Vinehealth AUSTRALIA

Australian Government

Australian Grape and Wine Authority

Strengthening the wine industry's biosecurity capacity and capability: analysis of current research, commercial management and government policy in California of three priority biosecurity pests to Australia



FINAL REPORT to
AUSTRALIAN GRAPE AND WINE AUTHORITY

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CONTENTS

ABSTRACT 3
EXECUTIVE SUMMARY 4
BACKGROUND 5
VISIT NOTES 6
1. International Phylloxera and Nematode Symposium 6
1.1 Overall impressions 6
1.2 Phylloxera in Europe (Astrid Forneck) 6
1.3 Phylloxera in US (Larry Bettiga) 7
1.4 Phylloxera in China (Lu Jiang) 7
1.5 Phylloxera in Argentina (Celeste Arancibia) 8
1.6 Phylloxera in US (Summaira Riaz) 8
1.7 Phylloxera in Europe (Markus Etile) 8
1.8 Phylloxera in Minnesota (Matt Clarke) 9
1.9 Phylloxera in Australia (Suzanne McLoughlin) 9
1.10 Nematodes in Australia (Harley Smith - CSIRO) 9
1.11 Phylloxera in Germany (Joachim Eder) 10
1.12 Phylloxera in Germany (Joachim Schmid) 10
1.13 USDA Geneva breeding program (Peter Cousins) 11
1.14 Rootstock effects on grapevines in Mount Vernon, Missouri (Zoe Migicovsky) 11
1.15 Dagger nematode X. index (Jordan Weibel) 11
1.16 Dagger nematode X. index (Cecilia Aguero) 12
1.17 Root lesion nematode in Brazil (Paulo Ricardo) 12
1.18 Genetic diversity and relationship of V. berlandieri and associated species (Jake Uretsky) 12
1.19 Field visit to Napa Valley 12
2. UC State-wide IPM Program 13
3. Treasury Wine Estates 15
4. Agri-Analysis virus testing laboratory 17
5. Treasury Wine Estates 17
6. University of California Extension - Napa 18
7. California Department of Food and Agriculture Pierce's Disease Control Program 19
8. Foundation Plant Services 20
9. Consolidated Central Valley Table Grape P&D Control District and treatment coordinator for GWSS area-wide control program 21
APPENDICES 24
APPENDIX 1. Sampling strategies for sensitive, accurate and cost effective detections of phylloxera for quantifying area freedom status AND Short-medium term phylloxera research requirements for Australia presentation 25
APPENDIX 2. Seven minute snapshop of phylloxera history in Australia presentation 28
APPENDIX 3 'State of play of phylloxera in Australia' report for inclusion in proceedings 32
APPENDIX 4 – Vinehealth Australia E-News article 35
APPENDIX 5 – Case Study: European Grapevine Moth Eradication 38

ABSTRACT

Suzanne McLoughlin, Technical Manager, Vinehealth Australia, attended the 7th International Phylloxera and Nematode Symposium, held at UC Davis, California, August 21-23, 2017. This symposium, held approximately every three years, brings together scientists including PhD students, from research institutes internationally. It is the main forum for scientists to present, listen to and discuss the latest research and information on aspects of phylloxera and nematode breeding. The symposium was attended by approximately 20 scientists from countries including US, Austria, Germany, Italy, China, Argentina, Canada and Australia and included a field trip to the Napa Valley. Post the symposium, Suzanne met with a range of grape and wine research organisations, government institutions and commercial businesses to discuss biosecurity activities, predominantly focused on management and communication of pests and diseases.

EXECUTIVE SUMMARY

The 7th International Phylloxera and Nematode Symposium provided Suzanne McLoughlin an opportunity to assess the current international research being undertaken for phylloxera against identified needs for the Australian Wine Industry. Symposium attendance confirmed that international phylloxera research is largely focussed on breeding and the assessment of rootstocks for tolerance/resistance to phylloxera. No international work was presented on general farm-gate hygiene, disinfestation techniques or surveillance. Consequently, the importance of identifying, supporting and adequately funding home-grown research continues to be imperative. Researchers identified the use of SSR markers as the cheapest method for verifying phylloxera presence. Australia's capability to undertake this diagnostic technique needs to be evaluated. Breakdown in the phylloxera resistance of 101-14 rootstock was recently identified by researchers, particularly associated with growth on weak sites with dry soils. This perception was not verified by local commercial growers in California.

Visits to commercial vineyards in the Napa Valley were important to verify high priority pest and disease issues and practices being undertaken to address these issues. Highly useful to building Australia's capability and capacity to prepare for exotic incursions, was hearing first-hand about the successful eradication strategy undertaken over six years for the European Grapevine Moth in California.

BACKGROUND

Biosecurity is a system to reduce the risk of entry, establishment and spread of pests, diseases and weeds that threaten the livelihood of vineyard owners and the sustainability of wine regions and the entire industry. Biosecurity is a joint responsibility between industry, government (regulators), researchers, contractors, agricultural suppliers, nurseries and the general public.

Vinehealth Australia (Vinehealth) is an industry-funded statutory agency based in South Australia, with a sole focus on protecting grape and wine assets from biosecurity risk and impact. A key priority for Vinehealth is to empower growers with information to enable them to make biosecurity a top consideration in their vineyards. As such, a core activity of Vinehealth is translating results of scientific research into practical information that growers, wineries, industry suppliers and regulators can rapidly consume and integrate into policy and practices.

The Australian wine industry has a lot at stake in the event of a biosecurity incursion – the health of vineyards, the security of wine regions and the sustainability of the entire wine industry. Our wine industry contributes $40.2 billion in gross output to the Australian economy each year. We sell 1.2 billion litres of wine internationally each year, worth more than $5 billion dollars. To supply these markets, 6,000 grapegrowers across Australia manage 132,000 hectares of vineyards, producing 1.8 million tonnes of grapes each vintage. With the wine industry employing 173,000 people, mostly in regional areas, the industry's productivity has significant flow on benefits to regional communities, agricultural suppliers and the tourism sector.

It is therefore vital for Vinehealth's effectiveness in contributing towards a prosperous Australian grape and wine community, that we learn from the successes and failures of other countries in managing exotic pest threats, so that we place significant focus on prevention, but should an incursion occur, we are well placed with knowledge and systems to enact eradication and containment plans.

Of the pests and diseases we currently have in Australia, one of our greatest biosecurity threats is the tiny insect, grape phylloxera. This devastating pest of grapevines worldwide destroys vines by feeding on their roots. *Xylella fastidiosa* causing Pierce's Disease in vines is Australia's number one plant pest exotic priority, and much is unknown about grapevine red blotch virus, recently identified and described in the Napa, California. Due to the latter two being exotic to Australia, our best chance to learn about how to combat them, is to learn *in situ*. These three pests are included in the Viticulture Industry Biosecurity Plan as significant threats to our industry.

VISIT NOTES

1. International Phylloxera and Nematode Symposium

1.1 Overall impressions

- Parts of Australia and perhaps Chile are the only countries in which Phylloxera has not been detected and therefore the use of phylloxera resistant rootstocks is a way of life.
- We are fortunate in Australia to not have large nematode issues, especially dagger nematode transmitting Fanleaf virus.
- Very limited number of researchers working on phylloxera (and nematodes) around the world). All groups working on rootstock breeding or on the evaluation of rootstock resistance for commercial registration.
- No research being undertaken on practical considerations such as disinfestation as is being performed in Australia. Evident that this research will need to be home-grown and adequately funded to ensure our commercial vineyards are adequately protected from phylloxera incursions.
- Lot of talk at the symposium about breakdown of 101-14 phylloxera resistance, particularly on weak sites with dry soils. However, this was not reflected by discussions with commercial growers.
- No mention of advancements in aerial imagery as a tool for early detection of phylloxera
- No agreed or standard way of analysing phylloxera resistance internationally yet – this makes comparisons between results difficult.
- Measurement of vine phenolic levels as a basis for tolerance/resistance to phylloxera is international research to keep abreast of.
- Salicylic acid and Jasmonic acid regulation as thought to be part of phylloxera population maintenance.
- With some phylloxera infestations, some growers are tending towards managing vines for longevity by looking to improve vine health with water and fertiliser applications, at the expense of wine quality – not really a long term viable option in all cases.
- After grubbing a block planted on own roots that has succumbed to phylloxera, there is no length of time adequate to fallow the soil before replanting to ensure all the phylloxera has died.
- Saw complete lack of biosecurity signage at vineyard entrances and only some vineyards were fenced. Visitors coming to cellar doors sometimes could be right up to the strainer posts and I noted several visitors walking into vine rows to take photographs.

Actions for Vinehealth:

- Develop a process for keeping abreast of published phylloxera research articles

1.2 Phylloxera in Europe (Astrid Forneck)

- Evidence of new phylloxera biotypes in south eastern Europe, Germany and Switzerland but need to carry out large scale population studies to validate.
- Getting more leaf-feeding aggressive biotypes over time.
- Emergence traps used for collecting phylloxera but are shallower and of the same diameter as those used in Australia. In their experience, leaving traps out for longer than a week results in the phylloxera dying and cannot be used in genomics work.
- Using hyperspectral imagery to correlate with polyphenol levels which are exuded by plants under stress situations.

1.3 Phylloxera in US (Larry Bettiga)

- Gave a history of phylloxera in California.
  - 1858 first evidence for phylloxera inferred from symptoms.
  - 1873 first identification of phylloxera on roots in Sonoma.
  - 1876 first introduction of resistant vines into California.
  - 1920s saw phylloxera in a lot of counties and it moved around quite rapidly (also vineyard decline due to Pierce's Disease at the same time).
  - By 1900-1960 there was a broad set of rootstock trials in place implemented by USDA and UC. By 1980s-1990s there was failure of AXR rootstock on vineyards in the North Coast of California and decline on own roots in Central Coast due to phylloxera. Nurseries were not able to cope with demands for new rootstock material. Phylloxera populations now existed in most grape growing regions but the impact varied by region. Biotype A, B or both together existed.
  - In 1980s and 1990s monitoring for phylloxera was undertaken. Early on used aerial imagery to look for weak spots. Some use of NDVI imagery evaluations year on year to monitor the damage.
  - Most Central Coast areas are on rootstock now. Adapting cultural practices such as reducing tillage to minimise spread across vineyard blocks, avoiding overcropping and irrigating and fertilising to reduce stress. *still saw a lot of tilled rows. Have some chemicals registered for use against phylloxera in California but success is limited with chemical control as they're unable to deliver a lethal dose of active ingredient through the soil profile.
  - Replanting with phylloxera resistant/tolerant rootstocks is main management tool for dealing with phylloxera infested soils. Trying options of replanting to minimise crop loss – for example, planting along midrows and planting a new vine in every second vine space. *Not sure the value of these techniques as old vines are reservoirs for a variety of pest issues and harvesting and irrigating appropriately would be difficult. Have had good results with 101-14 on phylloxera infested sites, however poor performance on weak sites with dry soils.

1.4 Phylloxera in China (Lu Jiang)

- 80% grapes in China are table grapes and most vineyards are very small, family-owned plots – 0.5-1 acre. Believe phylloxera is manageable with not much spread from property to property – probably because farms are fairly self-contained units with limited movement of people of equipment between properties.
- Majority of vines on own roots and China has both foliar and root types of phylloxera.
- 1935 phylloxera first found in Chiangyu vineyard in Shangdong province – this is now one of the largest commercial wineries in China and has operations all around the world. Source of this infestation was from cuttings brought in from Bordeaux and perhaps also from the US.
- 1950s found phylloxera in several other provinces. Between 1970 – 2004 no further reports and perhaps thought to be eliminated but in 2006 found in new province - Shaanxi showing a lot of root nodules. Another detection in same province in 2011.
- See 2 peaks in populations in July and October.
- Control measures tried by growers include pulling out infected vines, flood irrigation and midrow biocontrol plantings of spring onion, castor oil, garlic and tobacco. Results not scientifically verified.
- Rootstock breeding programs involve breeding for phylloxera-resistance and cold hardiness.
- Evaluation of Chinese wild grapes for phylloxera resistance involves the use of a grading looking at % of inoculated roots showing infection. Use SO4 and 5BB Kober as negative controls.

Rating	% of inoculated roots showing infection
0	0%
1	<10%
2	10-30%
3	>30%

1.5 Phylloxera in Argentina (Celeste Arancibia)

- Presumed origin of phylloxera was in 1878 from vines imported from France
    - Once phylloxera was noticed, vineyards were destroyed and *Vitis vinifera* plantings were stopped for 3 years – not successful though in stopping the spread.
    - 1895 – 1936 phylloxera spread and was found in different regions.
    - Today <10% of vines are on rootstock. With climate change and move from flood to drip irrigation they believe phylloxera does pose a potential threat to their industry.
    - Current research has started on investigating phylloxera genetics to use in breeding programs down the track. Looking at grapevine variety, soil type, climate (hot vs cold regions), trellis systems and more. About to start research looking at analysing phenolic compounds in roots to see whether these vary in individual grape varietal susceptibility to phylloxera.

