Hort Innovation

## Final Report

# Area wide management of vegetable diseases: viruses and bacteria (NSW report)

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**Delivery partner:**

NSW Department of Primary Industries

**Project code:**

VG16086

**Project:**

*Area wide management of vegetable diseases: viruses and bacteria (NSW report)* (VG16086)

**Disclaimer:**



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## Public summary

The NSW vegetable industry includes a diverse group of growers ranging from those operating large farms with a few crop types to smaller land holds growing a variety of vegetable types. The dominant crops grown are brassica, cucurbit and amaranth crops. Productivity of these vegetable producing regions are all impacted by the incidence of disease-causing pathogens. The key objective of this project was to minimise the effect of high impact endemic viral and bacterial diseases while taking a proactive approach to minimise the introduction and establishment of exotic vegetable diseases. The first step in this process is understanding the distribution and diversity of viral and bacterial pathogens endemic to NSW, addressed through three years of surveillance and working with farmers to identify the pathogens affecting their crops. This involved visiting 64 growers, many with repeat visits, and diagnosing 869 samples. This work was complemented with genomic and field trial studies using the prevalent pathogens watermelon mosaic virus (WMV) and *Xanthomonas campestris*, responsible for black rot, to investigate the link between genetic diversity and pathogenicity and survivability of the pathogen in plant debris.

The greatest output of this project is the baseline survey work that was conducted. In addition to undertaking a thorough disease census of the viral and bacterial diseases present in the NSW vegetable industry, we have formed relationships with growers, providing training and cultivated the networks necessary for better management of current and potential future disease threats. Our surveys also uncovered a new virus, knowledge around establishment of viruses into NSW and weed hosts that pose transmission risks. Genomic studies showed that there are several WMV types present in NSW. Virus trials were conducted investigating breakdown of the virus with different composting methods and evaluating resistant crop varieties and alternative weed hosts. *Xanthomonas campestris* and *Pseudomonas* spp. are the dominant bacterial pathogens causing problems in the NSW vegetable industry. Genome studies of *X. campestris* identified several different clonal groups and isolates have been used in the development a new diagnostic assay and to investigate if genetic diversity translates into more pathogenic strains. We have also investigated how long *X. campestris* survives in plant debris when buried or left on the surface. We now know that *X. campestris* can survive for extended periods in infected plant debris and this poses a risk for on farm health of brassica crops.

This project also supported capacity building for the vegetable industry in the form of training and development of vegetable pathologists working in our diagnostic service. Our project personnel have also trained and participated in emergency biosecurity responses, some directly related to the vegetable industry, thus enhancing our capacity to respond rapidly and effectively in the event of a new exotic disease detection.

Overall, project outcomes have led to a better understanding of vegetable diseases and how to better identify and manage them. While this is just the tip of the iceberg, incorporation of this knowledge into farming practices in larger Area Wide Management plans can make all the difference.

## Keywords

Bacteria, viruses, brassica, cucurbits, disease census, area wide management

# Introduction

The Australian vegetable industry accounts for around 7% of agricultural production in Australia, and was valued at $4 billion in 2018-19 (ABARES, 2019a) with production concentrated in NSW, Queensland and Victoria. Producers grow a large number of vegetable species and varieties, routinely growing multiple species at any given time based on local demand. Bacterial and viral pathogens currently limit production and profitability in many areas reducing yield and quality, resulting in a financial impact to producers.

### The NSW Vegetable Industry

The industry in NSW is diverse, heralding from many nationalities, long family linkages in the agricultural sector right through to first generation producers and spanning an age range from teenagers through to retirement age. The sector is predominantly male, although female producers and agronomists are becoming more common. Producers come from a rich cultural background including individuals from Iran, Cambodia, Vietnam, Lebanon, Malta, Italy, Iraq and China.

Data generated from the Peri Urban Pilot project (that also involved AWM project members) determined that brassica, cucurbit and amaranth crops such as beetroot, spinach and lettuce are the most common vegetable cropping options within the Sydney Basin, a key production region for NSW vegetables. Producers predominantly provide produce to regional markets, such as Flemington Markets in Sydney. Many also supply weekend farmers markets and local restaurants and cafes. Many producers also supply direct to supermarket. Very few export produce internationally or run a farm gate stall.

A key objective of this project was to minimise the effect of high impact endemic diseases whilst also taking a proactive approach to minimise the introduction and establishment of exotic vegetable diseases. In the latter case, a thorough knowledge of the diversity of endemic pathogens is critical to be able to distinguish new threats. Pathogen identification for vegetable diseases can take anywhere from days to months depending on the pathogen, availability of positive control material and accurate diagnostic protocols. Due to the complexity of the vegetable plant-pathogen model, it is essential to study the epidemiology of the disease in the field, in the laboratory and with genomic tools.

The recent detection of tomato potato psyllid (TPP) *Bactericera cockerelli* in Western Australia highlighted the importance of preparedness and rapid detection to permit a timely response to an incursion. Area Wide Management (AWM) programs that promote screening for diseases of national significance that threaten market viability are underpinned by national strategies, such as that developed for cucumber green mottle mosaic virus (CGMMV). Knowledge of the key pathogens, understanding of the mechanisms supporting and driving the industry and collaboration between technical specialists and vegetable producers was a key driver for this project.

This project focused on four main elements:

1. **The development of an area wide management strategy for bacterial pathogens in brassicas and viral diseases in cucurbits.** The primary focus of this strategy was the bacterial pathogen *Xanthomonas campestris* and pathogens in the genus *Potyvirus.* The strategy incorporated information generated via extensive field surveillance, interactions with producers, and collaboration with other state and territory jurisdictions working under the larger AWM project led by Queensland. The transfer of industry knowledge was facilitated via mentoring of key staff within the project team, workshops and site visits with vegetable producers, experimental assays, genomic analysis of isolates collected during surveillance and participation in an emergency biosecurity response that directly affected vegetable growers.
2. **Development of effective, innovative, and rapid diagnostics for *Xanthomonas campestris*.** Through a combination of field surveillance, genome sequencing of new and historical *X. campestris* isolates and testing on a range of plant material types (e.g. seed, plant tissue, soil and crop waste) the aim was to be able to differentiate *X. campestris* to the pathovar level.
3. **Contribute valuable surveillance knowledge of current bacterial and viral pathogen populations to benchmark the dominant pathogen issues for the NSW vegetable industry.** Vegetable production areas across NSW were targeted at various times of the year to survey both vegetable and non-crop hosts to build the profile of NSW pathogens and improve our biosecurity preparedness of naturalized and endemic disease threats.
4. **Expanding the capacity and capability of technical expertise available to the vegetable industry nationally**. This involved collaborative work with other state and territory jurisdictions, mentoring of project staff, the completion of a PhD candidature and intensive engagement with vegetable producers to directly communicate the outcomes of surveillance activities, diagnostic development, promotion of good biosecurity practices and management options for the key local vegetable disease issues.

