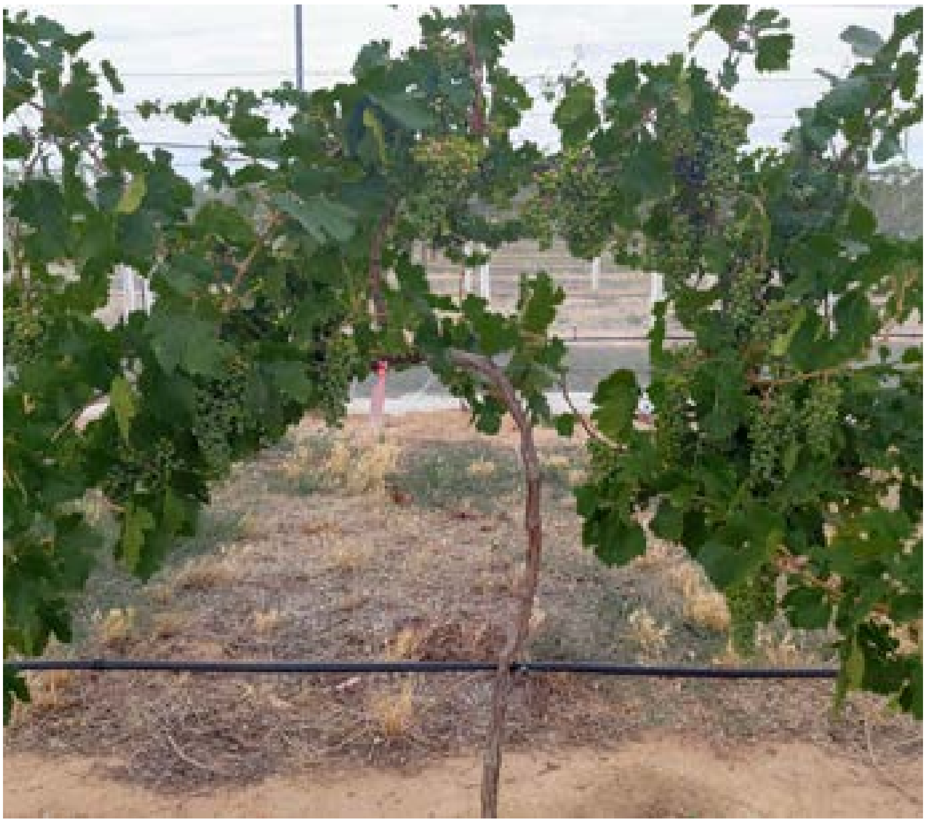
As research progressed the CSIRO team also discovered that plants with the *Ren4* gene also had resistance to downy mildew. The two separate resistance genes were identified and named; *Ren4* for powdery mildew resistance and *Rpv16* for the downy mildew resistance locus. CSIRO then decided to use *V. romanetii* to breed second generation plants that would possess all four resistance genes, two each for powdery and downy mildew, as a result of combining *Ren4* and *Rpv16* from *V. romanetii* with the *Run1/Rpv1* locus in the first generation plants.

At present Dr Dry says the strongest performers from the first generation *Run1/Rpv1* plants have been used as breeding parents to produce the second generation varieties. DNA marker assisted selection has identified those second generation progeny with all four resistance genes. The plan is to have more than 600 second generation progeny in the ground at Nuriootpa by the end of 2022, including a range of crossings using a broader selection of premium varieties.

BlackBird robotic system

Phenotyping, or the identification and quantification of specific genetic traits in grapevine leaves, is a laborious process. It is however, at the very foundation of powdery mildew research. The technique requires punching 1cm holes in grapevine leaves, examining the discs under the microscope and counting millions of fungal spores, hyphae and so forth. The BlackBird robotic system has transformed this extremely time consuming process to vastly reduce the number of hours spent at the microscope.

Developed at Cornell University, BlackBird uses automation and machine learning to rapidly complete phenotyping and, as Lance Cadle-Davidson explains to me, the accuracy demonstrated by BlackBird surpasses that of human work. Cadle-Davidson is a Research Plant



Second generation plants. Photo: Dr Ian Dry, CSIRO

Pathologist at the USDA Grape Genetics Research Unit and Adjunct Professor at Cornell AgriTech. In addition to his work with BlackBird, he was also one of the authors on the paper identifying mildew resistance in *V. romanetii*.

The process works by crossing an elite grape variety with a grape species possessing the desired genetic trait, such as powdery mildew resistance.

Cadle-Davidson said they realised AI could be used for phenotyping in order to produce quantification at very high automated throughput. BlackBird works by loading the 1cm leaf discs into the robot before high resolution microscopic images are collected and analysed. The system is capable of analysing 350 samples in approximately 2 hours, which Cadle-Davidson estimates to be 60-fold faster than manual work.

The machine learning was built offsite by an expert in computer vision who created a process whereby the leaf disc image was divided into 800 sub-images. The machine then identified the presence of powdery mildew spores, recording a Y/N response. The databank for the machine was created by experts who reviewed more than 16,000 sub-images. Results surpassed expectations with BlackBird demonstrating a far higher degree of accuracy than humans at detecting powdery mildew. Cadle-Davidson describes this as revolutionary for his area of research.

Future plans include building a new version of BlackBird with the capability to quantify the different biochemistries in one grapevine when compared with another. The aim is to investigate the host response to the mildew pathogen and the biochemistry of the host. While the pandemic has delayed a wider rollout beyond the Cornell laboratory, this year will see the BlackBird robotic system being delivered first to USDA scientists across the USA and by the end of 2022, to scientists globally as requested.

As the movement for reducing chemical use in food and wine production gathers momentum, it will be science, technology and innovation that will offer alternative practices to help secure industry longevity.

Simone Madden-Grey is a writer based in Melbourne, Australia writing about the people, places and stories she has discovered on her travels. Her portfolio can be found at happywinewoman.com including articles on climate and sustainability in the wine industry and travel covering the wine, regions and gourmet destinations of Australia and her home country, New Zealand.

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Vines inside the UV-C Robot

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