1.6 Phylloxera in US (Summaira Riaz)

- Foliar forms of phylloxera not a huge issue commercially but problem in rootstock breeding because can decrease vigour which can decrease grafting ability of the rootstock.
    - Foliar phylloxera within CA exclusively asexual and has wide host range. Almost no genetic diversity.
- Root phylloxera has 3 distinct groups of genetics ("Napa 1", "Napa 2", "Davis") which are very genetically distinct from foliar populations. Napa 1 populations prefer Freedom and 101-14 [riparia x rupestris])., Napa 2 prefer 1103 P [berlandieri x rupestris]. The asexual Davis populations prefer 110 Richter (berlandieri x rupestris). Rootstock parentage plays a huge role in providing an understanding of phylloxera host-rootstock interaction.

1.7 Phylloxera in Europe (Markus Etile)

- PhD thesis on salicylic acid/jasmonic acid pathways. Salicylic acid is plant induced by fungal feeding. Jasmonic acid is induced by disruptive insect feeding.
- Hypothesis of work – (i) wounding by phylloxera stylets activates JA signalling pathway and (ii) this pathway is suppressed with the release of SA via antagonistic crosstalk.
- On Teleki 5C. Wounding by phylloxera upregulated JA signals which also was seen with phylloxera probing without wounding.
    - After 24 hours, all JA genes in use are now down regulated and also still suppressed after 48 hours. By downregulating the JA genes, the phylloxera avoids being killed. At the same time the SA genes are upregulated at the feeding site and in the vicinity of the feeding site. Phylloxera feeding caused elevated SA levels (and) nodosities resulting in systolic release of monomeric NPRI molecules.
- Investigating the source of the salicylic acid
    - SA levels measured in all stages of crawlers and adults. High amounts already found at L1 phylloxera stage (smallest crawler) as well as high levels of SA precursor benzoic acid. Therefore, assume phylloxera inject SA into the plant root to induce galls. Injection of the SA

by the phylloxera causes volatiles (host defensive antimicrobial compounds) to be released to the root tips causing the nodosities.

Actions for Vinehealth:
- PhD paper submitted and awaiting publication. Review once published.

1.8 Phylloxera in Minnesota (Matt Clarke)

- Work focussed around understanding genetic resistance to foliar phylloxera in cold hardy hybrid grape populations.
- Grape breeding in Minnesota started in 1887 and into early 1900s.
  - Use leaf gall field rating system of 1-7 and root gall rating system of 1-7.
  - Aim to breed phylloxera and powdery mildew resistance.
  - Looking at yield response to foliar infestation of phylloxera.
  - Also, looking at spraying Movento and comparing with unsprayed controls. Collecting bunch weight, juice chemistry, overall yield etc.

1.9 Phylloxera in Australia (Suzanne McLoughlin)

- As part of the Symposium, Suzanne delivered three pieces of work:
  a) Sampling strategies for sensitive, accurate and cost effective detections of phylloxera for quantifying area freedom status AND Short-medium term phylloxera research requirements for Australia presentation (Appendix 1)
  b) Seven minute snapshop of phylloxera history in Australia presentation (Appendix 2)
  c) Submitted a report 'State of play of phylloxera in Australia' for inclusion in proceedings (Appendix 3)
- Feedback that using SSR markers would be a far cheaper alternative (~$5/sample compared to ~$50/sample) to qPCR for determining the presence/absence of phylloxera.
- Positive comments received on our strong quarantine measures to keep phylloxera out but it isn't the end of the world.

Actions for Vinehealth:
- Ascertain which labs in Australia have the SSR marker technology for phylloxera detection

1.10 Nematodes in Australia (Harley Smith - CSIRO)

- Spoke on developing molecular markers for phylloxera and root knot nematode resistance for breeding new rootstocks for Australian conditions.
- In Australia, we desire both resistance to phylloxera and root knot nematodes primarily, then want other things like salt exclusion, drought tolerance, reduce K uptake, water use efficiency, good grafting compatibility etc.
- Root knot nematodes and citrus nematodes often found in high numbers when rootstocks like 1103P break down
  - Of the root-knot nematodes – *Meloidogyne javanica* and *M. arenaria* are the most common
  - 1103P makes up 40-60% cutting sales in Aus (based on relatively old data); good drought tolerance particularly through 2007-2009 drought and good grafting ability so nurseries like it. Supposedly moderate to high resistance to root knot nematodes but have seen breakdown.
  - Looking for new sources of resistance to pyramid into breeding because old sources in Freedom and Harmony rootstocks are breaking down.

1.11 Phylloxera in Germany (Joachim Eder)

- Spoke on testing of *Vitis* scion and rootstock varieties for resistance to phylloxera.
- Use rating classes of susceptibility on roots. If rating below a 5, then allowed to plant these commercially, if not then not approved for commercial use:

Rating	Description
1	No root tuberosities
3 = little	Tuberosities separated from the vascular bundle
5 = moderate	Tuberosities weakly marked off. Necrosis as far as vascular bundle.
7 = degradation	Tuberosities imperfectly marked off. Necrosis partly expanded to vascular bundle.
9 = high degradation	Tuberosities without boundary. Necrosis up to vascular bundle.

- For leaf phylloxera also have a rating system but just used as advice, not formal. No official leaf gall rating system for breeders.
- Carry out the testing in mid-summer to early autumn looking for tuberosities by infecting roots with phylloxera eggs from wildtype strains proliferated on 3309C. Use SO4 and 5BB Kober as controls.
- Carry out testing on 4 replicates of 12 plants for 3 years' minimum, often as long as 5 years and average the ratings to ascertain whether a rootstock will gain registration.
- For 101-14 over 5 years found >5 rating so not registered for use in Germany. In preliminary results, Schwarzmann also failed to date. 3309C but more tolerant than Schwarzmann or 101-14.
- Between 2014-2016 done scion testing and seen different results by year as for rootstocks.
    - Seeing more galling in warmer seasons.
    - RIE and CHR scored between 3.5 – 5. Some other local varieties also more susceptible to leaf phylloxera, showed scores of ~7. The scion results though are out of the Phylloxera Act and up to breeders if they sell them or not.
- This testing regime is time consuming but yields important results to maintain a profitable viticulture industry for grapegrowers.
- No chemical treatments registered in Germany against root phylloxera, only Confidor for leaf phylloxera.
- Think temperature is the driver for variation in tuberosity ratings over years. Especially warmer temperatures in spring time leading to earlier start in phylloxera growth.
- Also, seeing phylloxera on wild vines and abandoned vineyards and think this is transferring phylloxera to commercial vineyards. Think need to get rid of these sources of inoculum.
- Government does not compensate growers for pulling out vines (nor in US).

1.12 Phylloxera in Germany (Joachim Schmid)

- Spoke on experiences with new phylloxera rootstocks at Geisenheim.
- In Germany, over 139 grape varieties over 100,000 Ha of vines. All of Germany now covered in phylloxera with no free areas. In 1960s – 1980s when grape prices were low, many vineyards were abandoned. Lots of wild vines growing in countryside, some showing leaf galling. In wild, even have crosses between rootstocks and *Vitis Vinifera* making phylloxera transfer even easier. Abandoned vineyards have led to a lot of phylloxera spread. Instances of wild rootstocks with galls spreading to commercial vineyards perhaps moved by wind? Then causing galls on the commercial vineyards.

- New ideas were to rip out vine rows and plant windbreaks, but after a few years old vine roots grew through these windrows showing leaf galling due to phylloxera.
- Finding different biotypes on *Vinifera* roots from galls and tuberosities.
- Problems with limited genetic base of varieties. 10 varieties are grown on 90% of vineyards worldwide.
- Börner, Cina and Rici are only truly resistant rootstocks (all V. riparia x V. cinerea) but phylloxera resistant rootstocks are not suitable for all planting sites. High pH and high lime soils result in bleached vines due to iron chlorosis, low yields with rootstock use in these conditions only lasting about 15 years.
    - Need more lime tolerance built into breeding programs (and drought tolerance) which working on now and have found success with *V. berlandieri*.
    - Newly bred rootstock varieties doing well in yield and quality especially when high pH and lime content: Gm 9228-45 (Börner x 125AA cross) and Gm 9230-3 (Börner x berlandieri cross) and being introduced commercially.

Actions for Vinehealth:
- Consider long term applicability of Börner rootstock in Coonawarra rootstock trial given high lime content

1.13 USDA Geneva breeding program (Peter Cousins)

- O39-16 rootstock (having dagger nematode resistance) can protect against fanleaf virus and crop loss associated with it. However, the high vigour conferred by this rootstock is not always desirable for growers.

1.14 Rootstock effects on grapevines in Mount Vernon, Missouri (Zoe Migicovsky)

- Interesting use of visual data display - leaf density measures and looking at effects of irrigation on lobing of leaves (more irrigated less is leaf lobing) shown like heat maps
- Iomics leaf elemental study, looking at variability of ions based on rootstocks
    - Leaf position on shoot and year were major sources of variation
    - Rootstock used had large influence in accumulation of the various elements in the leaves
        -

Actions for Vinehealth:
- Is anyone local doing research into iomics as a way of recommending certain rootstocks based on their ability to confer various elements to the scion

1.15 Dagger nematode X. index (Jordan Weibel)

- Important pathogen complex in grapevines causing yield reductions of up to 80%
    - Causes big problem with fruitset
    - Finding it on more rootstocks and own roots than originally thought
- This nematode vectors the fanleaf virus by feeding and by the probing action (doesn't have to actually feed to transmit the virus, the probing action is enough) as the virus is carried in the stylet.
- Sources of resistance – some occur naturally in the wild but not all accessions of these species are resistant. *V. rotundifolia* and *V. arizonica* have been the most studied to date.
- Major resistance loci found on chromosome 19 and more have been found on chromosome 13.

1.16 Dagger nematode X. index (Cecilia Aguero)

- Spoke on characterisation of *Xiphinema index* resistance genes in *V. arizonica*.
- Dagger nematodes still damage vine root tips causing characteristic galls even if not carrying the virus

1.17 Root lesion nematode in Brazil (Paulo Ricardo)

- Nematodes common in Brazilian soils and a major problem. *P. Brachyurus* classified as one of the worst pests in Brazilian agricultural production
- Utilising wild populations of grapevines to help increase genetic diversity in breeding programs

1.18 Genetic diversity and relationship of V. berlandieri and associated species (Jake Uretsky)

- Looking to expand the UC Davis germplasm and characterising V. berlandieri (synonym V. cinereal var helleri)
- Studied the genetic diversity of V. berlandieri on the Edwards Plateau in Texas where it is endemic and to the area to the east of it looking at wild type rootstock populations.
    - Land use can limit wild populations by controlling their ability to cross in the future. Also, presume impact of climate change will affect ability to cross as might variably affect flowering time of populations.

1.19 Field visit to Napa Valley

- Visited numerous greenhouse trials for rootstock breeding at UC Davis – nematodes, phylloxera and Pierce's Disease focus (Figure 1).
- Visited vineyard blocks used for rootstock breeding. Basically, grow single vines in the field and carry out all testing in pots in glasshouse and lab.
    - Little call for public table grape breeding any longer due to private breeding companies of which 4-5 large programs dominate. In CA alone, 85 different table grape varieties across red, white and pink grapes.
- Napa predominantly CAS (85%; some CHR, some PIN, some MER) – fetching around $5000/T; Solano area around $1800/T and Yolo around $1200/T. Location is everything.
- Oakville Research Station
    - Predominant issues (current and past) at Oakville research station in Tokulon area in Napa include European Grapevine Moth, LBAM, red blotch virus, LR3, vine mealybug. Focus on broadleaf weed control.
    - Red blotch virus (Figure 2) – vectored by the tri-cornered alfalfa leafhopper which comes off riparian habitat and spreads fast from vine to vine. Not well reported large



Figure 1. Visit to UC Davis glasshouse trials for rootstock breeding.



Figure 2. Red-blotch affected vine. Oakville Research Station.

scale anywhere else, only small reports in southern Europe.
    - DNA based virus (not common in vines) which doesn't kill vines but affects their primary metabolism (limiting their ability to use water and nutrients) which impacts secondary metabolism in terms of colour production and ripening – get much
      lower levels of anthocyanins so fruit is insipid and very acidic. Effects are more obvious in vigorous rootstocks (e.g. 110R compared to SO4). Don't know effects on whites.
    - must remove vineyards and replant on clean stock; really need regional plan "volunteered cooperation" where everyone in an area pulls out and replants together, else will have spread from one block to another through vine to vine spread, habit to vine spread and spread through cultivation and wind.
    - Block visited had 10% infection in 2013 and currently in 2017 at 85% infection. Constantly grubbing out infected vines.
- Opus One (Figure 3)
    - Extensive 25-year vineyard redevelopment plan based on rating system by vine for presence of various diseases. Leave blocks fallow for 2 years before replanting. Carry out complete soil surveys with backhoe pits prior to planting and deciding on rootstock needs.
    - Use lot of riparia rootstock for devigouration but also slow to establish
    - Use CAS clones 4, 169 and Entav 'b' clones because not as high in alcohol – 338, 685 and Entav C clone – 30. Originally planted whole blocks of a clone. Now using mixed clones across a block for complexity.
    - Have moved away from 101-14 rootstock to 1616C. Have a process of requesting virus testing of all mother vines of their material to ensure disease-free status.
    - Use 2 dripper lines to help irrigate replants to ensure survival – especially in case of red blotch
    - For Eutypa management train water shoots up and wait until established before cutting trunk off
    - Program looking to isolate wild yeasts from different owned vineyards and estate grown oak trees to spike into ferments to further enhance the 'sense of place'



Figure 3. Opus One Winery.