## Methodology

This project was delivered against four key objectives: field surveillance to identify key pathogens, experimental assays to understand the pathogens and explore treatment options, diagnostic development and industry extension and engagement activities to directly relay key findings to industry and provide an education opportunity to improve knowledge and understanding of important biosecurity principles.

### Surveillance

Surveillance was conducted across key vegetable production regions of NSW specifically targeting brassica crops for bacterial infection and cucurbit crops for viral infection. Crops were walked in a Z or W pattern to include crop edges and internal sections of the block and both symptomatic and asymptomatic leaf samples were collected for further assessment. Incidence of disease symptoms was recorded when visible symptoms were apparent, counting 300 plants and assessing the percentage infected. Samples were also collected for both asymptomatic and symptomatic plants to confirm pathogen identity. Further details are provided in Appendix 1 and Appendix 11. When COVID-19 restrictions prevented direct field access for surveillance, NSW DPI worked with growers to encourage mail-in samples to maintain diagnostic support for producers. To better understand the extent of *Olpidium* spp. present in NSW vegetable growing regions root and soil samples were collected within key host crops. Further details are provided in Appendix 2.

### Diagnostic Development

A historical collection of *X. campestris* consisting of 200 isolates collected between 1969 and 2016 was used for the genomic studies. The aim of this work was to investigate the genetic relatedness of *X. campestris* in Australia. Appendix 3 presents the results of the genomic study. Genome sequencing was used for the development of a *X. campestris* pv *campestris* specific assay. A genomic pipeline was used to identify regions present only in *X. campestris* pathovars. This work has resulted in a primer pair that has been validated with a testing panel of 67 different bacterial isolates. This primer pair will undergo limit of detection testing and will then be published as a scientific manuscript. The details of this work is contained in Appendix 14.

### Bacteria

Understanding our key bacterial pathogens requires studying them on multiple fronts. Based on our surveillance studies we know *X. campestris* pv *campestris* is the key bacterial pathogen in brassica vegetables in NSW. Repeated visits of farms saw the presence of this pathogen year after year. The genetic identities of these pathogens are being studies as part of the genomics work as described in Appendix 1. The other approach is outlined in Appendix 4 where we investigated how long *X. campestris* can survive in plant debris when buried or left on the surface of the soil profile.

The other key experiment was to investigate the pathogenicity of the representative *X. campestris* clonal groups as determined by genome sequencing (Appendix 3). Representative isolates were tested in pathogenicity assays in cauliflower, broccoli and cabbage as presented in Appendix 5.

### Viruses

Investigation into the transmission, treatment and management of cucurbit crop waste affected by the *Potyvirus* watermelon mosaic virus (WMV) was undertaken. Field observations pointed to the likelihood of mechanical transmission although WMV is conventionally thought to be an aphid transmitted *Potyvirus*. Trials tested the effect of applying WMV inoculum to cutting tools then cutting through healthy zucchini tissue to introduce the virus. The second component tested rubbing WMV infected leaves against healthy leaves in zucchini to simulate natural in field transmission of plants moving in wind. The trial plants were then tested after several weeks to determine if WMV infection had been successfully transmitted. Detailed methods can be found in Appendix 7. Treatment of WMV infection was also tested using the biological product chitosan. Chitosan was applied to both seed and juvenile plants prior to and post inoculation with WMV. Plants were then monitored for several weeks to test for the development of WMV infection. Further detail can be found in Appendix 7. Managing crop waste of virus infected plant material was also investigated. Many plant viruses are resilient to temperature and moisture effects during degradation in crop waste. No baseline data could be identified in the literature for WMV in crop waste to ascertain if composting could effectively render this pathogen inert. Zucchini crop waste infected with WMV was composted for several weeks using three different vessel types to determine if differing levels of temperature and moisture affected plant tissue breakdown and subsequent survival of WMV. Additional details can be found in the development of WMV infection. Further details on methods can be found in Appendix 6.

**Extension & Engagement**

Results from surveillance activities, laboratory and glasshouse trials were communicated to industry using direct grower engagement on farm, industry workshops, conferences and online presentations. Industry representatives, Ausveg, Greater Sydney Local Land Services (GS LLS), VegNet, growers and agronomists were invited to extension activities and, where possible, the AWM project team attended workshops and events hosted by other organisations to maximise the outreach of project material. Where face-to-face interactions were restricted during COVID-19 lockdowns, alternative delivery options were used including online webinars and surveys. Two manuscripts have already been published and a third is in progress to communicate the findings more broadly within the scientific community.

**Researcher Capacity Building**

Strong collaboration was fostered within the NSW AWM team and between the NSW and national AWM project teams by attending joint project meetings and surveillance opportunities (when open borders permitted). Experienced plant pathologist Dr Len Tesoriero mentored the AWM project team in field pathology and provided initial introductions to elements of the vegetable industry, expanded by the project team to include a network of 64 growers plus agronomists in the project. A PhD candidate was a key feature of the project, delivering the viral component of this project.

Through this mentoring we have two trained vegetable pathologists, one who has further specialised in bacteriology, the other in virology and emergency preparedness. We have two additional pathologists from our diagnostic service who have been trained in vegetable field pathology by participating in surveillance events. These personnel have also been Emergency Management trained and participated in numerous responses including serpentine leaf miner *Liriomyza huidobrensis* (SLM), varroa mite *Varroa destructor*, brown marmorated stink bug *Halyomorpha halys* (BMSB), and flood response and recovery in the Hawkesbury during the numerous flood events. These same staff members are also Local Emergency Management Committee (LEMC) and Regional Emergency Management Committee (REMC) representatives for the Sydney Basin, NSW to enable a more active role in responses. The NSW AWM team leader is also now the NSW SPHD (Subcommittee on Plant Health Diagnostics) representative. All this training and preparedness helps in our research capabilities for the vegetable industry.

**Biosecurity Preparedness**

The NSW AWM team worked with the national AWM team to develop contingency plans for key bacterial and viral pathogens as identified by the Queensland project team during their exotic pathogen review. The NSW AWM team also worked with growers to improve their understanding of good biosecurity practice, what to do if a suspect organism is detected and what happens before, during and after an emergency response is launched. This was achieved during farm visits and workshops.