- Use optical berry sorter on every parcel in the winery after hand harvesting between 3am-9am to keep fruit cold. Also, sort fruit in the vineyard to leave second crop (and rot).
- Employ cross-team winemaking competitions to keep staff connected to the brand and these wines go all way to being part of allocations
- Get about 150,000 visitors per year to Opus one

2. UC State-wide IPM Program

- Met with Jim Farrah (Director), and colleagues Tunyalee Martin (Assoc Director of Communications); Petr Kosina (Content Development Supervisor) and by video conference - Lucia G. Varela (North Coast IPM Advisor - UC) to talk about communicating to stakeholders on

P&D, setting up on-line education courses and eradication process for European Grapevine Moth (EGVM).

- The agriculture and natural resources extension arm of UC Davis look after communications for four main areas and gets about 35,000 hits per day on their website: (i) home garden, turf and landscape pests, (ii) exotic and invasive pests, (iii) agricultural pests, and (iv) natural environment pests. They have had an online presence since 1995 at the start of the internet and are now working to refresh their look.
    - They host guidelines for over 50 crops and have groups of extension staff who feed in information for these guidelines and responsibility for renewing them and keeping them up to date.
        - The fact that the guidelines are also peer-reviewed publications also entices extension officers to participate
    - Their material is used in university classes and by field-based pest control advisors. They aren't sure about use by growers per se (they assume growers rely on advisors for information).
        - These days their audiences mostly use online information rather than printing out pdfs; although they still provide that option
        - Have a range of material also as You-Tube videos for people to watch instead of reading – mostly for urban audiences and translated into Spanish
    - Offer a range of on-line courses
        - Pest control advisors are required to relicense every year or two and part of this is needing to complete a certain number of hours of online courses, particularly focussing on laws and regulations topics which are mandatory.
        - 80-90% of people completing the online courses are apparently these pest control advisors but they are also used as part of student courses.
        - When online courses were first delivered, they were just online PowerPoints and basic; then have moved to PowerPoints with online narration; now moving into use of videos to demonstrate various points and cartoons to make the information more fun and also having quizzes throughout the courses rather than just one big quiz at the end. Generally, courses are 1-2 hours in length broken into modules.
        - Challenge was to find a suitable host platform on which to develop the online courses. Started with Moodle but now are part of 'eXtension' which is a platform provided specially for extension providers.
        - UC IPM has a big job in the record keeping side of offering these courses because being offered as part of registration for pest advisers the students need proof of enrolment and marks as they must obtain at least a 70% pass mark.
            - Lot of testing required to ensure courses run on all types of devices (phones, tablets, computers with range of browsers). Have a help desk to assist with this.
            - Also, face poor connectivity in some parts of California which also must be considered when designing courses to ensure the file sizes are relatively small to minimise buffering and can't have courses that are full video – so use low resolution, video snippets. Also, must offer for hearing disabilities which is part of legal compliance. Some courses are free and some are fee paying.
            - Have voluntary user experience section at end with comments sections to help them improve technological or content aspects and star rating capability for the overall courses.
            - Newest complications with these courses is verifying the course takers to ensure people aren't getting others to take the courses for them

    - Each 1 hour online course takes about 400 hours behind the scene of building and testing. Have to take scientific information and generalise the language but still maintain scientific correctness.
  - Have decided to shy away from producing apps because of difficulty to develop, too many phone types and concentrating on making their current offering in the mobile form (framing to mobiles).
  - Also, have a citizen science app 'Coyotecacher'
  - Don't have pages or modules specifically on farm-gate hygiene
- Process for the six-year eradication of EGVM discussed in detail.
  - Refer Appendix 5 for EGVM article, a shortened version of which is to be published in the *Australian and New Zealand Grapegrower and Winemaker* magazine.

Actions for Vinehealth:
- Evaluate the UC IPM site to help us tailor our offerings to growers

3. Treasury Wine Estates

- Met with Michael Sipiora, regional Viticulturist
- Field visits saw many vines infected with Leaf roll virus, Pierce's Disease (Figures 4, 5) and Red-blotch virus.
- Growers moving from wooden posts to steel due to recycling issues with treated pine posts
- Have seen Grapevine Pinot Gris Virus (GPGV) as a singular infection on two-year-old vines, but at this stage don't think it's a virus to be concerned about as a lot of asymptomatic vines as well.
- Apparently Italian isolates and Californian isolates exist and the Californian isolate might be less virulent as they have found little effect on maturity and have not seen anything like 80% yield losses reported in Italy.
- The virus testing labs have seen bud mites in association with GPGV presence.



Figure 4. Pierce's Disease foliar and shoot symptoms.



Figure 5. Pierce's Disease affected vines adjacent to Napa River.



Figure 6. Virus-like symptoms in young vines.

- Use 3 points of internal quality control in attempt to improve chances of virus-free status of propagation material from nurseries:
  1. If collecting own scion material, cuttings ensure all material has been virus tested and found clean before it goes to the nursery for propagation
  2. Always inspect at nursery before accept propagation material (able to inspect within 48 hours of delivery as per contract) – can accept or reject material then). Use Australian-produced "Fit Vine" app.
  3. Leafroll 3 virus (LR3) and red blotch virus tests are undertaken on suspect 1 year old vines showing red foliar virus-like symptoms which if positive are then grubbed (Figure 6). Healthy tissue is also submitted as a control.
     - Not so concerned with whites – harder to detect virus impact visually and on quality.
     - Do now run 2 dripper pipes in new blocks so can irrigate replants separately from older vines as required.
- O39-16 mostly only rootstock option against dagger nematode fanleaf virus transmission. New rootstock breeding options "GRN1-5" from UC Davis becoming more available and being trialled.
- Vine mealybugs mostly in southern Napa but starting to spread. No quarantine setup to combat this spread at present.
  - Mealybugs are harder to address than EGVM for example because they bury under bark.
  - Prior to hot water treatment being instigated by nurseries, mealybugs were introduced through planting material to vineyards in the Napa.
  - Carry out pheromone trapping internally for vine mealybugs to help with spray timing or application of mating disruption (Figure 7). Government also has mealybug pheromone traps laid out.
  - Mating disruptor pheromones now available to apply via a spray tank rather via manual application.
  - Pheromone traps and mating disruptors are treated as pesticides in California and must go through same efficacy trials as other pesticides.



Figure 7. Vine mealybug pheromone trap.

- EGVM eradication effort affected growers by having significant compliance requirements to adhere to. To move each load of grapes had to gain permission from Ag Commissioners in both 'from' and 'to' counties. Also, could not compost stalks and stems on own property unless geared up to properly compost to required temperatures – had to send off to other commercial facilities. Consider mealybug issues might lead to the same composting requirements for industry, but these have not been mandated yet.
- Red blotch virus vector comes from bean/vetch type crops and therefore have had to alter components of midrow covercrops accordingly (Bell Beans were a common component and host the virus itself).
  - For managing red blotch infections, consider potential quality drop + quantity drop + spread from vine to vine. All about what willing to risk – for high quality blocks willing to tolerate less vine infection. Red blotch focus is on quality drop and spread, not the quantity drop as this has been minor in comparison.

        - Red blotch trials on Cabernet Sauvignon evaluated wine quality from small lot winemaking 15kg lot where four proportions (0%, 25%, 50%, 75%) of fruit from red-blotch affected vines was spiked into control fruit. Results showed that when 10-25% virus infected fruit was included, wine quality was negatively affected. There was a large delay in maturity from affected fruit, large decrease in ethanol content and large decrease in colour density and tannin level.
    - These results suggest that split picking should be employed for block infections at least greater than 25%. However, with infected vines being sporadically distributed, grubbing is really the only practical consideration
- Employ the use of drone imagery to assist with management decision. Leaf roll and red blotch fingerprint wavelengths are different which can be mapped, but in practice, drone mapping with VSP canopies from above is not as effective as the lower leaves show the infection.
- Lot of vineyards aged 20-25 years in the Napa being replanted; considered age of life of a vineyard. Vinehealth was not as considered as it is now with planting material.
- Red blotch virus effects vary considerably by variety. Quality of Sauvignon Blanc seems minimally affected whereas Pinot Noir, Merlot and Cabernet Sauvignon appear significantly affected. Chardonnay yield appears to reduce with Red blotch, whereas Cabernet Sauvignon and Merlot yields appear unaffected.
- Investigate purchase of a reference book that's just been published: "Grapevine viruses: Molecular Biology, Diagnostics and Management" Baozhong Meng et al. Published by Springer.

Actions for Vinehealth

- Investigate "Fit Vine" App

4. Agri-Analysis virus testing laboratory

- Met with Alan Wei, Director
- Developed the primer for the Leaf Roll test we now use in Australia
- Noted bud mite in samples that have tested positive to Grapevine Pinot Gris Virus

5. Treasury Wine Estates

- Met with Will Drayton, Director Technical Viticulture and Research Winemaking
- Pierce's Disease vectored in Napa by blue green sharpshooter which comes in from riparian zones along the Napa River and can fly several hundred feet (Figure 5. Two-four years after Pierce's Disease infestation). Starting to see the odd vines become infected further away from the riparian corridors, which seems to have occurred recently after a run of drought years and relatively warm winters.
    - Andy Walker (UC Davis) in process of breeding 97% *vinifera* vines with Pierce's Disease resistance. May consider these rootstocks for small areas adjacent to the Napa River in time.
    - Is still huge quarantine effort in place for the glassy winged sharpshooter to the south of the state, whereby every hostplant must be inspected to move north.
- Part of Oakville to Oak Knoll Restoration Project involving 25-35 growers (some who own multiple stretches along the Napa river). Each grower doing a different amount of work depending on their situation in terms of levee bank restoration, pulling out vines to set vineyards back further

from the riparian strip and removal of blue green sharpshooter host plants such as Himalayan Blackberry in riparian strips

6. University of California Extension - Napa

- Met with Monica Cooper, Viticultural Advisor
- LBAM incursion into California pre-the EGVM detection. Learning experience with a lot of mistakes not replicated for the EGVM strategy.
- EGVM
  - When faced with an incursion first thing to assess is whether it's even possible to eradicate based on money, time and resources available (# hosts very much plays into this)
  - Recommends we do apply for a grant to map urban vines as this will help identify them fast in the case of an incursion. Had to address these people by going door to door, using door hangers and a lot of after-hours visits
  - In the case of following quarantine requirements during an incursion, peer pressure from the grower network was almost more of a stick that fines for growers of non-compliance
  - Impartiality was a really important factor in the success of the eradication strategy – UC extension staff played the impartiality role very well as they were not tied to the regulators directly or the researchers but playing a glue role in between both those parties and growers
  - Having Italians there from the start was also important. They also attended group meetings with community at the beginning.
  - Each year of the eradication effort an open meeting was held where community and growers could ask questions of the technical working group
  - Having a single unified message was vital within both the technical reference group and outward facing to industry and community to ensure no confusion of message
    - Monica also prepared talking notes and a PowerPoint presentation for the Ag commissioner to ensure this consistency of message for the delivery of the science. This PowerPoint was used in all local meetings Ag Commissioner had within the county
    - Also, ran weekly electronic newsletter (real time with photos) and decided to do this early on to ensure all stakeholders were kept informed of the progress of the eradication process
    - The Ag Commissioners office has trained people to deal with communications in terms of talking to the media which mostly the Ag Commissioner did as well as writing media releases – with the aim to stop 'disasterifying' the efforts. For the media Monica did, she only chose to deal with media who allowed her to review scientific factors pre-publishing.
    - With the information that was sent out to stakeholders, individual wineries trained their tasting staff. The technical reference group or others did not specially train tasting staff or put out information for them. This was another public face so should be considered else the messages can get confused and disasterified. Monica said they can't do everything so important to let networks spread the information.
    - Held countless field days in English and Spanish to look for EGVM egg masses which was really important (and all communications also produced in Spanish so field workers included).
    - Grower reporting – growers more likely to report issues in small groups. Certain level of technical information is needed in the public space to self-empower growers but

then growers need to further learn by disseminating information through their networks. Setup grower groups of about 20 growers to discuss issues, enable them to ask questions. Initially Monica found she did all the talking but gradually growers were sharing their experiences with each other in that forum.
    - Another aspect of this incursion was that other people from overseas were interested in what they were doing so despite being flat out they had to entertain overseas personnel as well (sometimes this is part of export/import market protection).
- Very interested in agrochemical resistance work done in Australia and interested in setting up an international group to discuss.
- Vine mealybug first detected in California in 2002; had grape mealybug already. Monica undertook trials with parasitic wasps. Took 5 years of releases to get the issue under control but will probably have to keep releasing these wasps early in the mealybug lifecycle to ensure significant numbers are present when food source is available.
- Use pheromone traps for mealybugs as well. Is one for longtailed mealybugs. Need to use specific pheromone taps for each species of mealybug and place traps at least 30-50m apart with different pheromone buds to attract the different types of mealybugs

Actions for Vinehealth

- Send Monica 'Dog Book' resistance management recommendations
- Send B. Hall contact details and final project report from recent resistance management work
- Have we undertaken mealybug population studies using pheromone traps in Australia?

7. California Department of Food and Agriculture Pierce's Disease Control Program

- Met with Tom Esser, Sean Veling and Stacie Oswalt
- Goal of the program is to find long term sustainable options for Pierce's Disease (PD).
- Program mostly deals with glassy winged sharpshooter (GWSS) - regulating the movement of vectors, containing spread, undertaking state-wide surveillance and detection, undertaking rapid response, outreach programs and research.
- Look after 49 individual counties in California with varying levels of PD. Have successfully eradicated 17 areas since the start of the program.
- Biocontrol - rear parasitic wasps to release in certain areas against GWSS (especially in urban areas, hard to treat nursery areas and in fully or partially infested areas)
    - To date have released more than 2.56 million wasps
- Surveillance and detection
    - GWSS monitoring program undertaken by CDFA involves weekly servicing of yellow panel sticky traps non-specific to GWSS (no pheromone involved). Apart from in vineyards, trapping is also conducted in all nurseries in the quarantined counties and in nurseries in non-infested areas receiving shipments from Southern California.
    - Visual surveys are also conducted looking for egg masses, adults and nymphs.
- Regulating the movement of vectors
    - Nursery stock and bulk citrus shipments are regulated through the Pierce's Disease Control Program
    - Compliance agreements are setup with nurseries pertaining to movement and inspection of material for GWSS.

        - These involve requirements for foliar insecticide applications of every plant moved to be witnessed by county inspectors. Can be up to 3 inspections on each plant once it has reached its destination. These applications now allow plant material with GWSS egg masses to be shipped, with any hatching nymphs being controlled on contact.
    - Nursery sector and citrus sector compliance is monitored at the local level. Fines are issued for non-compliance and in addition, loss of market access is also incurred for non-complying businesses unable to move their stock.
    - Movement of bulk grapes was regulated in the past but this is no longer the case as it was determined not to be an infection pathway
        - If GWSS infected nursery material is found in non-infested areas, it is usually sent back to the issuing nursery. If this cannot be done in a timely manner it is then destroyed.
    - In urban areas, use ground-applied systemic insecticide applications (at most 2 per year in front gardens only) rather than foliar insecticides due to perception.
- Recent innovation within the last year was the development of an IPhone App called "GWSS Finder" which allows real-time entry of GWSS numbers caught on the sticky traps, replacing the use of bar-code scanning. This App now facilitates faster recognition of hot spot areas of infestation and therefore more rapid implementation of control measures. Results can be viewed online. Trap counts are currently undertaken by hand. I suggested they investigate software such as Image J or berry counting software to try to revert this manual counting process into an automated one.
- Outreach
    - Includes mock outbreak simulations in the counties and explanation of the quarantine processes enacted in the event of an outbreak.
- Research
    - Every 2 years they hold a symposium to share knowledge and updates on latest findings on the breadth of the research projects funded
        - Research projects funded are one to three years in length
    - Symposium proceedings can be found online https://www.cdfa.ca.gov/pdcp/Research.html
    - One third of the projects now being funded are non-PD related; including European grapevine moth, red blotch, leaf roll, mealybugs
    - Have a good designation process for deciding whether to fund a P&D issue by including comments from a range of experts to verify requests.
- Have a citizen science App called "Find a pest" where the public can take pictures and submit them along with associated details to determine the issue.

Actions for Vinehealth
• Review CDFA process for funding research

8. Foundation Plant Services

- Met with Maher Al Rwahnih, Laboratory Director and Josh Puckett, Head of Production
- Germplasm comprises 800 cultivars with hundreds of clones and two mother vines planted per clone. With these two vines, they predominantly supply nurseries with propagation material that the nurseries then propagate up and supply to customers.
- Carry out virus testing at a rate of 20% of all vines every year so no test is older than 5 years old.
    - Sometimes if they are requested for specific propagation material they will undertake additional virus testing as per supplier request (eg for red blotch virus)

- Have 4 discrete properties
    1. '1984 vineyard' which was the original germplasm planting. Here virus testing is undertaken using PCR and ELISA for 16 viruses.
    2. '2010 protocol' vineyard (Russell Ranch) which has more thorough virus testing. Forty viruses are tested via PCR and ELISA to ensure material is clean of all viruses bar Rupestris Stem Pitting. Biological indexing is then employed as an additional means to check for virus presence, whereby the scion material is grafted onto indicator vines susceptible to virus which are then field grown and evaluated.
    3. Positive controls block where the indicator vines are grown for the biological indexing process
    4. Field indexing block which contains the biological indexed grafted vines
- USDA requires hot water treatment (HWT) of all material coming into the US. Outgoing from FPS only surface sterilisation is undertaken using hydrogen peroxide.
- Nurseries are required to conduct HWT to control pests such as mealybugs and nematodes. Seems to be slight variations in the process documented:
    - For Mealybugs: (i) 5 mins at 30°C; 5 mins at 52.8°C (127°F); Cooling at 23°C to prevent damage (this last step is essential to limiting damage to the plant material from the HWT process.
    - For Nematodes, wash vines free of soil, then: (i) 5-10 mins at 25.6°C (78°F) to warm up the vines; 51.7°C (125°F) +/- 1°F (0.5°C) for 5 minutes; (iii) plunge vines into cold water or hose off to prevent damage.
- Material received from domestic clients (e.g. heritage material) generally comes to FPS after the client has had it tested through another virus testing facility and has received a positive virus test and the client wants the virus eliminated.
    - Over the last three to five years, FPS has had an increased call on cleaning up propagation material with red blotch virus.
    - Material received from foreign clients is accepted into FPS on the understanding that the material will become publicly available once cleaned up.
- Virus elimination by FPS can be a six-year process using tissue culture, but they can get it down to 4 years by concurrently running some of the required steps.
- Sampling for virus testing:
    - Best tissue for RT-PCR is petioles. Cane scrapings are fine where ELISA testing is performed.

Actions for Vinehealth

- Review Australia's current HWT practices for grapevine propagation material to ascertain whether a cooling component is undertaken. If not, could this reduce potential vine damage as is insinuated as a possibility in Plant Quarantine Standards.

9. Consolidated Central Valley Table Grape P&D Control District and treatment coordinator for GWSS area-wide control program

- Met with Judy Zaninovich
- 22 years as a pest control advisor mainly in citrus before moving into the GWSS program in 2005 for 2 counties that have been inundated with GWSS.
- GWSS have a broad host range. Thus, the GWSS area-wide program considers that eradication is unlikely, but that the treatment of citrus and other hosts can have a major impact on reducing its severity on the grape and wine industries. The GWSS area-wide program aims to keep GWSS

numbers as low as possible to stop further spread north in California and to minimise vectoring Pierce's Disease in grapes.

- Program includes citrus growers as the GWSS overwinters in citrus. However, involvement is non-mandatory, so treatments are not always carried out by these growers.
  - Old mantra was that you couldn't control a disease by controlling the vector but this program has proven otherwise.
    - As part of the program, treatment coordinator roles are to act as the impartial role or the glue between government and growers. Work closely with researchers to work out best control program for PD in citrus in these counties. Do a lot of checking on growers, answering queries, some hand-holding. Without this role, there would be too many holes in the system and an uncoordinated approach to limiting spread. Try to make treatment practices as simple as possible for the citrus growers to follow, and as beneficial as possible (e.g. using insecticides that might also affect some of their own pests; or at least use a program that is least detrimental to them) to improve uptake. Even though much of the time the citrus insecticide program for GWSS is not of direct benefit to citrus growers, most are happy to help another industry and many of them have both crops.
    - The use of treatment area coordinators was one learning from the GWSS program that was carried into the EGVM program and Asian Citrus Psyllid Program.
- Setting the treatment programs for each county is slightly different depending on infestation levels, seasonality of the produce for market, and product MRLs. To devise a program, generally start by working backwards from MRLs and then working out what the spray window is for the whole areas and the window of timing for application. The vast majority of insecticides are ground applied. Aerial application is only considered if the ground is too wet to access.
  - must consider the range of crops in a defined area, their growth stages, sensitivity to chemicals and requirement not to affect the bee population needed for pollination of some of these crops (e.g. treating citrus when cherry trees are blooming).
  - must consider the time required to cover the ground with a spray, considering ownership of own equipment by growers and use of contractors and their availability. Where there is a limitation to covering the ground in an ideal period of time, the treatment areas must be reduced in size and a more coordinated approach taken. Can't have random spraying in different areas because uncoordinated, the GWSS will just spread to reinfect sprayed areas.
  - In winter months when the GWSS overwinter in citrus, they don't fly. They can however fall into picking bags with the citrus being picked and then end up in the packing house. If this occurs, the packing house is required to be fumigated which effectively stops their citrus harvest. This is another reason why it is in the best interests of the citrus growers to apply the insecticides to avoid costly consequences. This includes having to pay for these fumigation treatments.
- Locating the citrus and grape growers to target for the treatment program
  - When the program began in 2003, all they had was shapefiles of the properties with no ownership (or contact details) attached which made identifying and contacting growers difficult. Had to then visit growers in person to identify them. Started by visiting older growers who had good knowledge of ownership in the area and then maps were annotated with these details.
  - Also, utilised the Pest Control Advisors Network who had knowledge about property ownership and who undertook spraying on many of the properties. This network already had established relationships with growers and was instrumental in also calling growers about the program. Two thousand growers had to be contacted so they needed to utilise networks!

- Communication with citrus growers about treatments and timing
    - In the early years of the program, this involved direct phone calls to all growers, then this progressed to weekly newsletter. Now communications are less frequent and involves both sending growers a generic email prior to a treatment round starting as a reminder, with the plan of attack and highlighting changes to chemical options, and sending growers a personal email to outline chemical choice and treatment timing.
    - New growers receive considerable contact until they are familiar with the system.

APPENDICES

As part of attending the 7th International Phylloxera and Nematode Symposium, two presentations were delivered and an article submitted:

Appendix 1. Sampling strategies for sensitive, accurate and cost effective detections of phylloxera for quantifying area freedom status AND Short-medium term phylloxera research requirements for Australia presentation

Appendix 2. Seven minute snapshop of phylloxera history in Australia presentation

Appendix 3 'State of play of phylloxera in Australia' report for inclusion in proceedings

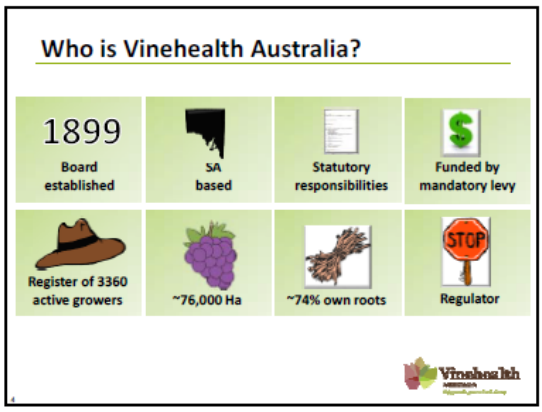
Within three weeks of returning from the travel, two articles have been produced based on learnings:

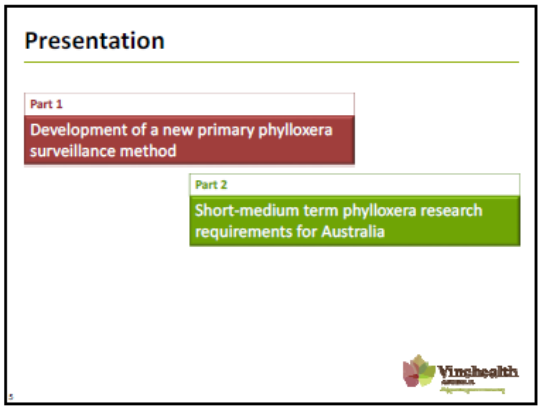
Appendix 4. Vinehealth Australia September E-News article "Warning from the US"
http://www.vinehealth.com.au/warning/

Appendix 5. "Learnings from European grapevine moth eradication efforts in Napa, California." A shortened version of this article is due for publication in the October 2017 *Australian and New Zealand Grapegrower and Winemaker* Magazine

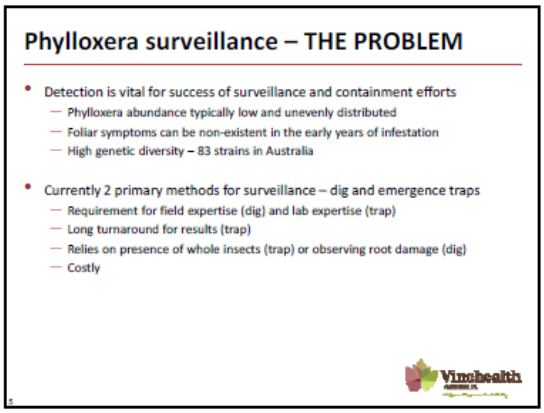
APPENDIX 1. Sampling strategies for sensitive, accurate and cost effective detections of phylloxera for quantifying area freedom status AND Short-medium term phylloxera research requirements for Australia presentation