## Results and discussion

**Background on Brassica growing regions of NSW**

Brassicas are one of the dominant vegetable crops grown in NSW with leafy Asian vegetables being the most common with 43% of production occurring in NSW, valued at $36.7M, followed by cabbage at $12.8M, broccoli at $11.6M and cauliflower at $8.5M. Understandably, the bacterial pathogen *X. campestris,* which thrives on these hosts and the climatic conditions of rain, humidity and a temperate climate, is a key pathogen for brassica crops as reflected in the vegetable surveys that were carried out between 2018 and 2022. The advantage this pathogen has in NSW is the volume of brassica production that occurs. This results in small landholders not being able to rotate crops effectively to result in die-off of the pathogen. To that end, the pathogen is likely remaining on the farm and reintroduced with new seed stock/seedlings.

Despite being considered the most devastating bacterial pathogen of brassicas globally, there are no real solutions for treatment of this seedborne pathogen. Despite knowing this pathogen is seedborne, it is still transmitted via seed globally due to insufficient regulation and testing of this pathogen. This can be observed through the genetic variability in the pathogen and the global distribution of these variants. There are some fundamental knowledge gaps for this pathogen for management, which this project has started to address by first doing the groundwork on collecting isolates from across the state to identify the genetic diversity in NSW (Appendix 1 and 3), determining if this genetic diversity impacts pathogenicity (Appendix 5) developing a diagnostic assay for the identification of *X. campestris* pv *campestris* (Appendix 14) and investigating how long it survives in plant debris, both above and below ground (Appendix 4).

**Background on Cucurbit growing regions in NSW**

The contribution of cucurbit commodities is valued at around $520 million annually across the country (Horticulture Innovation, 2020). Cucurbits are produced commercially in all states and Territories of Australia, except the Australian Capital Territory and Tasmania where the climates are unsuitable. The primary cucurbit crops grown in NSW include zucchini and squash (*Cucurbita pepo)*, pumpkin (*C. moschata, C. maxima)*, watermelon (*Citrullus lanatus)*, rockmelon (*Cucumis melo)* and cucumber (*Cucumis sativus)*. A small number of producers also grow more bespoke species including wax gourd (*Benincasa hispana*), gourd (*Lagenaria siceraria*), luffa (*Luffa spp.*) and bitter melon (*Momordica charantia*). *C. moschata* and *L. siceraria* are also produced as rootstock varieties that are grafted onto other cucurbits such as watermelon as a disease management strategy for the soilborne fungus *Fusarium oxysporum f. sp. Niveum.* Within NSW, zucchini, squash, cucumber and pumpkin production falls under the broader banner of the vegetable industry and they are typically grown almost year-round in the temperate coastal zones. Melons (rockmelon, honeydew, watermelons) operate under a separate industry governing body, the Australian Melon Association, and typically are grown as summer cash crops in the warmer southern and Central West parts of the state. There are isolated pumpkin and squash producers in the Central West and Hunter regions. Zucchini production occurs largely within the Sydney Basin extending up the Central Coast and into the Hunter, although a range of other cucurbits are also grown in the Sydney area. Cucumber production, mainly as protected cropping operations, exist across the Sydney Basin, Central Coast and Mid-North Coast regions. Melon production is centered mainly within the Riverina and Sunraysia in the warmer south-western parts of the state.

A review of the current biosecurity risks to the cucurbit industry, with a focus on viral pathogens, was undertaken to identify our baseline knowledge of viral pathogens in NSW ahead of broader surveillance activities. The full published manuscript for this review can be found in Appendix 10. Discussions were held with growers on site about general disease management and issues to provide greater understanding of disease history, current management strategies and operational decisions such as type of irrigation, source of seed and seedlings. Meetings with seedling producers have also been undertaken both to promote awareness of the project and discuss disease concerns. A key issue raised during these meetings was the need for regular feedback from the diagnostic community, particularly on potential biosecurity threats especially for seed borne pathogens, so that the seedling nurseries can maintain vigilance for exotic diseases. This project attempted to establish an improved communication platform to facilitate this knowledge sharing.

**Surveillance**

The NSW AWM team initiated disease surveillance operations in August 2018 with surveys conducted across the Sydney Basin, Central Coast, Central Tablelands, Riverina, Central West, North Coast and Sunraysia regions of NSW. Pathogen records were generated for multiple host crops (and non-crop hosts including weed species) across 7 different growing regions in at least 3 different climatic zones. As part of this project, we visited growers with a diverse range of farming systems including conventional field producers, organic growers, larger growers specialising in single commodities, smaller growers that have a diversity of commodities for market gardens, community gardens and protected cropping

operations. We also included samples that were submitted as part of the routine diagnostics occurring in our Plant Health Diagnostic Service and the Peri Urban Pilot project. As part of this surveillance, we have also included members of our Plant Health Diagnostic Service, AusVeg team members, Local Land Services personnel that are part of VegNet and local agronomists. These joint events allowed for cross-training and networking to occur with not only each other but with our growers.

*Potyviruses* were confirmed to be the dominant viral pathogen group affecting cucurbits (Appendix 1 & 11). Unlike other states in Australia, watermelon mosaic virus (WMV) was confirmed to be the dominant pathogen of this genus and was especially widespread in zucchini cultivation. Beet pseudo yellows virus and melon necrotic spot virus (MNSV) were also detected at low levels in cucurbit crops.

In addition to confirming the distribution and diversity of established pathogens, the surveillance conducted during this project recorded the first incidence of watermelon crinkle leaf associated virus-1 (WCLaV-1) in watermelons, a first report for Australia (Appendix 12), the first detection of cucumber green mottle mosaic virus (CGMMV) in cucurbits in NSW (Appendix 11) and provided confirmation of the establishment of impatiens necrotic spot virus (INSV) in the Sydney Basin (Appendix 1). INSV is a *Tospovirus* that was found to be more widespread in the Sydney Basin that first believed and, as a thrip transmitted infection, will continue to impose negative crop impacts on lettuce production in this region. INSV would be consider an emerging threat for the vegetable industry in NSW. Field surveys confirmed the presence of three distinct species of fungi *Olpidium*. All three species are capable of vectoring viruses in different host crops, confirming that viral transmission will be a persistent risk for these production regions (Appendix 2).