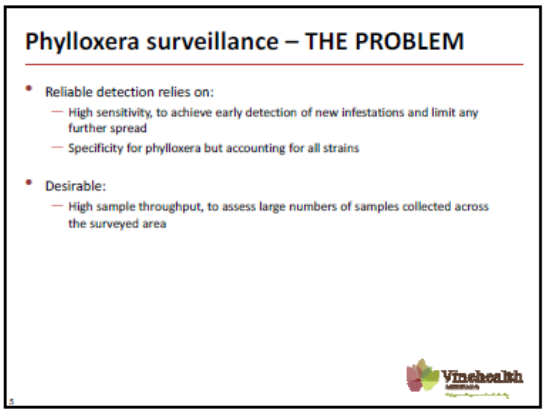












AIMS - An additional primary method of phylloxera surveillance

1. Develop a new phylloxera surveillance method quantifying phylloxera DNA by qPCR, for use by regulators and growers that is:
   - Accurate
   - Sensitive
   - Cost-effective
   - Rapid
   - Practical
   - Doesn't require field expertise
2. Establish sample collection, handling and storage protocols, optimised for the reliable detection of phylloxera in soil
3. Ensure endorsement of the DNA method and incorporation into National Phylloxera Management Protocol
4. Use the DNA method as part of an integrated approach to phylloxera surveillance to verify area freedom

SCOPE - An additional primary method of phylloxera surveillance

1. Assess impact of soil type, sample depth and distance from the vine trunk on the sampling efficacy.
2. Assess the impact of time taken transporting the sample from the field to the processing lab and storage conditions on sample degradation.
3. Determine the limit of detection of the qPCR for phylloxera.
4. Determine the density of sampling required per hectare for accurate and cost-effective detection.
5. Determine the effect of vine root on phylloxera detection using qPCR
6. Validate the field sampling method under different conditions (grapegrowing regions, different times of year, different known levels of phylloxera).
7. Produce a field sampling protocol and test it out with growers.

Field sampling protocol



- Timing
  - Detection throughout the year → highest density in mid-summer to early winter.
- Sample collection
  - Grid sampling method, every 3rd row, every 5th panel, ~ 40 cores per Ha
  - 14mm diameter x 100mm long corer
  - Collect 1 soil core per vine, placing 5 consecutive cores into a single sample bag
  - Position core within 10cm from vine trunk and at depth of 10cm from soil surface
  - Double bag each sample and transport at 10-20°C to lab within 24-48 hours for drying
- Laboratory analysis
  - qPCR technique validated with sensitivity of 1.5-2 phylloxera per 200g soil

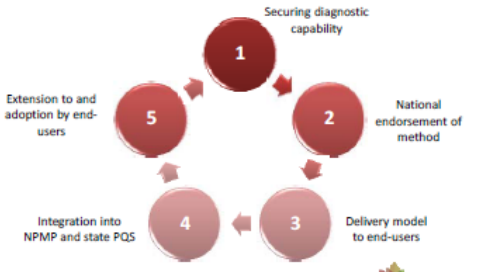
Supply chain use of the DNA method

GROWERS
- Early detection, management and farm-gate hygiene
- Potential for zoning change
- Management of other pests & disease

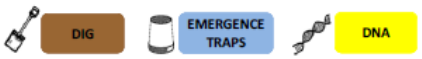
REGULATORS
- Early detection and ongoing surveillance
- Establishment and maintenance of phylloxera zones
- Enable better definition of areas of freedom

RESEARCHERS
- A tool for studying phylloxera biology, rate of movement and vectors
- Other soil-borne pathogens and soil health

What's still to be done?



An integrated approach to phylloxera surveillance



- Considering same sampling method for the three surveillance methods, important to ensure method has highest possible chance of detection
- Consider application of secondary methods of surveillance
  - aerial imagery, hyperspectral or multispectral imagery – weak vines, patterns
  - EM38 (electromagnetic induction-based soil sensing technique looking for variances in soil moisture across a block)

Future of phylloxera surveillance

1. Development of in-field qPCR diagnostic capability (negating the need to send soil samples to the laboratory)
2. A single integrated diagnostic test that can detect the presence of phylloxera, and determine the amount and strain of phylloxera in a sample

Short-medium term phylloxera R&D requirements for Australia

- Research priorities discussed in early 2017 between Vinehealth Australia and Australia's leading phylloxera researcher, Dr Kevin Powell.
- From a larger pool of 'what do we know' and 'what do we not know', priorities identified for future research



FOUNDATION STRAINS – investment in capacity to maintain and multiply 7 genetic strains

FUNDAMENTALS	QUARANTINE	DETECTION & SURVEILLANCE	MANAGEMT
- Soil chemistry that phylloxera like/dislike - Cuticle properties to tailor disinfestation techniques - What makes some strains more virulent than others? - How does phylloxera find roots using its chemoreceptors? Same for every strain? Can we apply a deterrent that blocks this? - Mechanism of resistance/ susceptibility of rootstock	- Updating National Phylloxera Management Protocol based on science - Alternatives to bleach for disinfestation - Commercial verification of dry heat treatment for machinery & equipment - Commercial testing of hot water treatment of propagation material to reduce vine damage - Identification of steam specifications for disinfestation - Commercial verification of hot water treatment for grape bins	- Methods for targeted surveillance of large scale areas and cost/benefit - Does a vine's chemical signature change when it is under attack from phylloxera and how can we detect this? - Does a vine's spectral signature change when it is under attack from phylloxera? Does this hold for different varieties? Can this be measured on a block scale and greater than a block scale? - Developing an in-field phylloxera DNA detection tool	- Understanding rootstock x strain x climate - Risk rating for each wine region based on strain presence - Alternative controls e.g.. biological control, biofumigants

EXTENSION – translation of science into commercial practice

Key research/extension needs

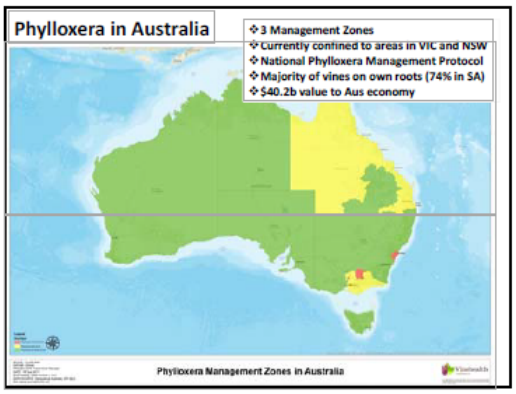
- Completing validation of disinfestation protocols in the NPMP, taking into account practical feasibility
  - Are we killing all the endemic phylloxera strains with our protocols?
  - Replacement for bleach to assist in adoption of farm-gate hygiene practices
- Early phylloxera detection - integral to the establishment and maintenance of PEZs
  - Focus on methods for large scale targeted and maintenance surveillance

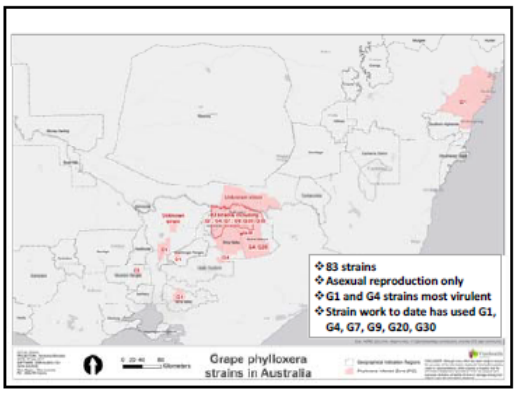
Key research/extension needs

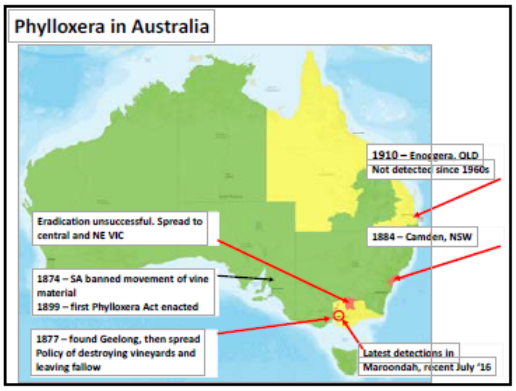
- Phylloxera-resistant rootstocks - an important practical outcome for industry
  - Important to relate to strain presence so ratings can be provided to growers for suitable plantings
  - Ensure all rootstock breeding programs incorporate a phylloxera screening component

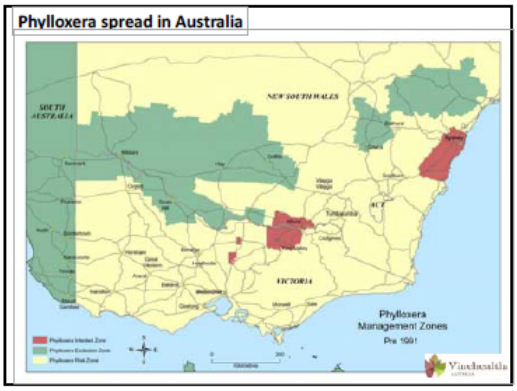


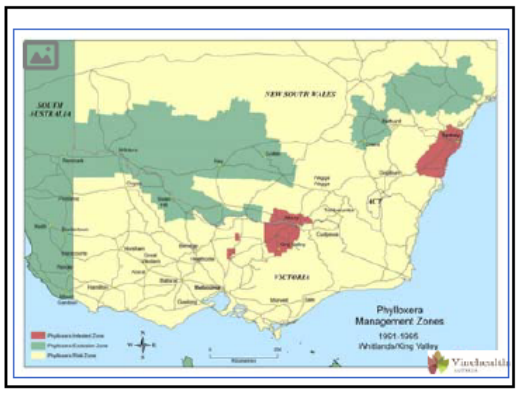
APPENDIX 2. Seven minute snapshop of phylloxera history in Australia presentation

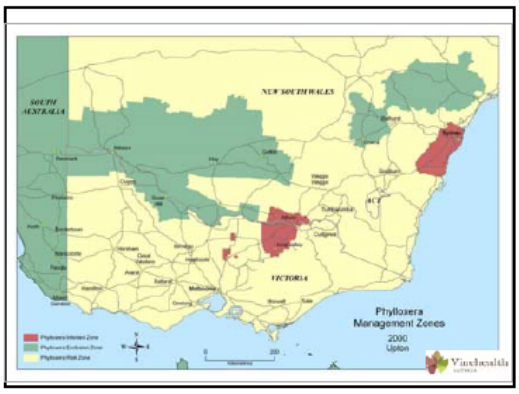


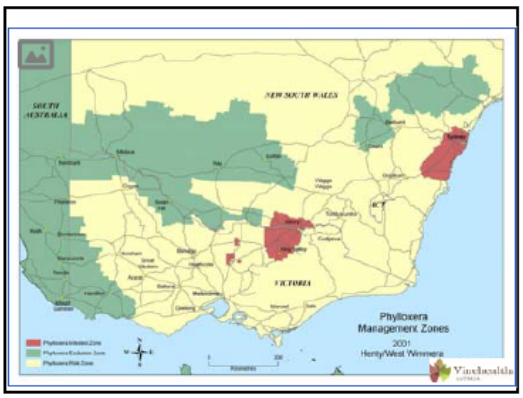


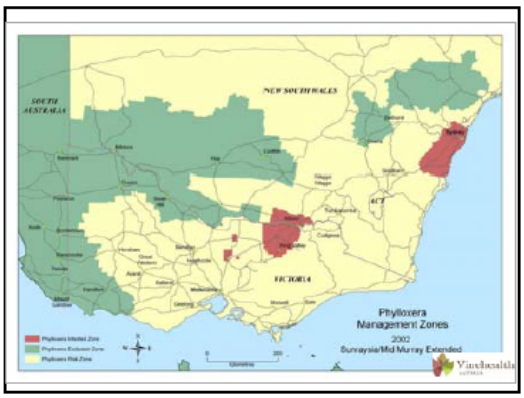


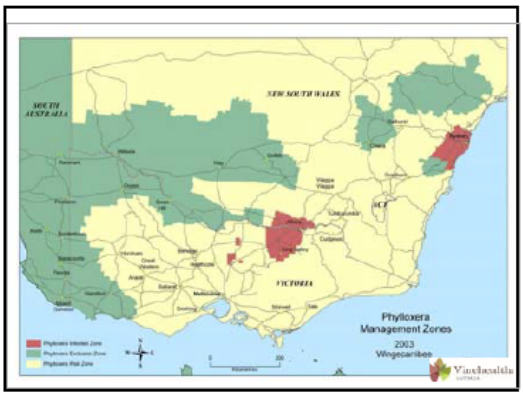


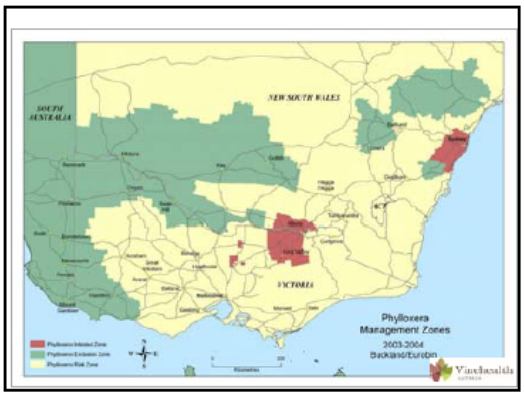


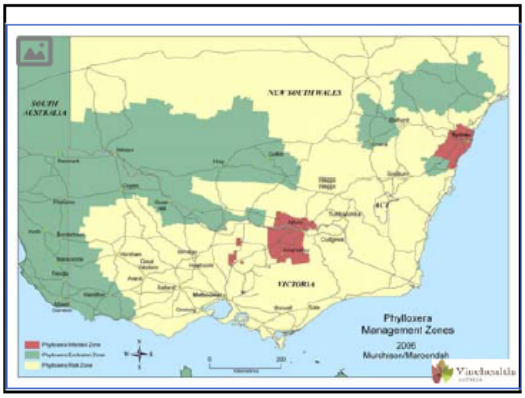



SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2001
Henty/West Wimmera

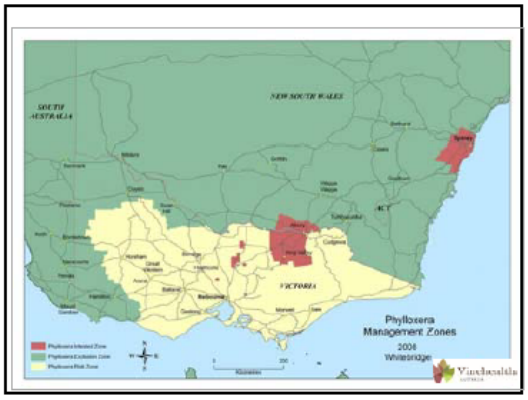

SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2002
Sunraysia/Mid Murray Extended

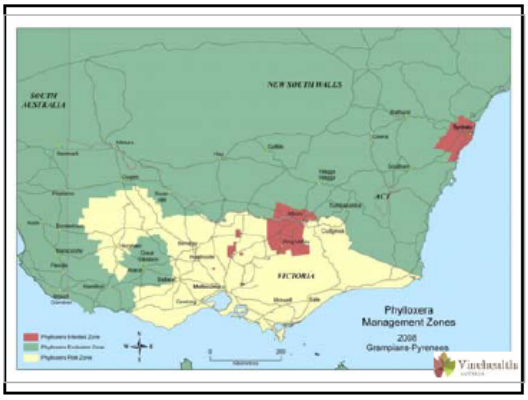

SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2003
Wingecarribee

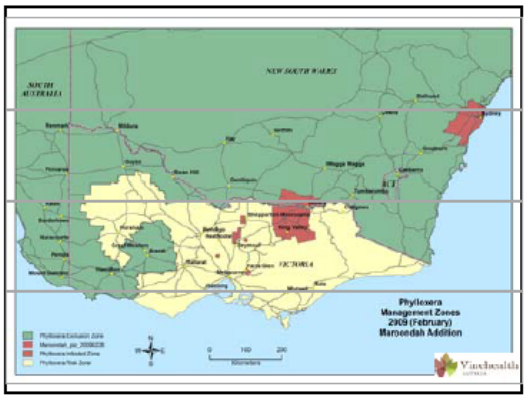

SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2003-2004
Bacchus/Eurobin


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2006
Murchison/Maroondah

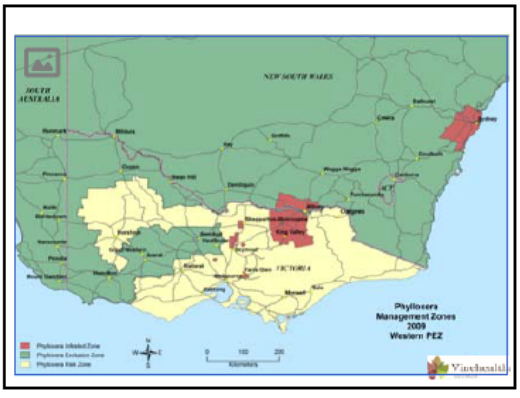

SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2006
NSW Regions


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2004
Whitsendigs


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2008
Grampians-Pyrenees


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2009 (February)
Maroondah Addition


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2009
Maroondah Addition


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2009
Western PEZ


SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
Phylloxera Management Zones
2010
Mansfield Addition


NEW SOUTH WALES
SOUTH AUSTRALIA
Phylloxera Management Zones 2012 Victoria PEZ


NEW SOUTH WALES
SOUTH AUSTRALIA
Phylloxera Management Zones 2014 Maroondah PIZ Extension


NEW SOUTH WALES
SOUTH AUSTRALIA
Phylloxera Management Zones 2016 Maroondah PIZ Extension


NEW SOUTH WALES
SOUTH AUSTRALIA
Phylloxera Management Zones 2017 Maroondah PIZ Extension


NEW SOUTH WALES
SOUTH AUSTRALIA
Phylloxera Management Zones 2017 Maroondah PIZ Extension (July)

APPENDIX 3 'State of play of phylloxera in Australia' report for inclusion in proceedings

General

- In Australia, grape phylloxera is currently confined to a number of geographic indicator (GI) regions within the states of Victoria and New South Wales (Figure 1).
    - The major grapegrowing states of South Australia, Western Australia and Tasmania have not become infested with phylloxera. Queensland is also thought to be free of phylloxera.
- Commercial vine plantings in Australia are predominantly ownrooted *Vitis vinifera*, highly susceptible to phylloxera (74% in South Australia).
    - Preventing phylloxera movement to currently uninfested areas is therefore of utmost importance.
- To prevent the spread of phylloxera from infested areas, each state has documented restrictions and allowable movements of phylloxera 'risk vectors' in Plant Quarantine Standards. These movement conditions are underpinned by Austrlaia's National Phylloxera Management Protocol.
- Grapegrowing regions in Australia are delineated by phylloxera status. Movement requirements are prescribed according to three phylloxera management zones. Phylloxera Exclusion Zones have been surveyed and found free or are declared free historically. Phylloxera Risk Zones are of unknown status. Phylloxera Infested Zones contain vineyards known to be infested.
    - In some cases, phylloxera detections have resulted in the whole GI being declared a PIZ, but in other cases, the PIZ has been declared only within a proportion of the GI boundary.
    - Phylloxera dectections within the Maroondah Phylloxera Infested Zone in Victoria are on the increase, with the most recent detections gazetted in July 2017 resulting in further changes to the boundary, 5km from infested properties.
- There is no evidence yet of sexual reproduction occurring in Australian phylloxera populations.

Strains

- 83 strains typed in Australia out of several hundred worldwide
    - 49 confined to root feeding only
    - 23 confined to leaf feeding only
    - 11 feed on both roots and leaves
- In some regions only a single strain has been detected, but in others, multiple phylloxera strains have been found (Figure 2).
    - Currenty, movment of phylloxera risk vectors is not adequately considered down to the strain level
- Rootstock testing to date has focussed on screening a range of rootstocks using six strains - G1, G4, G7, G19, G20, G30. Results from this rootstock testing are summarised in Table 1 and adapted from work completed by Powell and Krstic (2015) and reported by Dry (2007).

Research

- Phylloxera research priorities were discussed in early 2017 between Vinehealth Australia and Dr Kevin Powell (formerly of Department of Economic Development, Jobs, Transport and Resources, Victoria). Core priority pillars were identified as 'fundamentals', 'quarantine', 'detection and surveillance', and 'management'. These pillars are underpinned by the need to maintain foundation strains of phylloxera, and by extension to ensure the translation of science into commercial practice.
- In light of new phylloxera strain detection, the highest priority for research was identified as completing validation of disinfestation protocols in the NPMP, and taking into account practical feasibility.
- Early phylloxera detection was also identified as integral to the establishment and maintenance of PEZs, with focus on methods appropriate to undertaking large scale targeted surveillance for greater than a block level.
- Phylloxera-resistant rootstocks were also identified as an important practical outcome for industry. This area of research was also to ensure all rootstock breeding programs incorporated a phylloxera screening component.

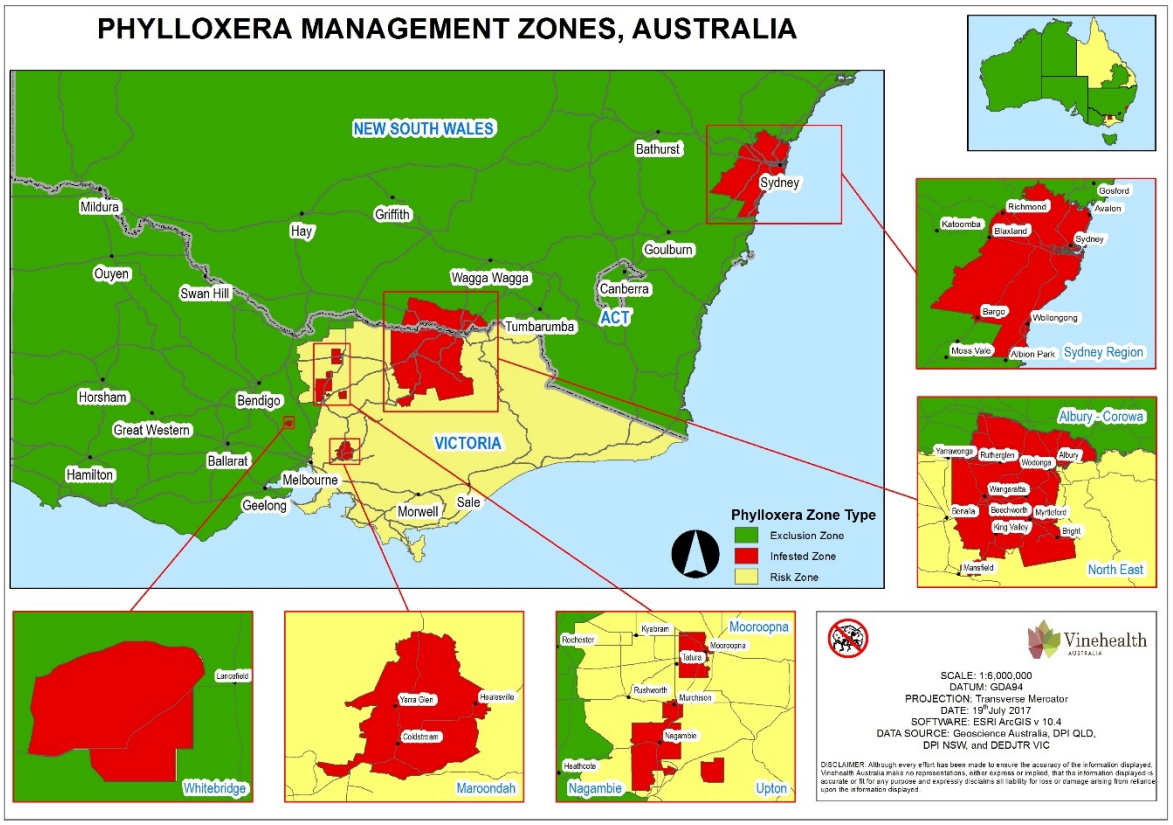


Figure 1. Phylloxera management zones in Australia

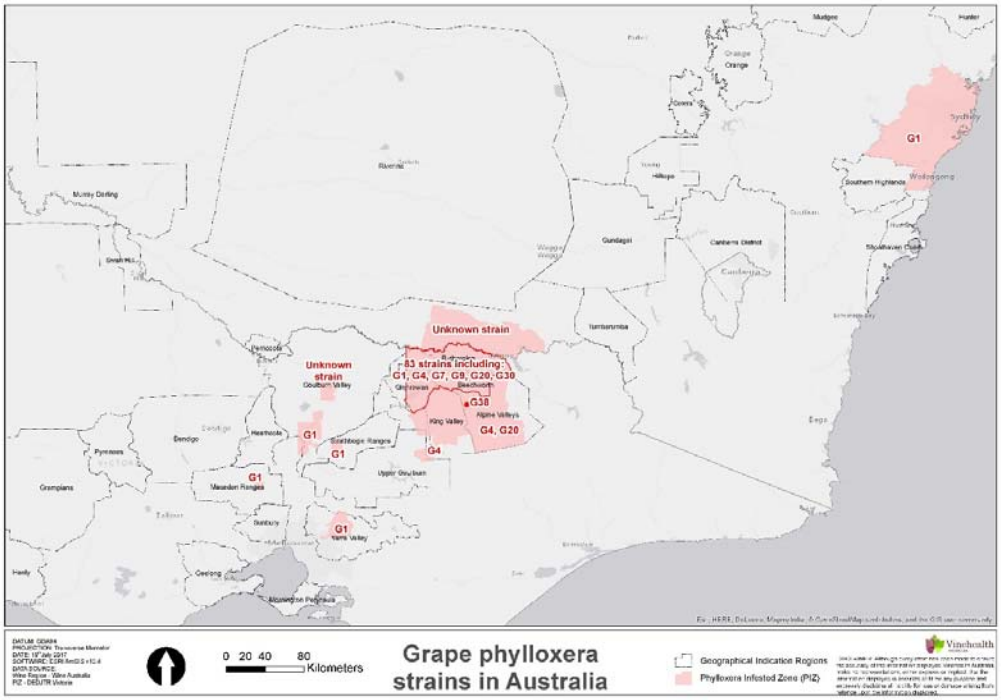


Figure 2. Spatial distribution of common *D. vitifoliae* strain (genotypic) linkages in Australia.