Surveillance activities were hampered during the summer of 2019-2020 due to the extreme bushfire conditions experienced by much of south-eastern Australia. Whilst none of the growers involved in this project were directly affected by the fires, access to the properties was frequently disrupted due to road closures or travel restrictions due to the extremely poor air quality. Surveillance in 2020-22 was also frequently interrupted due to the COVID-19 pandemic. Recurring lockdowns, movement restrictions and the unfortunate fact that many of the surveyed properties are located within the Greater Sydney area (the foci of recurring lockdowns and travel restrictions in NSW), meant the survey team were often unable to participate in field activities toward the latter part of the project. Growers were instead encouraged to mail submissions in to facilitate ongoing diagnostics. The growing seasons in 2021 and 2022 in the Sydney Basin, North Coast and Sunraysia were disrupted due to significant rainfall events and numerous major flood events. Sadly, growers involved in this project were impacted by flooding, particularly in the Sydney Basin, which did compromise additional surveys on some properties. An outbreak of serpentine leafminer (*Liriomyza huidobrensis*) was detected in the Sydney Basin in late 2020 triggering a biosecurity response. This pest insect has directly impacted many vegetable growers in this region and will be an emerging threat to vegetable production in Australia. It is now considered an established pest in Australia, although at present it is largely confined to the Sydney Basin and parts of southeast Queensland. AWM project staff were heavily involved in the emergency responses for both floods and serpentine leafminer to support the affected producers in the vegetable industry.

**Bacteria**

The work on *X. campestris* has highlighted the genomic diversity of strains present in Australia and how Australia has most of the dominant global strains (Appendix 3). This is not surprising given that this is a seedborne pathogen and, given the number of outbreaks globally and within Australia, clearly not receiving effective seed treatment. Further genomic studies of the survey isolates, anticipated as part of the project VG22001, will determine if the same isolates are residing on farm and reinfecting plants or whether there are new strains coming in with seed stock or seedlings. This information is important for management. However, given that the longevity assays are demonstrating that *X. campestris* can be recovered from plant debris and cause infection in brassicas 12 months after the plant has been removed from the ground, it is not surprising that disease is reoccurring (Appendix 4). The other key aspect of this work was to investigate the different genetic variants of *X. campestris* to determine if this translated to variable disease in crops. Based on the pathogenicity assays (Appendix 5), this does not seem to be the case. This is important information for disease monitoring and also supports on farm observations as there were only differences in disease susceptibility between cabbage varieties such as savoy being the most susceptible variety. This variation was not observed in any other brassica species. If this disease status changes and we see a new more pathogenic variant, it will sound alarm bells and be something worth investigating.

**Viruses**

Mechanical transmission experiments for WMV confirmed that this virus can be transmitted via cutting tools and direct

leaf contact. This is an important finding for industry in understanding potential on farm transmission routes for the most frequently intercepted cucurbit viral pathogen in NSW. Improved disease hygiene and careful management of infected crops could contribute to minimising available inoculum material and disease spread (Appendix 7). Treatment of viral infected zucchini with chitosan resulted in no significant reduction in disease severity or incidence. As positive outcomes have been reported for other viral pathogens in other vegetable hosts, this study confirmed the importance of specific testing on the plant-pathosystem combination to validate results as treatment effects are not always able to be extrapolated between different host and viral families (Appendix 7). Studies confirmed that composting cucurbit crop waste infected with WMV did result in the virus being rendered inert in a short space of time. Many viral pathogens can remain infective in crops waste for long periods of time after the crop has been killed or removed. This prolongs the risk of further disease transmission on the affected property. WMV rapidly breaks down in crop waste following plant death confirming this is not an important disease transmission pathway for this pathogen (Appendix 6).

**Extension and Engagement**

Industry engagement occurred throughout the project to work closely with producers and agronomists to communicate the results of surveillance (identifying key disease threats in various regions), clarifying disease transmission mechanisms, disease mitigation options and generally promoting sound biosecurity practices that can be adopted on farm. Table 1 details the events that were hosted or attended by the AWM project team. Growers typically displayed only basic knowledge of key pathogens in their region and often confused bacterial, viral and fungal pathogens. Knowledge of transmission mechanisms was also generally lacking, contributing to poor management outcomes as a result of applying the incorrect treatment strategy. Farm visits and direct collaboration with growers brought about a rapid improvement in their understanding and management of established diseases. Workshops also saw an improvement in their understanding of general biosecurity measures and biosecurity responses although there is more work to do in this space. There was general agreement among producers that biosecurity was largely the responsibility of government agencies and little recognition that the general public also contributed to biosecurity outcomes, however, extension material provided by government and researchers was well respected. Producers were very keen to learn about the key pathogens in their region and, importantly, the connection to how best to control these issues.

There was a large degree of trust placed in agronomists by growers particularly in regard to identifying new disease issues. This is a key sector of the industry that should be prioritised for additional capability building. Mentoring of several engaged agronomists and seed representatives by the AWM project team contributed to the detection of CGMMV and mapping of INSV in the Sydney Basin.

**Table 1: Events and Workshops conducted during the AWM Project**

| Event | Date | Attendance | Outcome |
|---|---|---|---|
| Field day hosted by Fairbanks Seed and Local Land Services | 15.06.18 | 100+ growers and local agronomists, Greater Sydney Local Land Services (GS LLS) | Promoted the vegetable project to industry via direct consultation and a flyer, article published in *Good Fruit and Vegetables* magazine. 12 cucurbit growers, 7 brassica growers and 3 agronomists expressed interest in participating in the project |
| Grower Engagement Event held in Melbourne, which included conducting surveillance at nine Victorian vegetable farms | 26-27.06.18 | 10 growers and consultants | This was a National project group session, this build collaboration between state team members and AusVeg |
| VegNet Event Hosted by Adam Goldwater from Applied Horticultural Research (AHR) in collaboration with NSW LLS, held in the Central West | 31.08.2018 | 20+ growers and agronomists | Promotion of the AWM vegetable project, increased number of vegetable growers that then participated in the project and of which we conducted repeated surveillance visits |
| Soilborne Disease Master Class hosted by VegNet, LLS and AHR in Griffith NSW | 20.11.18 | Local agronomists | |
| VegNET R&D 'Walk n Talks' | 25.10.18 | Local growers and | Toni Chapman and Shannon Mulholland |