Table 1. Resistance ratings of rootstocks to phylloxera strains. Susceptibility, tolerance or resistance of various Vitis rootstocks to different phylloxera strains, as assessed by in vitro (IV), glasshouse (G) and field (F) techniques.

Endemic grape phylloxera strain	G1			G4			G7			G19			G20			G30		
Rootstock	IV	G	F	IV	G	F	IV	G	F	IV	G	F	IV	G	F	IV	G	F
Vitis vinifera (own roots)																		
Ramsey									•			•			•			•
Schwarzmann												•			•			
Börner									•						•			•
110 Richter												•			•			
1103 Paulsen									•						•			•
140 Ruggeri												•			•			•
5BB Kober												•			•			
420 A			•	•					•	•		•			•	•		
3309 C	•		•	•		•			•			•			•			•
101-14			•	•					•			•			•			•
Merbein 5489							•	•	•	•	•	•	•	•	•			
Merbein 5512	•	•	•				•	•	•	•	•	•	•	•	•			
Merbein 6262	•	•	•				•	•	•	•	•	•	•	•	•			

KEY

IV	*In vitro*
G	Glasshouse
F	Field situation
	Susceptible
	Susceptible - Tolerant
	Tolerant
	Tolerant - Resistant
	Resistant
•	Work to be completed

References

1. Dry, N. (2007). Grapevine Rootstocks. PGIBSA.
2. Powell, K. S. and M. Krstic (2015). Phylloxera: Rootstock tolerance and resistance to different genetic strains of phylloxera. *Wine and Viticulture Journal* 30(5): 48-51.

APPENDIX 4 – Vinehealth Australia E-News article

Warning from the US

Vinehealth Australia Technical Manager Suzanne McLoughlin recently returned from a trip to the US, part funded by a travel bursary from Wine Australia, to attend the 7th International Phylloxera and Nematode Symposium held at the University of California, Davis.

While there, Suzanne met with grape and wine research organisations, government institutions and commercial businesses.

While the symposium was strongly focussed on grapevine breeding for both phylloxera and nematode resistance, updates on activities and state of play in the varying countries was given by the participants from US, Austria, Germany, Italy, China, Argentina, Canada and Australia.

“There are few researchers working on phylloxera around the world and none working on disinfestation other than in Australia, so it’s vital to foster our home-grown research to help us to better manage our situation,” Suzanne said.

A presentation on phylloxera resistant rootstock breeding at Geisenheim, Germany noted that Börner, Cina and Rici are the only truly phylloxera resistant rootstocks (all Vitis riparia x Vitis cinerea), but these are not suitable for planting in soils with high pH and lime, with vineyard longevity limited to 15 years in these conditions and poor yields recorded.

Current breeding programs have focussed on improving lime and drought tolerance, and rootstocks showing genuine promise include Gm 9228-45 (Börner x 125AA cross) and Gm 9230-3 (Börner x berlandieri cross), recently released commercially.

“When driving around the Napa, it was sobering to see the vastness of the pest and disease issues facing the area, and consequently all the replanting e□orts,” Suzanne said.

“This certainly made me feel fortunate for our situation here in Australia. Vineyard life is only expected to be 20 to 25 years in the Napa, well short of the expected productive life span for vineyards in Australia at around 40 years.”

Owners of a large commercial business took Suzanne through their three-stage internal quality control efforts to improve chances of cleanliness of new propagation material and ultimately health of new vineyards.

“If cuttings are taken from their own blocks as the scion material for grafting, they ensure that the scion material is clean through virus testing. Then, before accepting the grafted material from the nursery, they make an onsite visit to inspect the quality of the material within 48 hours of delivery, using the Fit Vine App to undertake assessments,” Suzanne said.

“Lastly, once the young vines are around a year old, any showing virus-like symptoms are tested for Leaf Roll 3 and Red Blotch viruses (including submitting control samples) and if deemed positive, these vines are grubbed.

“This focus on virus testing and grubbing is predominantly on reds at present, for which foliar symptoms are easier to detect and effect on yield and wine quality seems more apparent compared

to for whites. Grubbing the vines when they are young means new replants are not too dissimilar in age to the remainder of the block and spread of the viruses can be limited. Generally, two dripper lines are now installed as part of new developments so that replants can be irrigated separately from more established vines.

“After seeing the intensity of their vineyard health work, I had to ask myself, how do we compare in Australia?”

Suzanne said it was also interesting to see the effects of Pierce’s Disease first hand. “Despite the absence of the glassy-winged sharpshooter in the Napa, the blue green sharpshooter is still causing significant localised vine death from Pierce’s Disease in blocks adjacent to the Napa river as the vector comes out of the riparian zones,” she said. “There is extensive multi-agency managed restoration work occurring along sections of the Napa river with one of the aims being to remove host species of the blue green sharpshooter.”

Suzanne was also impressed by the work done in the Napa on European Grapevine Moth. “I spoke to two University of California Extension Farm Advisors who were at the coalface, as part of the team coordinating the six-year successful eradication e□ort of the exotic European Grapevine Moth,” she said. This eradication strategy will be described in more detail in an upcoming article in *Australian and New Zealand Grapegrower and Winemaker* magazine.

“One interesting component of this effort during the quarantine phase was confining the composting of grape marc, stalks and stems to registered commercial facilities, where temperature control on the composting process was assured for kill of any pests or diseases present,” Suzanne said.

“Growers are now wondering whether this practice will be reintroduced with mealybug issues on the rise. We need to consider whether, in Australia, there are many vineyards and wineries undertaking onsite composting, perhaps not in accordance with Australian standards, that may be potentially contributing to the spread of pests and diseases.”



Pierce’s Disease affected vines adjacent to Napa River



Pierce's Disease, Napa



Red blotch virus affected vine, Oakville Research Station, Napa

APPENDIX 5 – Case Study: European Grapevine Moth Eradication

Head:
Best practice eradication

Subhead:
Learnings from European grapevine moth eradication efforts in Napa, California.

Standfirst:
While in the US on a study tour in September, Vinehealth Australia Technical Manager Suzanne McLoughlin met with Monica Cooper and Lucia Varela, University of California Cooperative Extension Farm Advisors, to discuss efforts in controlling, containing and ultimately eradicating *Lobesia botrana* (European grapevine moth). This article provides insight into the collaborative approach taken to eradicating this exotic pest, which earnt program leaders a federal Administrator's Award in September 2012. What can we in Australia learn from this?

Body copy:
Native to Mediterranean Europe, the European grapevine moth (*Lobesia botrana)* is a serious pest of grapes. It has invaded Europe, west Asia, North Africa and East Africa, Middle East, eastern Russia, and was detected for the first time in Chile in April 2008, in California in September 2009; and in Argentina in April 2010 (Ioriatti et al. 2012 and Varela et al., 2013).
Grape is the preferred host and larvae feed on flowers, and on or inside both green and softening berries (Smith et al, 2010).
In the United States, the first detections were in the Napa county, California, where this invasive pest and associated fungal rot caused significant crop damage in 2009. Crop loss of $150,000 was reported in the vineyard in which *L. botrana* was first detected.
How did the wine industry respond? With a coordinated, award winning eradication program.

Setting the plan of attack
Getting the right people around the table
Within 2 months of detection, the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS) agency put in place a Technical Working Group (TWG) of subject-matter experts, comprising federal, state and county government personnel, researchers, extension staff and a representative of the winegrape industry. The group was tasked with providing urgent scientific recommendations to regulatory program managers in California. International scientists were also identified and engaged from Italy, Spain, Chile, France and Germany, and invited to be part of this group. These specialists were imperative to share knowledge; particularly the Chilean who had dealt with an incursion a year prior. The Chilean management program was in fact replicated in the first instance for the Californian situation.
While vines were dormant over winter 2009, the TWG of 11 had time to develop of plan of attack. They recommended to pursue eradication in California provided that:

1. The *L. botrana* population did not become substantially more widespread than was recorded in 2010;
2. The grape industry remained supportive of the effort; and
3. Control methods available in 2010 remained available for use by the program (Varela et al., 2015).

Five University of California staff travelled to Chile to visit the Chilean Department of Agriculture and review the Chilean eradication approach. This visit also served to forge a tight relationship between both countries, which proved invaluable during the six years it took to eradicate *L. botrana* from the Napa.

Setting the eradication strategy

The TWG set an eradication strategy as follows:

1. Identify the geographic range of the insect in California;
2. Develop and implement detection and management programs;
3. Regulate the movement of plant material and equipment to minimise the threat of dispersal;
4. Incorporate research-based information developed by subject-matter experts into policy decisions; and
5. Promote a wide-reaching educational program for grapegrowers, the public and local officials.

The activities of this strategy drastically reduced insect populations and limited the distribution in Californian vineyards such that previously affected areas were removed from quarantine. Within six years, *L. Botrana* was eradicated.

Value of conducting research in parallel with outbreak management

In previous quarantine situations, research had not been allowed inside a quarantine zone. However, a new approach was taken by the TWG to ensure tight collaboration between extension and research staff, which meant work was done in parallel to eradicate the pest. This proved vital. An extensive literature review was conducted focussing on pest biology and control measures, identifying three generations of the moth in a season. This review included translation of many papers and articles from numerous countries, to ensure all decisions made by the TWG were informed by science. Comprehensive extension material was produced; initially published via the web and then in brochure and poster formats.

CONSIDERATIONS FOR AUSTRALIA:

- Do we have lists of local and international specialists for our high priority plant pests that we can call on as needed?
- Do we have the right mix of people around the table for our Emergency Plant Pest Response Deed (EPPRD) discussions?

Gauging the enormity of the problem

Monitoring

Monitoring of male moth flights was undertaken both outside and inside the quarantine zones using pheromone-baited sticky traps. Traps were distributed by government staff on a standard 10 traps per km^2 grid system for planted vineyard inside a quarantine area and at three to six traps per km^2 outside a quarantine area.

In urban environments, traps were placed on potential host species at a density of two traps per km^2. These traps gave the TWG a guide as to hotspot areas where additional surveillance could be deployed at a higher density. It also offered a guide to initiation and peak of flights, to help time insecticide applications for larval emergence. Monitoring for larvae and egg masses was also undertaken.

In 2010, the largest moth populations were found in the Napa County at 100,831, compared to 128 total moths in the remaining counties (Varela et al., 2015). In 2011, at peak quarantine activity, there were 10 regulated counties in California with monitoring activity covering a vineyard area of approximately 61,000 hectares out of a total 605,000 hectares. The monitoring of male moths was highly successful for demonstrating the effectiveness of the eradication effort and ultimately leading to eradication across California (Table 1).

Table 1. Number of *L. botrana* male moths trapped in Napa County and traps deployed at peak trapping (modified from Varela et al., 2015 and Eberling, 2015).

Year	Males moths trapped	Traps deployed
2010	100,831	3,882
2011	113	4,930
2012	77	4,706
2013	40	11,621
2014	0	11,656
2015	0	11,627
2016	0	unidentified

Identifying host plant species

Pheromone traps and treatments were deployed in all potential host species of *L. botrana*, including blackberry, elderberry, olive, wild rose, wild and domestic grapes, wild and domestic plums, peach, nectarine, blueberry and gooseberry (a host list of 40 species, but true hosts were few and grape was identified as the favoured host).

Olives were found to be a minor host of *L. botrana*, but only to the first generation, as flowers were the preferred feed source.

The TWG identified that *L. botrana* did not venture into commercial crops other than grapes in California. Eradication probably wouldn't have been possible if this wasn't the case.

In the Chilean scenario, the insect spread to blueberries, significantly hindering prospects of eradication. In addition, the number of backyards in California with vines was relatively low and therefore *L. botrana* was relatively easy to contain. Riparian zones were also feared initially to be a habitat for the insect, however wild grapes growing along the river courses were found to be less preferred compared to commercial vines, because of the lack of fruit which was often hard and late maturing.

Identification of these host species on a landscape level was critical to the eradication effort in terms of trapping. Digital land use maps were available to identify location of host plants. Location of commercial vineyards was also well known, but location of urban vines proved an issue initially. In the first year of the eradication effort, many of the urban properties with vines were unidentified and subsequently fell through the cracks for treatment or fruit removal, but this was addressed thereafter.

Quarantine

Setting up quarantine zones

In the first year of the eradication strategy in 2010, a conservative approach was taken to setting up quarantine zones, also known as 'regulation' zones. These were established in an 8km radius of a detection, where a detection was defined as either:

1. Two or more adult moths trapped within 5km of each other during the same life cycle[1]; or
2. Immature stages proved to be *L. botrana* by DNA analysis.