| | | | |
|---|---|---|---|
| at LLS Demo River Farm | | agronomists | presented an update on surveillance findings for NSW vegetable regions. This presentation showed key symptoms for a range of bacterial and viral pathogens to raise awareness with growers on how to identify these pathogens |
| Australasian Plant Pathology Society Conference, Melbourne | Nov 2019 | Plant pathologists | Toni Chapman provided an update on *Xanthomonas campestris pv. campestris* – a genomic analysis of Australian historical isolates presented as an Oral Presentation. This work presented to the scientific community the value of historical culture collections and provided information on the diversity of *Xanthomonas campestris* previously isolated in Australia |
| Australasian Plant Pathology Society Conference, Melbourne | Nov 2019 | Plant pathologists | Shannon Mulholland presented a poster on Area Wide Management of bacterial and viral pathogens in the vegetable industry: What do we really have in NSW? This work presented to the scientific community information on the surveillance occurring in NSW as part of the AWM project and what viruses were being identified |
| Peri Urban Pilot - Workshop | March 2021 | Local growers, agronomists and Ausveg | Shannon Mulholland provided a seasonal update to vegetable producers for the Sydney basin looking at pest and disease trends and dominant pathogens being identified in vegetables |
| Peri Urban Pilot - Master Class | 14.10.21 | Vegetable growers and agronomists from the east coast, government and university staff | Shannon Mulholland and Len Tesoriero presented an online Master Class to the vegetable industry (due to COVID-19 restrictions) to provide an update on the serpentine leafminer transition to management, an update on the detection og CGMMV in NSW and a session on the common Tospoviruses the project team had identified in the Sydney basin as a result of AWM surveillance |
| Peri Urban Pilot - Workshop | 14.10.21 | Local growers, agronomists and Ausveg | Shannon Mulholland presented on how to collect a “good” sample for diagnostic confirmation, explained the diagnostic process and then conducted a practical demonstration on farm about how to collect and package suitable pathology specimens |
| Protected Cropping Australia Conference | Mar 2022 | Australian protected cropping industry | Shannon Mulholland presented at the 2022 PCA conference. The presentation was entitled ‘The dynamic landscape of viruses in cucurbit production systems in NSW |
| Peri Urban Pilot – Farm tour | May 2022 | Cucurbit growers in Kemps Creek and local greenhouse supplier | Shannon Mulholland attended a farm tour with the local VegNet representative to raise awareness of the emerging threat of CGMMV in a key cucurbit production zone, following its detection in the Sydney Basin. The visits allowed for one-on-one discussion with producers about critical biosecurity measures, factsheets showing the symptoms were provided and the reporting mechanism for submitting samples reinforced |

**Project Governance**

The NSW DPI team collaborated with the national AWM project on monitoring and evaluation panels, project reference committees, surveillance opportunities and annual face-to-face project meetings. The NSW AWM team also contributed to the development of the National Project Bacterial and Viral Pest Disease Guides.

In addition to the contracted objectives for this project the NSW AWM team aimed to meet key objectives and strategic priorities listed in the Vegetable Strategic Investment Plan and Vegetable Biosecurity Manual. Further detail on activities that contributed to meeting these objectives are listed in Appendix 9.

## Outputs

**Table 2: Output summary**

| Output | Description | Detail |
|---|---|---|
| Data on the genetic and biological diversity, survival and spread of endemic bacterial and viral pathogens affecting vegetable crops including a list of priority pathogens for the vegetable industry | Surveillance was conducted throughout the project, visiting vegetable farms across NSW | • Factsheets and news articles produced during the project can be found in Appendix 8<br>• The full list of pathogens identified during the surveillance can be found in Appendix 1, 2, 11 and 12<br>• CGMMV webinar and webpage was provided following the detection of CGMMV in NSW. These can be found at: https://www.dpi.nsw.gov.au/biosecurity/plant/insect-pests-and-plant-diseases/cgmmv |
| Bacterial and viral isolates will be added to the NSW DPI herbarium within our Collections Unit to maintain a register of endemic pathogens for the vegetable industry of NSW | Bacterial and viral isolates appropriately preserved and lodged with the NSW DPI Herbarium at the Orange Agricultural Institute for longevity | Viral and bacterial isolates were accessioned within the NSW DPI Collection during the course of this project. This also includes a new disease record for NSW (CGMMV) and a new disease record for Australia (WCLaV-1) |
| Data on the identity of previously unknown alternative plant hosts that occur in vegetable growing regions that may host key viral pathogens | Surveillance operations including the sampling on numerous vegetable and non-crop hosts (e.g. weeds) to verify if key viral pathogens affecting cucurbits were also present in the nearby environment on farm, potentially acting as a reservoir to continuously reinfect vulnerable host crops | Full details of the alternative hosts identified during surveillance can be found in Appendix 1 and 11 |
| Identification of alternative management options, including cultural and biological strategies, that can be incorporated into an integrated management program for selected bacterial and viral pathogens with a view to reducing crop losses and chemical usage. This information can be communicated to industry via the appropriate platform e.g. factsheets, grower workshops, VegNet etc | There are limited chemical control options to manage key viral and bacterial pathogens in vegetable and there is a community and industry appetite to seek alternative management strategies including the use of biological and mechanical control options. Several of these options were reviewed during this project to assess treatment options, transmission mechanisms and how to manage crop waste safely to mitigate further infection in subsequent crops | • Longevity assays on *X. campestris* confirmed that the bacteria can be recovered from plant debris 12 months after the crop had been removed (Appendix 4)<br>• The use of the biological product chitosan was trialled on potyvirus infection in zucchini but did not result in a convincing disease management strategy (Appendix 7)<br>• The mechanical transmission of WMV to zucchini via cutting tools and direct leaf contact was confirmed, further confirming that both insect vectored and mechanical transmission is contributing to widespread outbreaks of this disease in NSW (Appendix 7)<br>• Experimental assays confirmed that unlike other cucurbit viruses, WMV breaks down rapidly in crop waste and that composting even using basic methods can result in the disease being rendered inert soon after the plant dies (Appendix 6)<br>• Numerous workshops and farm visits have promoted increased awareness of the various infection pathways, suitable management options, management options to steer away from and better biosecurity practices to adopt |