Regulating movement

In June 2010, a federal order indicated plant host species as well as plant parts, products, farming and processing equipment, and green waste residues could not be transported interstate from a European grapevine moth quarantine area, except under specific conditions. State quarantine enforced restrictions parallel to those in the federal order, for intrastate movement of regulated items within or from quarantine areas. Businesses were required to sign compliance agreements that mandated specific activities prior to and during harvest, transport, processing and waste handling (Cooper et al., 2014).

[1] Confirming that *L. botrana* was reproducing at the detection site, and not just transported to the detection site, as could be the case for a single moth.

Continual research into the biology of the insect determined that it was in fact a weak flier, flying less than 50m in distance. With this additional knowledge, the 8km quarantine zone was reduced to 5km by 2013, and the treated area reduced to 500m from the point of detection occurring in the current year and previous two years.

Qualifying for deregulation from quarantine status

The TWG recommended that all portions of an entire contiguous regulated area should be deregulated at the same time, and specified a range of conditions underpinning qualification for deregulation:

1. No moths captured during five consecutive generations;
2. Insecticide treatments to continue to target the first and second generations;
3. Mating disruption may not be used during the final two generations within the area under regulation; and
4. During these final two generations, trap density must increase to 39 traps per km^2 in all vineyards within 500m of previous detections.

Based on the above criteria, four counties were removed from regulation at the beginning of 2012. By the end of 2012, another three counties were fully deregulated and two counties partially deregulated, leaving Napa county and parts of Sonoma and Solano counties remaining under regulation in 2013.

Further changes to the deregulation conditions advised by the TWG were:

1. High-density traps at 39 traps per km^2 deployed county-wide must be free from detections during four full flights; and
2. Any moth captured will trigger the delimitation and establishment of treatment areas within 500m of the detection.

Because of these changes, trap density nearly tripled in Napa County in 2013. The remainder of the Solano county and most of the Sonoma county, as well as southern Napa County were deregulated in 2014, leaving the remainder of the Napa Country and a small portion of northern Sonoma County of 115,500 hectares regulated during 2015.

No moth was detected in 2015 or in the first two flights of 2016. As a result, *L. botrana* was declared eradicated from California in August 2016.

CONSIDERATIONS FOR AUSTRALIA:

- Do we know where our urban vines are?
- Do we have an identified host species lists for all high priority exotic plant pests?
- Do we have digital land use maps showing the location of these species?
- What are our guidelines for continued monitoring after an eradication is declared?

Management of winery waste

While it is still unclear as to how *L. botrana* entered the state of California, winegrape movement was deemed the movement vector responsible for spreading the pest within the state. In addition, spread also occurred by machinery moving between vineyards.

One research project focussed on investigating potential pest spread through the movement and treatment of winery waste. Results showed that winery waste was not a large contributing factor to spread, as *L. botrana* was killed during the (whole bunch) pressing stage when pressed to 28 psi. However, accidental spills of grape matter were found to be a potential mechanism for spread in the winery, so cleaning disassembled winery machinery with hot water was found to be critical. During the quarantine period, a mandated practice was that all stalks and stems were required to be properly composted inside the quarantine zone, to ensure specified temperatures were reached to kill the insect. In practice, this meant composting at commercial facilities.

CONSIDERATIONS FOR AUSTRALIA:

- Do we have a gauge on the amount of composting of grape marc, stalks and stems that is conducted away from commercial facilities that could pose a pest and disease risk?

Action in the field

The eradication strategy involved the use of three tools – insecticides, pheromone-based mating disruptors and host removal, which varied in combination based on land use and occurrence of potential host species. In the urban environment, fruit removal from backyard grapevines in spring or early summer was the preferred approach.

Identifying insecticides and timing of applications

In the first year, two large insecticide research trials were undertaken. Every registered insecticide for use on grapes was evaluated for effectiveness to kill *L. botrana* eggs and larvae, to ascertain whether 'soft' products were as effective, to identify off-target issues and to test effects on beneficial insects. This was important research given both conventional and organic management systems needed to be provided for. In Chile, pyrethroids were commonly used because they were cheap, but these products burnt the vine canopies. Chemical registrations for the affected counties also had to be assured.

These research trials determined insecticide options to be used in conjunction with mating disruptors for non-organic growers – Intrepid[2] (chlorfenapyr) and Altacor (chlorantraniliprole), for use in alternation for each moth flight. For organic growers, *Bacillus thuringiensis* (Bt) and Entrust Naturalyte (spinosad) were identified. The latter was not used by growers, however, due to cost. A limited product list allowed fewer negotiations with chemical companies to ensure sufficient product was available for the eradication effort. In addition, fewer product choices meant that varying efficacy did not affect the eradication effort.

Timing of insecticide applications played a very important part in leading to the eradication of *L. botrana*. Through literature reviews, the insect was known to complete two to five annual generations, as determined by latitude, climate and microclimate (Ioriatti et al., 2012). Local research using temperature modelling, predicted three generations per year in the Napa Valley, which was then validated through ground observations (Gutierrez et al., 2012).

A subgroup of the TWG met every week to revise the spray schedule for growers, based on degree days, to model the lifecycle development of the insect. Insecticide applications were timed to coincide with the most vulnerable stages of the pest. Grape flowers were determined to be more nutritious than berries for the insect and therefore a higher number of degree days was required for development of the second and third generations (which coincide with infections on green berries and softening berries respectively) so degree day intervals for spraying increased from the second generation onwards during the season. A three-week window was instituted around each spray timing, to allow the required insecticide applications to be tank mixed with other agrochemicals to limit additional passes.

Peer pressure between growers to follow the quarantine requirements during the incursion appeared more effective than the issuing of fines for non-compliance.

Despite chemical registrations being in place for use on grapes, work had to be done with chemical companies to register products for use on olives.

Once preferred products were identified, discussions with manufacturers occurred in attempt to gain registration for use in affected crops in the required counties. Some chemical companies did not chose to take out registrations for their products for this cause.

[2] Not registered for use on grapes in Australia at present

CONSIDERATIONS FOR AUSTRALIA:

- How quickly can we obtain chemical registrations in an emergency scenario?
- Do we maintain a current agrochemical registration list for host commercial crops against our exotic high plant pest priorities in Australia?

Mating disruption

The use of mating disruptors in the form of ISOMATE pheromone dispensers applied over large, contiguous areas, in conjunction with well-timed insecticides, were found to be very successful in controlling *L. botrana*. Significant research was undertaken by the TWG to evaluate the efficacy and longevity of four pheromone lures before a suitable lure was chosen, approved and registered for use.

Mating disruption works by using many ISOMATE dispensers (ISOMATE®EVGM twist-ties), applied by hand at 200 dispensers per acre, to saturate the air with synthetic female sex pheromones which confuses the male moths and renders them unable to locate females, suppressing mating and therefore crop damage. Although mating disruption does not completely inhibit *L. botrana* mating, delayed mating reduces populations because older females produce fewer eggs than younger females (Torres-Vila et al., 2002).

Communicating the eradication strategy

Program leaders provided transparent, consistent, timely and coordinated communication to parties directly and indirectly affected by the eradication effort (Cooper et al., 2014), which became a hallmark of the program.

Toll free number

A toll-free number was established for reporting possible *L. botrana* finds.

Education materials

A range of education materials was used to communicate to growers, winery personnel and the public. These included brochures, posters, a training video, postcards, door-hangers, magnets, billboards, signs, radio announcements, social media and websites.

Community meetings

Well before any spraying was scheduled, community meetings were held in Napa and Sonoma to engage environmental groups in the eradication strategy, given their concern after the aerial spraying efforts in 2007 for Lightbrown apple moth. Multiple public meetings were also held, involving the international specialists. In each year of the eradication strategy, a meeting open to the public was held where growers and community members could pose questions to the TWG. Having a single unified message was vital to avoid confusion. This included the same PowerPoint presentation and talking notes used to communicate the science at all meetings within the county.

Field days

Countless field days were held, both in English and Spanish, showing growers how to look for and identify *L. botrana* egg masses to aid in identifying hotspot areas in the quarantine zones. All communication materials produced were bilingual.

Newsletters

Weekly electronic newsletters were prepared and distributed from early in the eradication plan, providing stakeholders with real time updates and photographs on progress and tasks being undertaken. This information was then used by individual wineries to train their public-facing staff, for example cellar door and customer relations staff. In addition, grower liaison staff played a central role in information dissemination.

Grower groups

Extension staff found that growers were more likely to report and discuss issues when in small groups. Grower groups of around 20 growers were set up as 'safe' places to have open discussions. Extension staff found that initially they were doing all the talking, but gradually growers started sharing their experiences among their peers in these forums.

Hobby winemakers

Hobby winemakers were identified as an 'at risk' group to contributing to the spread of *L. botrana* through their movement of grapes; often moving grapes from the Napa to other states. In addition, this group generally falls outside the commercial winemaking groups, meaning they have less access to information.

Reaching this group was considered an issue. However, it was identified that hobby winemakers often belonged to clubs, which were listed on the internet. The TWG contacted these clubs and presented at numerous meetings to ensure this target group was armed with required knowledge about the eradication strategy and the role they played in it.

Carriers

Carriers were another core group identified for targeted communication. At the beginning of the eradication effort, loads were instructed to be tarped to minimise potential hatching of the larvae and transfer into vineyards en route to the winery. However, an increase in load temperature due to the tarps was touted to ruin wine quality. As a result, transporting to reduce spillage specifications were instead put in place. For hand-picked fruit, bins were not to be filled within 300 mm of the lip of the bin and even more for machine picked fruit.

CONSIDERATIONS FOR AUSTRALIA:

- Do we have contact lists of non-commercial winemakers and a plan for reaching them in an incursion?
- Do we have a list of concerned lobby groups that require consultation in the event of an incursion?
- Do we have a list of grower liaison staff and wine industry consultants who could be key to information dissemination in times of an incursion?
- Do we have a public relations plan that includes consistent messaging for public-facing industry personnel?
- Should we consider setting up multiple small grower groups in the event of an incursion, where growers can openly ask questions of each other and extension staff and share knowledge?

Funding

While grapegrowers did not contribute extra levies to the *L. botrana* eradication strategy, they were responsible for paying for and applying the required insecticides. Application of mating disruptors was not adopted as effectively as the insecticides, with only approximately 50% of growers applying them in the first full year of the strategy in 2010. The following year, a grant was obtained which paid for the pheromone dispensers, which growers then applied.

A state-wide spend of at least US$105 million has been reported for the *L. botrana* eradication activity. USDA contributed US$46.5 million, Napa County spent US$9.8 million and the wine industry, US$49 million, with activity including trapping, insecticide application and quarantine compliance (Eberling, 2015).

Given the value of the grape industry at more than US$4 billion in California alone (European Grapevine Moth Post-Eradication Response Working Group, 2016), the high cost of the eradication program for *L. botrana* at more than US$100 million was justified, along with maintaining a robust and sensitive early detection trapping program for the insect.

Unforeseen activity
Despite being extremely busy managing the incursion activity, one initially unforeseen activity by the TWG was the interest shown from overseas personnel (some interest linked to export markets) who wanted to observe, in person, the eradication activity.
Although the largest *L. botrana* infestation in this case was in a winegrape producing region, adults were detected in very low numbers in a table grape vineyard in the Central Valley of California. Significant economic impact to the Californian table grape industry could have resulted from export restrictions imposed by importing countries (Varela et al., 2015).

Current activity
For three years' post eradication, pheromone-baited trap monitoring continues for *L. botrana* in grapegrowing areas of California and the United States, as part of early detection programs.
A postdoctoral researcher in the Department of Entomology at the University of California, Riverside is studying the spatiotemporal dynamics of the *L. botrana* invasion. The dataset of moth distribution from the years of monitoring is being used to understand the factors that contributed to moth establishment and spread, and to evaluate the efficacy of regulatory procedures.

Major lessons learned
- When faced with an incursion, the first thing to assess is whether it's even possible to eradicate, based on money, time, resources available and pest host range. The ease and success of an eradication effort is far more likely for an insect with a limited host range.
- All participants in an eradication effort need to be on board.
- Having extension staff as part of the TWG playing an impartial role between the regulators, researchers and growers was important to ensure the needs of all parties were met when devising the eradication strategy.
- Permitting researchers to undertake research concurrently with rolling out the eradication strategy hastened learnings and practical solutions.
- Ensuring research funding bodies were at the table from the start meant research priorities were identified and appropriately funded.
- Availability of a continual funding source at the required level for the life of the eradication strategy allowed the strategy to be fully implemented, contributing greatly to the result.
- Communication to industry personnel must continue post eradication, to ensure recognition of the pest, so that any new outbreaks are rapidly identified.
- A single, unified message to industry and community is vital to ensure no confusion of message.
- Effective control measures must be available for use.
- Stakeholder networks must assist in communicating messages. This will be the fastest way to reach everyone.
- Transparency and honesty is key – distrust takes a long time to repair.
- Don't make assumptions.
- Learn from previous eradication efforts around the world.

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