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| Development of new diagnostics and protocols for viruses and bacteria affecting nominated vegetable crops | Ensuring the vegetable industry has access to accurate, rapid and validated assays in Australia is critical for the confirmation of established pathogens but also the detection of exotic incursions. Publicly available assays are not always of equitable quality and validation within an Australian context is vital | • NSW DPI developed a new diagnostic assay for *X. campestris* (Appendix 14)<br>• Participated in ring testing nationally for other newly developed virus and bacteria assays<br>• Validated published assays for *Olpidium* spp. (Appendix 2) and WCLaV-1<br>• Work up of genome sequencing protocols for bacterial pathogens |
| PhD study on zucchini virus epidemiology in the Greater Sydney Basin | As part of the capability building for industry a PhD candidature focused on the viral pathogens of cucurbits in NSW | A doctoral degree was conferred to Shannon Mulholland in 2023 following the successful completion of her candidature in 2022. This project examined the existing biosecurity threats faced by the cucurbit industry with a specific focus on viral pathogens, conducted extensive surveillance to benchmark the pathogen population in NSW resulting in the detection of CGMMV (and subsequent launch of an emergency biosecurity response) and a new disease record for Australia following the detection of WCLaV-1 in watermelon, tested control options and two manuscripts have been published in 2022 from this work and a third is pending (Appendix 7, 10, 11, 12) |
| Build and establish partnerships in plant pest and disease surveillance for early detection and reporting of exotic emergency plant pests in horticulture increasing the likelihood of effective eradication, preserving market access and minimising ongoing management costs | There are multiple avenues in which the NSW AWM project team have been strengthening existing and creating new relationships between key researchers, diagnosticians and technical experts nationally to improve early detection and response to new biosecurity threats | • Shannon Mulholland was the NSW lead in the Peri Urban Pilot project with Ausveg and government jurisdictions in Victoria and South Australia to build cross border linkages and better understand grower attitudes and understanding towards biosecurity measures, surveillance and reporting. This allowed for comprehensive attitudinal surveys to capture industry perspectives from three states, data which was then utilised by the AWM project team to help craft more tailored interactions with NSW growers<br>• Greater collaboration internally with NSW DPI plant biosecurity teams (preparedness and research & diagnostics), agriculture, climate change and emergency management are helping to improve strategic surveillance programs for key vegetable pests and diseases, further additional research and climate suitability modelling into newly arrived pests such as serpentine leafminer and improving emergency response outcomes following the detection of new threats<br>• Collaboration with national state and territory government plant biosecurity teams and diagnosticians to improve diagnostic capacity and capability<br>• Building IMT capacity of key plant biosecurity personnel with technical knowledge and sound understanding of plant industries (especially vegetables) of NSW to respond to outbreaks. This has involved dedicated emergency management training and response experience for key AWM personnel to better support future biosecurity incursion responses<br>• To date key AWM personnel have been involved in the following biosecurity emergency responses (during the course of his project): cucumber green mottle mosaic virus, serpentine leafminer, watermelon crinkle leaf associated virus-1, khapra beetle, varroa mite, brown marmorated stinkbug and multiple flood responses |

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| | | • Targeted surveillance has helped to establish our baseline knowledge of distribution, diversity and host range of endemic diseases as well as identify newly arrived pathogens including *Pseudomonas* host range expansion, detection of WCLaV-1, range expansion of INSV and CGMMV<br>• Collaboration with Plant Health Australia and industry liaison officers to improve targeted communication during a response and account for the unique needs of individual plant industry |
| Development of risk mitigation strategies for seed treatment for bacterial pathogens | It is a fine balance between effective seed disinfestation and not effecting seed viability. The literature has been used as a source of knowledge for this topic | • Based on literature searches an experimental plan has been worked up for the testing of seed disinfestation assays. This work will be conducted in VG22001 (Appendix 13) |
| Scientific peer-reviewed publications and conference presentations on the outcomes of the project | | • Appendix 10, 11 and 12 detail manuscripts published or in progress during this project<br>• Conference presentations have been provided at the Protected Cropping Australia conference and Australasian Plant Pathology Conference (see Table 1) |
| Consideration of linkage of plant material testing protocols to PEQ and nursery applications if/as required and linkage with SPHDS | | • Toni Chapman is the NSW SPHDS representative and was on the committee for the development of the Vegetable Industry Biosecurity Plan<br>• Shannon Mulholland participated in the review of the National CGMMV Management Strategy in 2022<br>• Shannon is also the NSW representative on the vegetable industry biosecurity reference panels |
| **Additional outputs beyond the original project scope** | | |
| Surveillance network – create training manual and postal kits for growers to submit samples | | Factsheet was created and postal kits given to growers when attending LLS demo days or posted directly to growers upon request. This was used more frequently during the COVID lockdown to enable growers to continue to submit samples to the lab in lieu of field visits |

## Outcomes

### Table 2: Outcome summary

| Outcome | Alignment to fund outcome, strategy and KPI | Description | Evidence |
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| Faster identification of endemic and suspect bacterial and viral pathogens with validated reference isolates available of known endemic species. | Outcome 1, Strategy 3 | A new diagnostic assay has been developed for *X. campestris*<br>New assays have been validated in NSW from the literature following the detection of WCLaV-1 and CGMMV<br>Widespread surveillance has improved our benchmark understanding of the current vegetable pathogen population in NSW | Reference isolates banked in the Collection<br>Diagnostic assay development manuscript being prepared for publication<br>Appendix 1, 3, 10, 11, 12, 14 |
| Development of low-cost specific diagnostic assays for rapid identification of bacterial and viral presence in horticultural crops, insect pests or seed lots. | Outcome 1, Strategy 3 | A new diagnostic assay has been developed for *X. campestris*<br>New assays have been validated in NSW from the literature following the detection of WCLaV-1 and CGMMV<br>Widespread surveillance has improved our benchmark understanding of the current vegetable pathogen population in NSW | Reference isolates banked in the Collection<br>Diagnostic assay being prepared for publication<br>Appendix 14 |
| Improved capacity and speed at which disease outbreaks can be diagnosed in the field, ultimately of benefit to horticultural industry stakeholders and biosecurity agencies involved in suppression of disease outbreaks. | Outcome 1, Strategy 3<br>Outcome 3, Strategy 1<br>Outcome 3, Strategy 2<br>Outcome 3, Strategy 3 | Experience in field surveillance has improved capacity for field diagnosis of numerous pathogens<br>Surveillance benchmarking now provides a good basis for expected pathogens to be found in key production regions<br>Numerous emergency responses in NSW during the project has seen the development and refinement of key protocols for standing up high throughput surge capacity for lab diagnosis, which has involved the AWM project team<br>Engagement with the vegetable industry and key partners such as VegNet and Ausveg has improved industry awareness of correct sample submission procedures, the diagnostic process, knowledge of key established diseases in their region and better biosecurity practices to mitigate the | Better knowledge of key endemic pathogens<br>Internally working on more diagnostic assays and preparedness plans<br>Greater field pathology capacity of AWM team<br>Better industry understanding of the need for laboratory diagnostics from a grower perspective<br>Linkages to peak industry bodies such as AusVeg and other vegetable projects such as the Peri Urban Pilot program to highlight the value of diagnostics<br>Increased sample submission by growers to the PHDS laboratory<br>Greater collaboration between growers and agronomists and NSW DPI at the initial detection of suspect pathogens and then during emergency responses |

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| | | introduction and establishment of new diseases onto their property. | |
| Increased grower capacity to understand and manage bacterial and viral diseases in vegetables | Outcome 1, Strategy 2<br>Outcome 3, Strategy 1<br>Outcome 3, Strategy 2<br>Outcome 3, Strategy 3 | Producers have a better understanding of the differences between a bacterial, fungal and viral infection and the related transmission mechanisms courtesy of numerus workshops and direct engagement with growers in the field<br>Improved understanding of key vegetable and non-crop hosts can allow growers to make decisions on crop rotation if affected by particular pathogens<br>Improved understanding of factors that contribute to disease reoccurrence e.g. planting new crops onto fields laden with *X. campestris* crop waste or disturbing viral infected crops leading to a sudden dispersal of viral vectors into a vulnerable neighboring crop | Factsheet on weed hosts of key viruses and key viral pathogens<br>AWM Strategy provided to industry on key disease recognition and mitigation options<br>Numerous workshops and site visits with vegetable growers to educate them on key risks |
| Capitalising on NSW's physical position, straddling temperate and tropical horticultural commodities, greater understanding of endemic pest and disease threats will contribute to capacity of responding to future pest incursions. | Outcome 1, Strategy 2<br>Outcome 1, Strategy 3<br>Outcome 3, Strategy 1 | Surveillance was conducted in multiple key vegetable production regions to capture different types of crops, different seasonal production patterns and different farm management options to ensure thorough collection of pathogen population diversity and distribution data | Data on pathogen populations from 7 different growing regions in at least 3 different climatic zones – Appendix 1<br>Serpentine leafminer incursion – knowledge of grower and nursery networks and locations, knowledge of endemic pests and diseases rapidly highlighted that a new species had been detected and intimate knowledge of grower networks rapidly facilitated critical delimiting surveillance |
| Greater diagnostic capacity and knowledge of endemic pests and diseases will assist future research and management endeavours via determining the sampling protocols that provide meaningful data, especially in the event that the target pathogen may be present but asymptomatic to identify acceptable parameters for extrapolating “not detected” results as evidence of pathogen absence. | Outcome 1, Strategy 2<br>Outcome 1, Strategy 3<br>Outcome 3, Strategy 3 | The development of new diagnostic assays and validation of recently published assays following detections of new pathogens has increased the diagnostic capacity and capability for a key national diagnostic laboratory servicing the vegetable industry<br>Ensuring that both symptomatic and asymptomatic plant samples were collected helped to identify cryptic infections including a new disease record | Virus surveillance revealed higher than expected levels of asymptomatic infection highlighting that visual surveys may be underestimating incidence<br><br>Virus surveys revealed higher incidence of CMV than expected as past surveys did not specifically screen for this pathogen<br><br>Bacterial surveys identified |

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| | | for Australia | emerging issues with Pectobacterium and Pseudomonas which will direct future research<br><br>Surveillance work already contributed to maintaining market access for CGMMV by generating "surveyed but not detected" results for many cucurbit growing regions, regions distinct from the export area |
| By reducing pathogen populations, AWM of bacterial and viral diseases in NSW will reduce the selective pressure on pathogen evolution thereby increasing the longevity of resistant genetic breeding lines. | Outcome 1, Strategy 2<br>Outcome 1, Strategy 3<br>Outcome 3, Strategy 1<br>Outcome 3, Strategy 3 | Selecting breeding lines based on key pathogens for your region can reduce disease pressure | Reviewing tolerance of existing zucchini lines confirmed that some varieties are more tolerant than others to viral infection |
| **Additional outcomes beyond the initial project scope** | | | |
| Capacity building | | Having dedicated operators with experience in a specific industry allows for rapid assessment of new and existing threats, permits comparison of "healthy" vs "affected crops to minimise unnecessary testing for non-pathogen related issues e.g. nutrient deficiencies | Multiple pathologists within DPI now have intimate knowledge of the vegetable industry, crop types and key pathogens<br>Key AWM personnel experienced in emergency responses have directly assisted the vegetable industry during recent natural disasters and biosecurity responses<br>Key AWM personnel now sit on the Regional Emergency Management Committee (REMC) for the Sydney Basin to mentor local EMC in biosecurity to improve detection and response to exotic pests and diseases |

## Monitoring and evaluation

### Table 3: Key Evaluation Questions

| Key Evaluation Question | Project performance | Continuous improvement opportunities |
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| **Effectiveness** | | |
| **1. To what extend have the project achieved its expected outcomes?** | | |
| 1a. In what form has the project provided information specific to the vegetable industry to drive the adoption of better disease management practices for key bacterial and viral pathogens? | • Surveillance / site visits allowed us to work with growers on the identification of diseases, inform on how they spread and ways to manage and prevent diseases<br>• Workshops allowed for the presentation of project findings, diseases being identified and how they can be managed to a wider audience of growers and agronomists<br>• Delivery of factsheets and the bacterial and viral guides (National VG16086 project contribution) allows for a wide audience and delivery of important project findings | • Continued surveillance of properties and working with growers on disease identification both on farm and in workshops would expand our knowledge of the pathogens present on vegetable farms and would help drive better on farm management of diseases through the sharing of knowledge |
| 1b. What new technologies/diagnostic assays has the project developed which are readily available and provide fast answers to industry? | • The project has worked up the isolation and identification of key bacterial pathogens through both MALDI-TOF analysis and PCR. The MALDI-TOF provides results with a reduced cost for growers and the PCR's provide fast turnaround results when needed<br>• In addition, we have also extensively used genome sequencing for the identification of pathogens which allowed for the optimisation of the MALDI-TOF and development of PCR assays | • The methods developed during this project would be valuable to expand to additional pathogens on the priority list as only limited target pathogens were included |
| 1c. What are the key bacterial and viral issues for the brassica and cucurbit growing regions in NSW? | • The key bacterial pathogens for brassicas in NSW were:<br>- *Xanthomonas campestris* pv *campestris*, responsible for black rot in brassicas<br>- Numerous *Pseudomonas* spp. in brassicas and other veggies<br>- *Pectobacterium* spp. causing soft rot<br>- Key viral pathogens included *Potyvirus* and cucumber mosaic virus, CGMMV is an increasing threat and now established in NSW | • Continued surveillance of properties will ensure we remain on top of the pathogens that are present, it also allows for early detection of potential exotic pathogens |
| 1d. How well has the project addressed the needs of NSW | • This project has help inform NSW growers of the bacterial and viral | • This project addressed what bacterial and viral pathogens are |

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| growers and completed the National AWM projects? | disease present and how spot the symptoms and management options | present, however there are limited options on treatment options and management options<br>• Given the level of interaction and interest with this project and growers it would be opportunistic to work further with growers to highlight exotic pathogens and what to look out for and continue to build industry relationships and extension |
| **Relevance** | | |
| **2. How relevant was the project to the needs of intended beneficiaries?** | | |
| 2a. How has the project met the needs of the industry levy payers? | • Based on our interactions with growers both at their farms and at workshops this project has been highly relevant. The growers and agronomists we have been working with are highly receptive to information and they are happy to contact us with disease concerns | • It would be fortuitous to continue building on these relationships for both industry and biosecurity preparedness |
| **Process appropriateness** | | |
| **3. How well have intended beneficiaries been engaged in the project?** | | |
| 3a. To what extent were the target engagement levels of industry levy payers achieved? How was this achieved? | • The majority of growers were extremely responsive to this project, the site visits and the collection of samples and receival of the information we provided them with. This was also the case for participation in workshops | • It would be highly beneficial to continue building on these relationships for both industry and biosecurity preparedness<br>• Face to face engagement is highly sought after by industry |
| 3b. Have regular project updates been provided through available industry communication pathways? How was this provided? | • Project updates have been provided in several forums including progress reports, factsheets, industry newsletters and workshop events | • Presentation of data in the form of scientific manuscripts will be ongoing for the next 12 months, in addition we would like to provide an end of project outcome update to AusVeg on the key findings of the project |
| **4. To what extend were engagement processes appropriate to the target audience/s of the project?** | | |
| 4a. Did the project capture the learning styles of the industry levy payers that were engaged with the project? | • The project provided interactive workshops and direct contact with growers, this was all effective and well received | • Face to face engagement is highly sought after by industry |
| 4b. What extension events/documents were provided to industry levy payers and how accessible were they? | • Workshops were provided to growers in different vegetable growing regions<br>• Factsheets have been provided and the NSW team contributed to the National VG16086 project 'Guide to Understanding and Managing Bacterial Diseases and Viral Diseases' publications | |

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| 4c. Were the target levels considered appropriate by the vegetable industry? | • From direct feedback from growers they were happy with the delivery methods | |
| **Efficiency** | | |
| **5. What efforts did the project make to improve efficiency?** | | |
| 5a. Based on the project research objectives, how were these achieved or improved on? | • The project team reviewed the M&E project management document, project milestones and objectives regularly to ensure we were on track and on target<br>• The project team kept on top of scientific literature to ensure we maintained efficiencies and updated any protocols necessary | |
| 5b. How was the governance in the project meet and what was done to improve it? | • During the life of the project we had annual National project team meetings and PRG meetings, which our Hort R&D manager attended and 6 monthly project team meetings and the NSW team had fortnight-monthly meetings | |

## Recommendations

The vegetable industry would benefit from a national biosecurity and communication strategy to ensure cohesive and consistent approaches to industry engagement, surveillance and mitigation strategies. It would also bolster preparedness for key exotic biosecurity threats by facilitating national strategies for their detection and response aligned to the existing Vegetable Industry Biosecurity Plan.

Communication to and engagement with the vegetable industry must take into account the diverse cultural background of producers and consider production of material in different languages as the regional demographic demands. Care should also be taken with the type of extension material as many producers involved in this project had limited access to or poor experience in the use of technology and greatly favored the use of hard copy documents they could take home rather than just relying on digital material alone.

Professional development of key industry leaders, agronomists and seed representatives in the recognition of key exotic threats will rapidly improve detection timeframes in the field and ensure they understand the appropriate reporting mechanisms to ensure the diagnostic process is triggered. They can also act as valuable advocates for on farm biosecurity, improved pest and disease management outcomes and reduction in unnecessary chemical usage for pathogens that do not respond to currently registered chemistry.

Regular targeted surveillance campaigns are a critical way of detecting new and emerging disease threats and should be repeated every 5 years for a period of at least 2 years to maintain currency of knowledge. This project identified two new viral diseases and confirmed emerging disease threats for one virus and two bacterial pathogens that would otherwise have gone undetected by sporadic passive surveillance efforts.

Additional work is required to improve the uptake of farm biosecurity plans and help growers to identify the measures appropriate for their business type. This also involves the need for greater understanding of risk pathways and disease transmission mechanisms to ensure they are deploying appropriate safeguards.

Further engagement with industry is recommended to improve understanding of emergency responses and preparedness measures that may assist ahead of the detection of an exotic pathogen. Fear of severe consequences is a key limiting factor in growers not reporting suspect organisms and helping industry to understand the full spectrum of outcomes following an exotic detection may help to decrease that reluctance. It can also prepare growers for what may eventuate so that in the event of an incursion they understand the likely or possible next steps, including but not limited to, further work in the business continuity space.

The bacterial pathogens *Pseudomonas* and *Pectobacterium* were identified during this project as key emerging threats to the vegetable industry. Further work is required to ascertain the true incidence, genetic diversity and management options of these pathogens as they can infect multiple vegetable crop hosts.

This project catalogued the diversity of various *Olpidium* spp. Further investigation is recommended to ascertain sensible control strategies as a way of reducing key viral infections vectored by this fungal group.

Vigilance for WCLaV-1 is recommended for both the vegetable and melon industries to fully understand its distribution and potential impact on cucurbit species in Australia. It's detection in a mixed infection made it difficult to determine the likely impact on crop health but early indications are that it seems to induce less severe symptoms than international reports. Ascertaining whether this is a result of genetic diversity, environmental conditions at the time of detection or varietal tolerance would help to confirm the seriousness of this new pathogen

This project focused only on brassica and cucurbit crops and specific pathogen groups. Inclusion of other commodities and fungal pathogens is highly recommended as many pathogens occur across a broad spectrum of hosts and fungal pathogens significantly impact vegetable production

## Refereed scientific publications

### Journal article

Mulholland S, Wildman O, Kinoti W. M, Constable F, Daly A, Tesoriero L, Maina S, Chapman T, 2022. First report of watermelon crinkle leaf associated virus-1 (WCLaV-1) in watermelon (Citrullus lanatus) in Australia. Journal of Plant Pathology, https://doi.org/10.1007/s42161-022-01250-8.

Mulholland S, 2022. Cucurbit production systems in Australia and biosecurity risks associated with viral pathogens. Australasian Plant Pathology, https://doi.org/10.1007/s13313-022-00892-7.

Mulholland S, Wildman O, Daly A, Tesoriero L, Chapman T (submitted). Distribution and diversity of viruses affecting cucurbit production in New South Wales, Australia. Australasian Plant Pathology.

## References

Mulholland, S, 2022. Recommendations for the provision of a national biosecurity strategy for the Australian vegetable industry. Peri Urban Vegetable Biosecurity Pilot

## Intellectual property

No project IP or commercialisation to report

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